Clean Energy Standard: Potential Qualifying Energy Sources

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Summary

A clean energy standard (CES) has been identified as one possible legislative option to encourage a more diverse domestic electricity portfolio. A CES could require certain electricity providers to obtain a portion of their electricity from qualifying clean energy sources. A CES is broader than a renewable energy standard (RES), including "clean" energy sources along with renewable energy sources. The RES has been a topic of legislative attention since at least the 105th Congress. Some assert that a CES could lead to economic growth, reduce greenhouse gas emissions, and secure U.S. leadership in clean energy technology. Others argue that a CES could lead to higher electricity prices, necessitate additional financial investment in grid infrastructure, and—in some cases—depend on energy technologies that are not yet established for widespread commercial-scale use.

Without a CES, some clean energy sources—mostly the renewables—may face barriers to penetrate and gain traction in the electricity market. Renewable sources (including conventional hydroelectric) constituted roughly 10% of total electric power net generation in 2010. Analysis from the Energy Information Administration (EIA) suggests that without a CES or RES, electricity-generating capacity for renewable sources will grow 0.9% from 2009 to 2035, with renewables comprising approximately 13.6% of total electricity-generating capacity in 2035, compared with 12.5% in 2010. EIA analysis indicates that most of the growth in renewable electricity generation in the power sector from 2009 to 2035 will consist of generation from wind and biomass facilities.

Policy, economic, and technical considerations arise when evaluating CES options. A primary question in the CES legislative discussion is which energy sources would be eligible to participate. Congress could take into account the following clean energy source selection criteria: geographic location of the energy source, energy source supply levels, job creation associated with the energy source, the implementation time frame, environmental regulations (existing and forthcoming), and cost. Each potential qualifying energy source has advantages and disadvantages, and has different natural resource, economic, and technical challenges. For instance, the cost to build, operate, and maintain clean energy power plants varies widely, from $63 (natural gas advanced combined-cycle) to $312 (solar thermal) per megawatt-hour. Moreover, some of the sources proposed have encountered public opposition (e.g., nuclear energy). Many proposed sources (e.g., solar) have received government support in the form of research and development assistance or favorable tax treatment. In some cases, the technology that might allow certain sources to qualify for a CES is not yet at commercial scale (e.g., coal-fired plants equipped with carbon capture and sequestration). Cross-cutting issues including electricity transmission, variability, and material cost and supply are associated with large-scale electricity production for many of the commonly discussed clean energy sources.

Many questions will need to be answered if a CES is established. How much clean electricity can be generated from each qualifying energy source, given the proposed CES time frame? Should a carbon accounting parameter be assigned to each source? Will a time come when some resources (e.g., wind, solar) used to generate clean electricity cease to be considered a "free" resource? Should energy efficiency be included in a CES, and if so, how should it be included? How would a CES interact with state renewable electricity requirements? Who would assume the costs of new transmission capacity?

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Introduction

A clean energy standard (CES) has been proposed as a tool to provide a more sustainable domestic energy supply, reduce greenhouse gas emissions, and secure the United States as a leader in clean energy technology. Some assert that a CES could contribute to economic growth. Opponents of a CES contend that a CES could raise electricity prices, introduce grid reliability concerns, require significant investment in additional transmission lines, and depend on adopting some technologies not yet established for widespread commercial-scale use. A CES could require certain electricity providers to obtain a portion of their electricity from qualifying clean energy sources. In his 2011 State of the Union address, President Obama challenged the country to produce 80% of its electricity from clean energy sources by 2035. A CES could be one approach if Congress chooses to act. On March 21, 2011, Senators Bingaman and Murkowski issued a white paper on a clean energy standard that laid out some of the key questions and potential design elements of a CES, in order to solicit input from a broad range of interested parties, to facilitate discussion, and to ascertain whether or not consensus can be achieved.[1]

The CES expands on the concept of a national renewable energy standard (RES), an idea that has received significant congressional attention. An RES would encourage the production of electricity from renewable resources.[2] RES legislative discussions date back to at least the 105th Congress. A CES expands qualifying energy sources to include other “clean” energy sources (e.g., nuclear, natural gas, clean coal) along with renewable energy sources (e.g., wind, solar). Any CES would need to define which energy sources would qualify as “clean.”

The bulk of electricity generation in 2010 was from coal, natural gas, and nuclear (see **Figure 1**). Renewable sources constituted roughly 10% of total electric power net generation in 2010 (including conventional hydroelectric). Analysis from the Energy Information Administration (EIA) that does not include the addition of a federal RES or CES suggests that electricity-generating capacity for renewable sources will grow 0.9% from 2009 to 2035, with renewables comprising approximately 13.6% of total electricity generating capacity in 2035, compared with 12.5% in 2010 (see **Figure 2**).[3] EIA projections of renewable energy-generating capacity and generation are provided in **Figure 3** and **Figure 4**. EIA analysis indicates that most of the growth in renewable electricity generation in the power sector from 2009 to 2035 will consist of generation from wind and biomass facilities.

Multiple features of a CES may require congressional action.[4] Eligible energy sources would likely be among the topics at the forefront of a CES debate; at stake is what resources could and

[1] Paper available at http://energy.senate.gov/public/index.cfm?FuseAction=IssueItems.View&IssueItem_ID=7b61e406-3e17-4927-b3f4-d909394d46de.

[2] Renewable resources are those generally not depleted by human use, such as the sun, wind, and movement of water.

[3] Energy Information Administration, *Annual Energy Outlook 2011*, April 2011, http://www.eia.doe.gov/forecasts/aeo/index.cfm. Energy Information Administration, Annual Energy Outlook 2011, April 2011, http://www.eia.doe.gov/forecasts/aeo/chapter_executive_summary.cfm. EIA reports that the growth in generation from wind plants is driven primarily by state renewable portfolio standard (RPS) requirements and federal tax credits. Generation from biomass comes from both dedicated biomass plants and co-firing in coal plants. Its growth is driven by state RPS programs, the availability of low-cost feedstocks, and the federal renewable fuels standard, which results in significant cogeneration of electricity at plants producing biofuels.

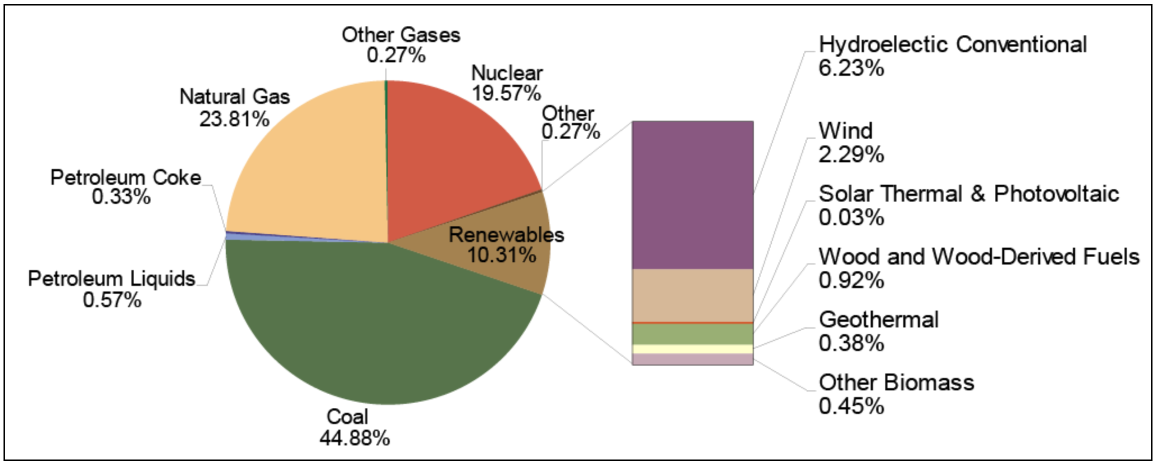
[4] For more information on clean energy standards, see CRS Report R41720, *Clean Energy Standard: Design Elements, State Baseline Compliance and Policy Considerations*, by Phillip Brown. For more information on a federal RES, see CRS Report R41493, *Options for a Federal Renewable Electricity Standard*, by Richard J. Campbell.

could not participate in a CES. Each energy source has advantages and disadvantages, and each brings different natural resource, economic, and technical challenges. For example, the cost to build clean energy projects and operate and maintain them is expected to vary (see **Table 1**). Additionally, sources for supply-side energy options are dependent on regional resources; energy efficiency is a demand-side source that is available everywhere because it is derived from power consumption locations—not from natural resource geography. Congress might consider these factors, among others such as how a federal CES would interact with state power provisions, in determining which energy sources would be eligible for a CES.

This report begins with a brief examination of clean energy, renewable energy, and alternative energy. It then presents possible selection criteria Congress could use to determine which sources could be eligible for a CES depending on the goal(s) of the CES. The report provides an overview of the energy sources most commonly discussed as potential CES qualifying sources: biomass, fossil fuels (natural gas combined-cycle and coal-fired power plants with carbon capture and sequestration), geothermal resources, nuclear, solar, water, and wind. The report describes where each source can be found in the United States, the estimated quantity available for electricity generation, technologies used to create electricity from the source, advantages and disadvantages of using the source for electricity generation, and policy implications should the source be included in a CES.[5] The report also contains a section on energy efficiency and its potential inclusion in a CES.

Figure 1. 2010 Electric Power Net Generation by Energy Source

(4,120,028 thousands of megawatt-hours total)



Source: U.S. Energy Information Administration, *Electric Power Monthly*, April 2011, http://www.eia.doe.gov/cneaf/electricity/epm/epm_sum.html. Adapted by CRS.

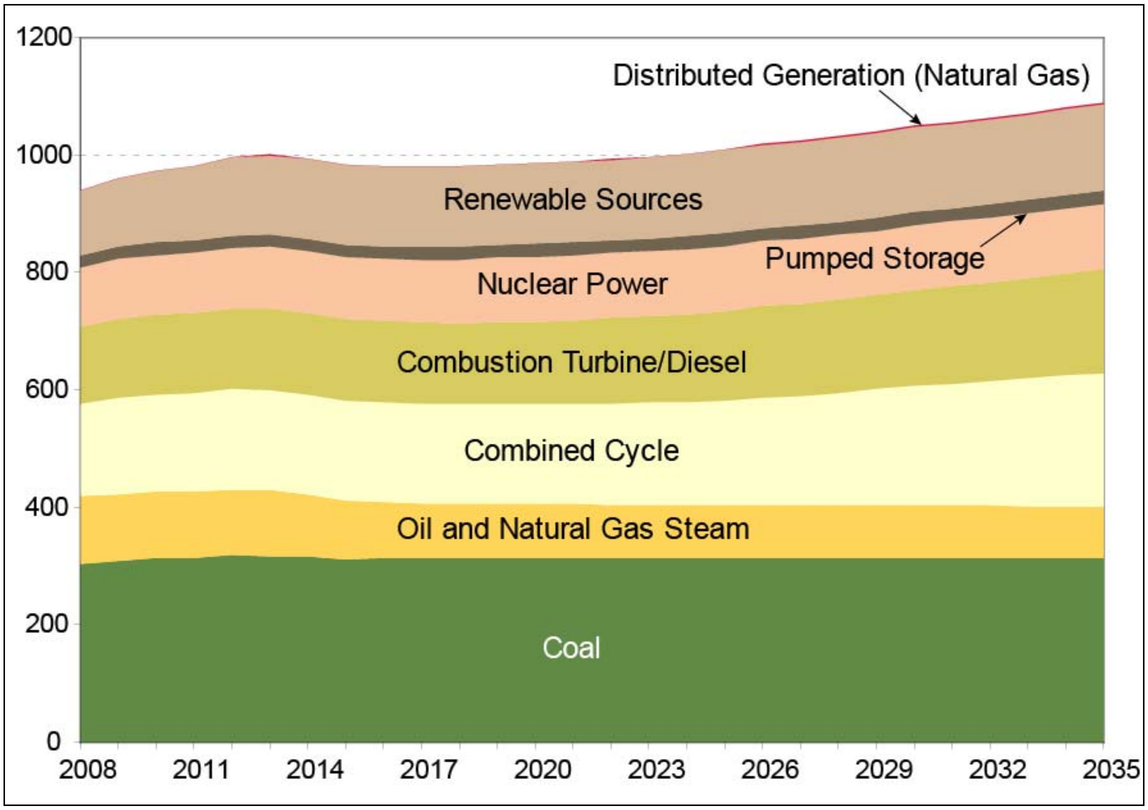
Notes: Coal includes anthracite, bituminous, subbituminous, lignite, waste coal, and coal synfuel. Petroleum liquids include distillate fuel oil, residual fuel oil, jet fuel, kerosene, and waste oil. Other gases include blast furnace gas, propane gas, and other manufactured and waste gases derived from fossil fuels. Other includes non-biogenic municipal solid waste, batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, tire-derived fuel, and miscellaneous technologies. Wood and wood-derived fuels include wood/wood waste solids (including paper pellets, railroad ties, utility poles, wood chips, bark, and wood waste solids), wood waste liquids (red liquor, sludge wood, spent sulfite liquor, and other wood-based liquids), and black liquor. Other biomass includes

[5] This report will generally identify electric supply (megawatt-hours). In a few instances (e.g., geothermal resources) only capacity (megawatt) estimates are available.

biogenic municipal solid waste, landfill gas, sludge waste, agricultural byproducts, other biomass solids, other biomass liquids, and other biomass gases (including digester gases, methane, and other biomass gases).

Figure 2. Electricity Generating Capacity, 2008 to 2035

(gigawatts)

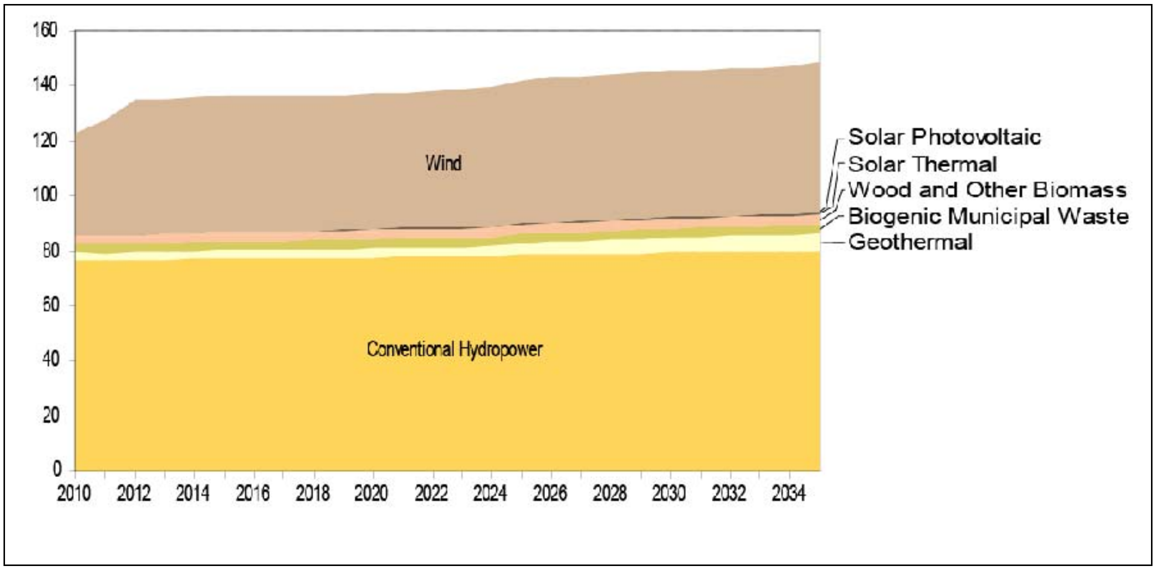


Source: Energy Information Administration, *Electricity Generating Capacity, Reference case*, Annual Energy Outlook 2011, April 2011, http://www.eia.doe.gov/forecasts/aeo/index.cfm. Adapted by CRS.

Notes: Data shown are for electric power net summer capacity. Net summer capacity is the steady hourly output that generating equipment is expected to supply to system load (exclusive of auxiliary power), as demonstrated by tests during summer peak demand. Includes electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public. Oil and natural gas steam includes oil-, gas-, and dual-fired capacity. Nuclear capacity includes 3.8 gigawatts of uprates through 2035. Renewable sources include conventional hydroelectric, geothermal, wood, wood waste, all municipal waste, landfill gas, other biomass, solar, and wind power. Facilities co-firing biomass and coal are classified as coal. Distributed generation (natural gas) includes primarily peak-load capacity fueled by natural gas.

Figure 3. Renewable Energy Generating Capacity, 2010 to 2035

(gigawatts)

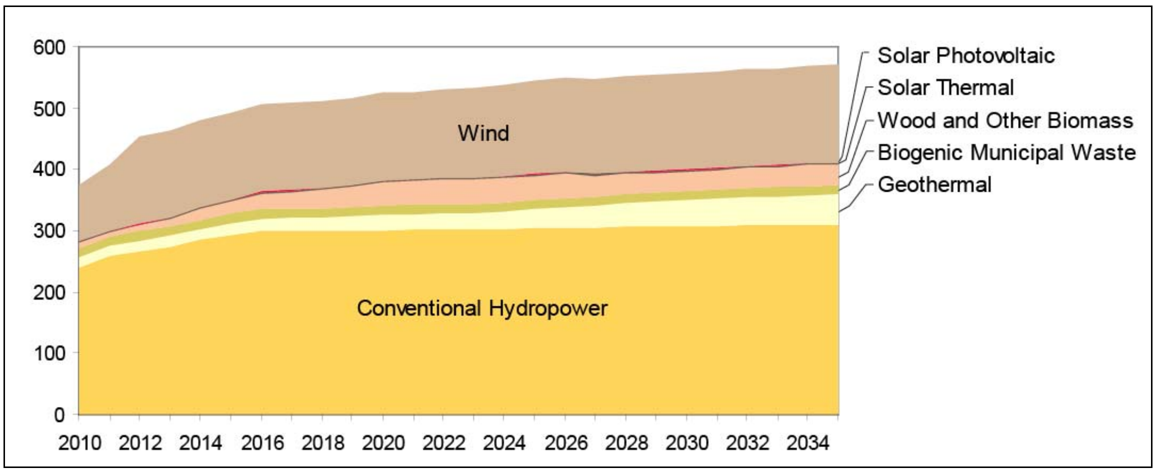


Source: Energy Information Administration, *Renewable Energy Generating Capacity and Generation, Reference case*, Annual Energy Outlook 2011, April 2011, http://www.eia.doe.gov/forecasts/aeo/index.cfm. Adapted by CRS.

Notes: Electric power sector net summer capacity includes electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public. Geothermal includes both hydrothermal resources (hot water and steam) and near-field enhanced geothermal systems (EGS). Near-field EGS potential occurs on known hydrothermal sites, however this potential requires the addition of external fluids for electricity generation and is only available after 2025. Municipal waste includes municipal waste, landfill gas, and municipal sewage sludge. Incremental growth is assumed to be for landfill gas facilities. All municipal waste is included, although a portion of the municipal waste stream contains petroleum-derived plastics and other non-renewable sources. For wood and other biomass, facilities co-firing biomass and coal are classified as coal. Solar photovoltaic does not include off-grid photovoltaics (PV).

Figure 4. Renewable Energy Generation, 2010 to 2035

(billion kilowatt-hours)



Source: Energy Information Administration, *Renewable Energy Generating Capacity and Generation, Reference case*, Annual Energy Outlook 2011, April 2011, http://www.eia.doe.gov/forecasts/aeo/index.cfm. Adapted by CRS.

Notes: Geothermal includes both hydrothermal resources (hot water and steam) and near-field enhanced geothermal systems (EGS). Near-field EGS potential occurs on known hydrothermal sites, however this potential requires the addition of external fluids for electricity generation and is only available after 2025. Biogenic municipal waste includes biogenic municipal waste, landfill gas, and municipal sewage sludge. Solar photovoltaic does not include off-grid photovoltaics (PV).

Table 1. Estimated Levelized Cost of Selected New Generation Resources, 2016

(U.S. average levelized cost [2009 $/megawatt-hour] for plants entering service in 2016)

Plant Type	Capacity Factor (%)	Total System Levelized Cost
Conventional Coal	85	94.8
Advanced Coal	85	109.4
Advanced Coal with CCS	85	136.2
Natural Gas-fired		
Conventional Combined-cycle	87	66.1
Advanced Combined-cycle	87	63.1
Advanced Combined-cycle with CCS	87	89.3
Advanced Nuclear	87	113.9
Wind	34	97.0
Solar PV[a]	25	210.7
Solar Thermal	18	311.8
Geothermal	92	101.7
Biomass	83	112.5
Hydro	52	86.4

Source: DOE Energy Information Administration, *Levelized Cost of New Generation Resources in the Annual Energy Outlook 2011* , Annual Energy Outlook 2011, December 2010, http://www.eia.doe.gov/oiaf/aeo/electricity_generation.html. Adapted by CRS.

Notes: Levelized cost represents the present value of the total cost of building and operating a generating plant over an assumed financial life and duty cycle, converted to equal annual payments and expressed in terms of real dollars to remove the impact of inflation. Levelized cost reflects overnight capital cost, fuel cost, fixed and variable O&M cost, financing costs, and an assumed utilization rate for each plant type.

a. Costs are expressed in terms of net AC power available to the grid for the installed capacity.

Clean, Renewable, Alternative—What Is the Difference?

Clean energy, renewable energy, alternative energy—these terms have been used interchangeably. However, they are not synonymous, although one term can encompass another. The terms differ with respect to an energy source's point of origin (e.g., fossil or non-fossil), replenishment time frame (e.g., instantaneously or millions of years), supply (e.g., exhaustible or inexhaustible), and environmental impact (e.g., greenhouse gas emissions and other pollutants), among other qualities. In general, a renewable energy source is naturally replenishing but flow-limited.[6] A clean energy source is typically a source that produces little to no air pollution. The term "alternative" usually describes a non-conventional energy source. Most but not all renewable energy sources qualify as clean energy, depending on how electricity is produced from the source. Some clean energy sources (e.g., nuclear) are not generally considered renewable.

Possible Selection Criteria for CES Energy Resources

Potential CES energy source selection criteria could depend on the goal of a CES. While a CES generally would have the basic goal of producing a significant portion of electricity from clean energy sources, the reasoning behind this goal could influence which sources are selected. In evaluating individual energy sources for possible inclusion, Congress might consider the following criteria:[7] geographic location of the energy source, energy source supply levels, job creation associated with the energy source, implementation time frame, EPA regulations (existing and forthcoming), environmental issues (air quality, water quality, water quantity, wildlife), greenhouse gas emissions, baseload versus non-baseload, energy balance,[8] energy content,[9] land use change, scalability, and cost.

Potential Supply-Side CES Qualifying Energy Resources

This section discusses selected energy resources that are commonly identified as potential qualifying sources for a CES.[10] Each overview describes where the source can be found in the United States, how much is estimated to be available for electricity generation, the technologies used to create electricity from the identified source, advantages and disadvantages of using the source for electricity generation, and policy implications. Potential resources are renewable (e.g., wind) or technology-aided (e.g., fossil fuels). The energy resources may include biomass, clean energy fossil fuels, geothermal resources, nuclear, solar, water, and wind.[11]

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[6] The Energy Information Administration states that renewable energy resources are virtually inexhaustible in duration but limited in the amount of energy that is available per unit of time.

[7] The criteria are not presented in any order of priority. The criteria presented are not a complete list, but are provided to give an indication of the range of policy options.

[8] Energy balance is the difference between the total incoming and total outgoing energy of a clean energy production system.

[9] Energy content is the amount of energy contained in a given mass of a source.

[10] An explanation of every proposed clean energy source is beyond the scope of this report.

[11] Overviews for landfill gas, coal-mine methane, and waste-to-energy—three other potential qualifying CES energy sources—are not provided in this report. The captured gas from landfills and coal mines can be used to generate electricity. For more information on this process, see CRS Report R40813, *Methane Capture: Options for Greenhouse Gas Emission Reduction*, by Kelsi Bracmort et al. Waste-to-energy is the combustion of municipal solid waste for electricity production.

Issues Applicable to All Clean Energy Resources

A number of cross-cutting issues are associated with large-scale electricity production for many or all of the clean energy sources:[12]

- **Technology.** For certain energy sources, technology to capture the resource and generate electric power is likely to require significant upgrading and financial investment.
- **Electricity Transmission.** In some cases, the energy source is located a considerable distance from where the electricity is needed. Transmission lines may have to be constructed to transmit the electricity from its point of origin to its point of use. This raises concerns not only for capital investment, but also siting issues.
- **Variability.** Electricity generated from certain sources (e.g., wind, solar) is variable; it is subject to acts of nature, and is not always available. This may affect grid stability if sufficient back-up generation is not available.
- **Project economics.** It may be cost-prohibitive to embark on certain clean electricity investments if the rate-of-return on the investment is not favorable. The rate-of-return is likely to vary across the United States, depending on source availability and regional market prices among other things.
- **Material cost and supply.** Certain clean electricity projects may require expensive or scarce amounts of raw materials. Use of these materials for electricity generation may have an impact on other markets that rely on the same materials.

Biomass[13]

Biomass is organic matter that can be converted to energy. Common types of biomass are wood, wood residues (e.g., branches), agricultural biomass (e.g., corn stover), aquatic biomass (e.g., algae), animal manure, and industrial biomass wastes. Relative to other locations in the United States, large quantities of biomass have been identified east of the Rocky Mountains, and in the Northwest, Alaska, and Hawaii.[14] Biomass can be converted to electricity (biopower) by either a thermochemical or a biochemical conversion process. Biopower conversion processes include combustion, co-firing, gasification, pyrolysis, and anaerobic digestion. The technologies are at varying stages of maturity.[15]

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[12] The issues are not presented in any order of priority.

[13] This section was written by Kelsi Bracmort.

[14] For a map of biomass resources available throughout the United States, see Figure 1 in CRS Report R41106, *Meeting the Renewable Fuel Standard (RFS) Mandate for Cellulosic Biofuels: Questions and Answers*, by Kelsi Bracmort. For an estimate of how much biomass (tons/year) is available for biopower production at the county level, see the National Renewable Energy Laboratory BioEnergy Atlas for Biopower http://maps.nrel.gov/bioenergyatlas.

[15] For more information on biopower conversion technologies, see CRS Report R41440, *Biomass Feedstocks for Biopower: Background and Selected Issues*, by Kelsi Bracmort.

Approximately 1.4% of electricity generation in 2010 originated from biomass.[16] Biopower was the third-largest renewable energy source for electricity generation (following conventional hydroelectric power and wind).[17] The EIA estimates that electricity generation for all sectors from biomass will grow 5.6% from 2009 to 2035, and its contribution to the total U.S. electric power capacity will be 0.5% in 2035.[18]

There are advantages and disadvantages to pursuing biomass for electricity generation under a CES.[19] Proponents of using biomass point out that various types of biomass are available in more than 35 states for electricity generation. In addition, they suggest that a CES would establish another market for biomass producers to sell their product,[20] and that it would serve as an economic incentive to remove and use pest-infested woody biomass for electricity generation. Also, some biomass feedstocks can be used for baseload power production (minimum amount of electric power delivered or required over a given period of time at a steady rate), unlike wind or solar, which are variable resources. Some suggest that biomass use may be unsustainable, or that biomass combustion could increase carbon emissions.[21] If it is economically advantageous to use biomass for electricity generation, some contend, less biomass will be available for traditional purposes. In particular, some are concerned there may not be enough biomass to meet both liquid transportation fuels and electricity needs under a CES.[22]

The natural resource implications of using biomass will depend on management of the sources from which it originates. For example, woody residues are more likely to remain available if woodlands are sustainably managed. The following policy questions might arise when considering biomass as a qualifying CES energy source:

- **Will agricultural producers continue to receive support from the federal government to grow certain crops if a CES is established?** Some agricultural producers receive financial assistance from the federal government to grow select crops (e.g., corn). In certain cases, these same producers could sell the residues of these crops for electricity generation to meet a CES mandate.

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[16] U.S. Energy Information Administration, *Electric Power Monthly*, April 2011, http://www.eia.doe.gov/cneaf/electricity/epm/epm_sum.html.

[17] Biopower includes electricity generated from wood and wood-derived fuels and biogenic municipal solid waste, landfill gas, sludge waste, agricultural byproducts, other biomass solids, other biomass liquids, and other biomass gases (including digester gases, methane, and other biomass gases). U.S. Energy Information Administration, *Electric Power Monthly*, April 2011, http://www.eia.doe.gov/cneaf/electricity/epm/epm_sum.html.

[18] Energy Information Administration, *Annual Energy Outlook 2011*, April 2011, http://www.eia.doe.gov/forecasts/aeo/index.cfm.

[19] For more information on the advantages and disadvantages of using biomass for electricity generation, see CRS Report R41440, *Biomass Feedstocks for Biopower: Background and Selected Issues*, by Kelsi Bracmort and CRS Report R40565, *Biomass Resources: The Southeastern United States and the Renewable Electricity Standard Debate*, by Richard J. Campbell.

[20] For example, forestry residues from timber cuttings for sawmill and paper operations currently remain in the forest or on wooded lots. It is argued that these residues could be used as a biopower feedstock.

[21] For more information on the carbon neutrality of biopower, see CRS Report R41603, *Is Biopower Carbon Neutral?*, by Kelsi Bracmort.

[22] For more information on biomass used to meet the Renewable Fuel Standard, a mandate whereby a minimum volume of biofuels is to be used in the national transportation fuel supply each year, see CRS Report R40155, *Renewable Fuel Standard (RFS): Overview and Issues*, by Randy Schnepf and Brent D. Yacobucci.

- **Will the inclusion of biomass as a qualifying CES source conflict with other energy mandates?** The Renewable Fuel Standard (RFS) is a liquid transportation fuels mandate that drives demand for some of the same biomass feedstocks used for electricity generation.
- **Will the CES be economically competitive for those entities that require feedstock collection and transportation?** Some biomass is located in areas that are difficult to reach. Would-be participants may demand that a CES offer a price that will compensate them for feedstock collection and transportation efforts.
- **Will the CES include biomass-to-thermal applications?** While discussions about a CES have focused on energy in the form of electricity, some assert that the standard could be broadened to include other non-electric energy applications such as space and domestic water heating, process heat, and the thermal portion of combined heat and power.

Fossil Fuels Qualifying as Clean Energy

Natural Gas Combined-Cycle[23]

Natural gas, predominantly methane, is present throughout all 50 states in various forms, and is commercially produced in 33 states.[24] The recent development of large shale-gas resources has increased U.S. reserves and production, and has contributed to a steep drop in natural gas prices. Possible changes in government regulations regarding hydraulic fracturing—in part due to local opposition—raise uncertainty about future development of the resource. All 50 states consume natural gas, as vast pipeline networks transport the fuel around the country and within states.[25]

Natural gas is used for electric power generation in 48 states (all but Hawaii and Vermont),[26] and natural gas combined-cycle (NGCC) facilities—among the most efficient combustion technologies for natural gas—are in 40 states.[27] This highlights the role of natural gas in electric generation throughout the United States. Natural gas ranked second behind coal as the largest fuel source for U.S. electricity generation in 2009, accounting for almost 24% of U.S. generation.[28] Natural gas has the most electric generation *capacity* in the United States, approximately 41%, with NGCC facilities accounting for about half.[29] However, many natural gas power plants are

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[23] This section was written by Michael Ratner.

[24] The United States has the sixth-largest natural gas reserves globally and was first in production worldwide in 2009. The United States was the largest consumer of natural gas in 2009, with domestic sources supplying over 90% of this usage. BP Statistical Review of World Energy 2010, http://www.bp.com/subsection.do?categoryId=9023762&contentId=7044550.

[25] The United States uses over 300,000 miles of transmission pipeline to move natural gas to markets in all 50 states. Natural gas is distributed to customers by pipeline as well, but these pipelines are in addition to the transmission pipelines.

[26] Vermont does use landfill gas to produce electricity.

[27] Combined-cycle electric generation burns fuel, most commonly natural gas, in a natural gas turbine, which turns a generator to produce electricity. The exhaust heat from this process is then used to turn a steam turbine, which turns a generator to produce additional electricity. The alternative to combined cycle is simple cycle, which only uses one turbine to produce electricity and the exhaust heat is not captured to produce electricity..

[28] U.S. Energy Information Administration. http://www.eia.doe.gov/cneaf/electricity/epm/table1_1.html.

[29] U.S. Energy Information Administration. http://www.eia.doe.gov/cneaf/electricity/epa/epat1p2.html.

not operated at capacity. While coal-fired electric generation plants operate on average at 64% of their maximum generation capacity, NGCC facilities operate at only 43% of their capacity.[30] This is due both to the relative prices of natural gas and coal, and to the flexibility of NGCC facilities, which can be shut down and restarted (i.e., "cycled") depending on economic conditions. Coal plants are difficult to cycle and thus are less able to respond to economic factors and demand fluctuations.

With respect to a CES, NGCC facilities have certain advantages over other fuel sources. NGCC power plants display the highest efficiency in converting thermal energy to electric energy and can be installed quickly and cheaply relative to other generation types. NGCC facilities can provide operational flexibility and can offer baseload or peak generation. Additionally, the more than 50% decline in natural gas prices since their peak in 2008 has led utilities and generators to substitute natural gas-fired electric generation for other generation types.[31]

Relative to coal and oil, natural gas—whether in NGCC or simple cycle—produces fewer greenhouse gas emissions (almost 40% less carbon dioxide) and other pollutants, including carbon dioxide, nitrogen oxides, sulfur dioxide, and particulate matter.[32] However, natural gas still emits greenhouse gases. Methane (CH_4), the main component of natural gas, is a potent greenhouse gas when released into the atmosphere, but is not emitted in the electricity generation process. When combusted, natural gas produces nitrogen oxides and carbon dioxide, but in lower quantities than would occur burning oil or coal.

The following policy questions could arise when considering natural gas as a qualifying CES energy source:

- **Does the United States have enough natural gas to devote to a CES?** Development of shale gas will be critical for the long-term use of natural gas. With prices as low as they are currently, some companies have proposed and applied for permits to export natural gas as a way to increase demand. Environmental concerns regarding water and air may limit development of shale gas resources.
- **Will the inclusion of natural gas as a qualifying CES energy source conflict with other energy mandates?** Natural gas qualifies as an alternative fuel under various programs targeting the transportation sector.
- **Will including natural gas as a CES energy source have negative consequences for other consumers of natural gas?** Increased demand from inclusion in a CES could put upward pressure on natural gas prices. Natural gas is used in industrial manufacturing and residential heating, both of which would be negatively affected by a rise in prices. However, increased demand could also make some additional natural gas resources economic to develop. Some producers have stopped production because of low prices during the last two years.[33]

[30] U.S. Energy Information Administration, http://www.eia.doe.gov/cneaf/electricity/epa/epat5p2.html.

[31] U.S. Energy Information Administration, http://www.eia.doe.gov/dnav/ng/hist/rngwhhda.htm.

[32] *Environmental, Health, and Safety Guidelines for Thermal Power Plants*, International Finance Corporation, World Bank Group. December 19, 2008, pp. 8 and 23.

[33] "Exxon not shutting N. American gas wells," Reuters, October 28, 2010.

Clean Coal[34]

There has been considerable discussion about including clean coal (coal-fired power plants equipped with carbon capture and sequestration) as a qualifying energy source for a CES.[35] Coal was the largest fuel source for electricity generation in 2009, accounting for nearly 45% of U.S. generation.[36] U.S. coal deposits are mainly in three large regions: the Appalachian Coal Region, the Interior Coal Region, and Western Coal Region.[37] Coal is mined in 25 states. The top coal-producing states are Wyoming, West Virginia, Kentucky, Pennsylvania, and Montana. In 2009, about 5.5% of coal produced in the United States was exported, over half to Canada, Brazil, Netherlands, the United Kingdom, and France. At the same time, 2.3% of coal consumed in the United States (mainly barged to the Gulf and east coast states) is imported, primarily from Colombia.

Carbon capture and sequestration (or storage)—known as CCS—involves capturing carbon at its source, transporting and storing it to prevent or minimize its release to the atmosphere. Currently, three main approaches are available to capture CO_2 from large-scale industrial facilities or power plants: post-combustion capture, pre-combustion capture, and oxy-fuel combustion capture. After capture, the next step is transportation. Most CO_2 transport in the United States is through pipelines. The last step is sequestration in geological reservoirs. Three main types of geological formations are being considered for carbon sequestration: depleted oil and gas reservoirs, deep saline reservoirs, and unmineable coal seams.

Coal-fired electricity-generating plants are strong initial candidates for CCS or reuse of CO_2 because they are usually large, stationary, single-point sources of emissions.[38] According to the Environmental Protection Agency, the United States produces over 5.1 billion metric tons of CO_2 each year from fossil fuel combustion, and 42%, or 2.15 billion metric tons, of that is from generating electricity.[39] The United States can potentially store CO_2 for decades or longer at current emission rates from power plants and other stationary sources. According to the Department of Energy (DOE), storage estimates range from 1.65 trillion to 20.2 trillion metric tons for deep saline reservoirs, the geological formation with the highest potential for long-term CO_2 storage.[40] If these estimates are correct, then the United States has the capacity to store all of its emissions from electricity generation for the next 770 to 9,400 years in saline reservoirs at today's emission rates.

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[34] This section was written by Peter Folger.

[35] For more information, see CRS Report RL34621, *Capturing CO2 from Coal-Fired Power Plants: Challenges for a Comprehensive Strategy*, by Larry Parker and Peter Folger.

[36] U.S. Energy Information Administration, *Net Generation by Energy Source: Total (All Sectors)*, Electric Power Monthly, March 2011, http://www.eia.doe.gov/cneaf/electricity/epm/table1_1.html.

[37] U.S. Energy Information Administration, *Annual Coal Report 2009*, DOE/EIA-0584 , October 2010, http://www.eia.doe.gov/cneaf/coal/page/acr/acr_sum.html.

[38] Large industrial facilities, such as cement-manufacturing, ethanol, or hydrogen production plants, that produce large quantities of CO_2 as part of the industrial process are also good candidates for CO_2 capture and storage. Intergovernmental Panel on Climate Change (IPCC) Special Report, *Carbon Dioxide Capture and Storage*, 2005.

[39] U.S. Environmental Protection Agency (EPA), Draft *Inventory of U.S. Greenhouse Emissions and Sinks: 1990-2009*, Table ES-3; February 2011, http://epa.gov/climatechange/emissions/downloads11/US-GHG-Inventory-2011-Executive-Summary.pdf.

[40] Department of Energy, *Carbon Sequestration Atlas of the United States and Canada*, 3rd edition, 2010.

Questions to consider about CCS as a qualifying source for a clean energy standard include the following:

- **Can CCS be a long-term component of a CES portfolio?** Using CCS to limit CO_2 emissions to the atmosphere is widely perceived as a medium-term option, allowing continued use of coal to generate electricity until less carbon-intensive technologies can substitute at an equivalent cost. Adding CCS to coal-fired generation, however, reduces the efficiency of the plants and increases the cost to produce electricity, especially during the capture step.[41]
- **Will inclusion of CCS as a qualifying CES source spur the adoption and deployment of CCS in the energy sector?** Without an economic incentive or a regulatory requirement to install CCS at existing power plants or to build new plants with CCS, it is unlikely that CCS would be deployed commercially, unless its costs decrease dramatically. In addition to the cost of capture, the legal and regulatory framework for storing CO_2 underground is under development.
- **At what stage of research, development, and deployment is CCS?** Many experts call for a series of industrial-scale CCS projects to demonstrate how CO_2 can be captured, transported, and stored safely and efficiently in a variety of environments throughout the United States and how costs, decreases in efficiency, and transportation issues might be managed.

Geothermal Resources[42]

Geothermal resources are found where circulating groundwater contacts the heated rocks near the Earth's surface, and where the resulting hot fluid can potentially be exploited for heat or electricity. To generate electricity, wells are drilled into the geothermal resource to extract the hot water or steam, which is then used to drive a turbine. In general, geothermal resources above 150^{o}C (300^{o}F) are used for electricity generation.[43] Resources below 150^{o}C are typically used for direct heating.

The United States is the largest producer of electricity from geothermal resources, with 2,256 megawatts (MW) of installed capacity in 2008 (0.2% of total summer electric generating capacity in 2008).[44] The size of individual geothermal power plants ranges from small (less than 5 MW) to large (greater than 30 MW). Most of the installed capacity is in California and Nevada, with additional capacity in Hawaii, Utah, Idaho, and Alaska. The Geysers, comprising 45 square miles in northern California, contains a large geothermal complex with multiple power plants and over 300 steam wells; these facilities account for most of the electricity generated from geothermal resources in California, and a large share of the U.S. installed capacity.

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[41] For detailed CCS cost estimates, see CRS Report R41325, *Carbon Capture: A Technology Assessment*, by Peter Folger.

[42] This section was written by Peter Folger.

[43] Lund, John W., "Characteristics, Development and Utilization of Geothermal Resources," Geo-Heat Center Quarterly Bulletin, vol. 28, no. 2 (2007), p. 1.

[44] U.S. Department of Energy, Energy Information Administration, http://www.eia.gov/cneaf/solar.renewables/page/trends/table1_12.pdf. The U.S. Geological Survey cites a slightly higher number: 2,500 MW of installed and utilized power production capacity; USGS Fact Sheet 2008-3082, http://pubs.usgs.gov/fs/2008/3082/pdf/fs2008-3082.pdf.

In a 2008 assessment of U.S. geothermal resources, the U.S. Geological Survey estimated that the mean electric power generation potential from identified geothermal systems is slightly over 9,000 MW, distributed over 13 states.[45] California has nearly 60% of the identified geothermal resource base, followed by Nevada (15%) and Alaska (7.5%). The USGS also indicated that undiscovered geothermal resources could add over 30,000 MW of potential production capacity from public and private lands.[46]

A different category of geothermal resource, called enhanced geothermal systems (EGS), further adds to the nation's potential geothermal resource base. EGS require some form of engineering to drill down to high temperature zones to access the hot water or steam and recover the heat to generate electricity. Conventional geothermal systems take advantage of naturally circulating hot water and steam. Enhanced geothermal systems require elevated temperatures at drillable depths, which expands the potential resource base outside the boundaries of conventional geothermal resources but also increases the technical difficulty to harness the resource. Assuming that EGS technology is feasible, the USGS estimated that the mean electric power-generating capacity from EGS could be over 517,000 MW.[47]

Future exploitation of these resources depends in part on their nature compared to other sources of energy. A potential advantage of geothermal resources is that, in contrast to fossil fuel energy resources, the heat from geothermal fluids may be used without combustion, thus avoiding releases of carbon dioxide and other waste gases. A possible disadvantage involves the accessibility of geothermal resources. Geothermal plants must be built at the resource site, and are thus limited to locations where geothermal resources occur in the United States. By contrast, while proximity to the fuel source is considered in determining the economic viability of a fossil-fuel power plant, fossil fuels like coal and natural gas can be transported to the plant site; thus conventional plants may be built almost anywhere in the United States.

Other policy questions in considering geothermal resources for a CES include the following:

- **If geothermal is included in a CES portfolio, what other factors may affect its expansion and deployment as a source of energy for electricity generation?** Similar to mineral and energy resource development, geothermal resources need to be discovered and characterized, and the reservoir itself engineered and managed to most efficiently extract its energy. That process can require significant investment and long lead times before any electricity is actually produced. Factors such as accessibility, distance to electricity consumers, the presence of adequate supplies of cooling water, and other site-specific factors affect the economic and regulatory (e.g., transmission siting) viability of the resource.
- **At what stage of research, development, and deployment are enhanced geothermal systems?** Enhanced geothermal systems (EGS) could expand the potential geothermal resource geographically, but require large engineering and

[45] USGS Fact Sheet 2008-3082.

[46] Ibid.

[47] The USGS cautions that this estimate should be considered provisional, as EGS technology is in an early stage of development. The total electric generating capacity for the electric power sector (power only) in 2010 was approximately 973,400 MW. EIA, Energy Information Administration, *Annual Energy Outlook 2011*, April 2011, http://www.eia.doe.gov/forecasts/aeo/index.cfm.

> infrastructure investments that so far constitute an unproven technology. Key technical challenges must be met for EGS to succeed, such as creating an efficient closed-loop system and limiting the amount of fluid loss.[48] In addition, water resources for EGS may be constrained in the more arid portions of the country. The role of the federal government in advancing EGS technology is an ongoing question.

Nuclear[49]

Nuclear energy results from the fission (splitting) of the nuclei of heavy isotopes, such as uranium-235 and plutonium-239, in a nuclear reactor.[50] The United States has 104 commercial nuclear reactors that generated about 20% of U.S. electricity in 2010.[51] Nuclear power plants are the largest U.S. source of non-carbon-emitting electricity generation, although some carbon is emitted during the production of nuclear fuel.

U.S. nuclear reactors are fueled by enriched uranium (uranium with an increased proportion of uranium-235). About 15% of the uranium purchased by U.S. reactor operators in 2009 came from domestic sources, with most foreign supplies coming from Australia, Canada, and Russia.[52] Using the classification system of the International Atomic Energy Agency, worldwide reasonably assured uranium resources are estimated to equal about 80 years of current annual consumption.[53] Some countries, particularly France, are reprocessing and recycling spent fuel from nuclear reactors to modestly extend uranium supplies. Research on technologies that could extend uranium supplies much further is being conducted by DOE and in several other countries. A major concern about such technology is that it may encourage the production of material that could be used in nuclear weapons.

Growth in U.S. nuclear power generation is expected to be small without favorable federal policies, such as carbon controls or a CES that includes nuclear energy. EIA projects that under current policies, U.S. nuclear power generating capacity will rise from 101 gigawatts in 2009 to 111 gigawatts in 2035, with the increase coming from five new reactors and increased capacity at existing reactors.[54] One new power reactor is currently under construction in the United States, the Watts Bar 2 reactor owned by the Tennessee Valley Authority. Construction of Watts Bar 2 began in the 1970s but had been suspended until recently. License applications to build 18 additional reactors have been submitted to the Nuclear Regulatory Commission (NRC),[55] but

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48 MIT, *The Future of Geothermal Energy: Impact of Enhanced Geothermal Systems (EGS) on the United States in the 21st Century*, 2006, http://geothermal.inel.gov/publications/future_of_geothermal_energy.pdf.

49 This section was written by Mark Holt.

50 For more information on nuclear energy policy, see CRS Report RL33558, *Nuclear Energy Policy*, by Mark Holt.

51 U.S. Energy Information Administration (EIA), "Net Generation by Energy Source: Total (All Sectors)," http://www.eia.doe.gov/cneaf/electricity/epm/table1_1.html.

52 EIA, "Uranium Purchased by Owners and Operators of U.S. Civilian Nuclear Power Reactors by Origin Country and Delivery Year," http://www.eia.gov/cneaf/nuclear/umar/table3.html.

53 World Nuclear Association, "Supply of Uranium," December 2010, http://www.world-nuclear.org/info/inf75.html. International Atomic Energy Agency, *Classification of uranium reserves/resources*, 1998, http://www-pub.iaea.org/MTCD/publications/PDF/te_1035_prn.pdf.

54 Energy Information Administration, *Annual Energy Outlook 2011*, "Electricity Generation," April 2011, http://www.eia.doe.gov/forecasts/aeo/index.cfm.

55 U.S. Nuclear Regulatory Commission, "Expected New Nuclear Power Plant Applications," March 21, 2011, http://www.nrc.gov/reactors/new-reactors/new-licensing-files/expected-new-rx-applications.pdf.

some of those have since been suspended or delayed, and the number of projects that will actually proceed to construction is unknown.

Along with low carbon and other emissions, a major advantage of nuclear power is its lack of vulnerability to volatile fuel prices. The cost of uranium is a small fraction of the total cost of nuclear generation, unlike coal- and gas-fired plants, in which fuel is a major cost driver. However, the cost of building nuclear power plants is higher than that of fossil-fuel plants, placing new nuclear plants at an overall economic disadvantage, especially if natural gas prices remain relatively low. EIA estimates that a new two-unit nuclear plant would cost $5,335 per kilowatt of capacity (in 2010 dollars without interest), compared with $978 for a combined-cycle natural gas plant and $2,844 for a two-unit advanced pulverized coal plant.[56] Nuclear power is also facing renewed scrutiny over safety in the wake of the recent accident at the Fukushima Daiichi nuclear plant in Japan, and continued concern over storage and disposal of highly radioactive spent fuel.

Following are some policy questions that arise when considering the expansion of nuclear power in the context of a CES:

- **Would inclusion of existing nuclear power capacity in a CES encourage life extension of existing reactors?** Concerns have been raised about the safety of older reactor designs, including those that are similar to the damaged Fukushima reactors. NRC contends that no U.S. reactor would be permitted to keep operating if it did not meet U.S. safety standards, regardless of any economic incentives for continued operation.
- **How would an expansion of nuclear power affect the management of highly radioactive waste?** The Obama Administration has moved to halt further development of the proposed national nuclear waste repository at Yucca Mountain, Nevada. The Administration established the Blue-Ribbon Commission on America's Nuclear Future to develop an alternative strategy for nuclear waste management. Until such a strategy can be implemented or barriers to Yucca Mountain can be eliminated, spent nuclear fuel will continue to be stored at nuclear plant sites.
- **Could new nuclear fuel technology lead to the proliferation of nuclear weapons?** Advanced spent fuel reprocessing and reactor technologies could greatly increase the amount of energy extracted from uranium supplies and reduce the long-term radioactivity of nuclear waste. Such technologies are often viewed as crucial for long-term expansion of nuclear power. However, such technologies also raise concerns about the separation of weapons-useable plutonium from spent fuel. A major goal of DOE nuclear research is to minimize that problem. The spread of uranium enrichment technology also poses proliferation concerns.

[56] EIA, "Updated Capital Cost Estimates for Electricity Generation Plants," November 2010, http://www.eia.gov/oiaf/beck_plantcosts/.

Solar[57]

Solar energy, in the context of electricity generation potential, might be defined as radiation from the sun that reaches the earth's surface. Energy from the sun can be used for heat and electricity. Converting solar energy into electricity is generally accomplished by capturing and converting solar photons (photovoltaic), or capturing and converting heat from the sun (solar thermal).

Photovoltaic conversion typically uses semiconductor material (i.e., silicon) that absorbs photons of a certain wavelength. Absorbed photons create electricity by dislodging electrons from the semiconductor material. Electricity from this conversion process can be used at the generation source or transmitted on the electrical grid to the areas of demand.[58]

Solar thermal electricity conversion (also known as concentrating solar power) typically uses heat from the sun to generate electricity. Technologies used for solar thermal electricity generation include parabolic trough, power tower, linear fresnel, and dish stirling technologies. Trough, tower, and fresnel technologies typically use thermal energy from the sun to heat water and make steam. The steam then powers a turbine generator, which in turn produces electricity. Dish stirling technology typically does not require water for electricity production and instead relies on thermal expansion properties of gases, usually hydrogen or helium, to mechanically power a stirling engine.[59]

At the end of 2009, total solar electricity installations in the United States were approximately 2,100 megawatts, up from 494 megawatts in 2000.[60] U.S. electricity generation in 2009 from photovoltaic and solar thermal technologies was 891,179 megawatt-hours, which represented 0.02% of total electricity generation.[61] The majority of this electricity generation came from photovoltaic solar systems.[62] California, New Jersey, Pennsylvania, Hawaii, and Massachusetts are the top five states for installed photovoltaic systems.[63] Concentrated solar power (CSP), a much less mature solar market segment, is typically better suited for high solar insolation areas in desert regions. Most CSP existing capacity and planned projects are located in southwestern states such as California, Arizona, and Nevada.[64]

Some argue that solar electricity provides a number of benefits to the United States, such as zero-emission electricity generation, electricity that can be consumed at the point of generation, and peak power production.[65] Critics of solar electricity point out several limitations to widespread

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[57] This section was written by Phillip Brown.

[58] For more information about photovoltaic technology, see National Renewable Energy Laboratory photovoltaic information available at http://www.nrel.gov/learning/re_photovoltaics.html.

[59] For more information about solar thermal technologies, see National Renewable Energy Laboratory solar thermal information available at http://www.nrel.gov/learning/re_csp.html

[60] Solar Energy Industries Association, *U.S. Solar Industry: Year in Review 2009*, April 15, 2010.

[61] Energy Information Administration, "Electric Power Annual 2009—Data Tables: 1990-2009 Net Generation by State by Type of Producer by Energy Source", available at http://www.eia.doe.gov/cneaf/electricity/epa/epa_sprdshts.html.

[62] For more information about solar markets, see Department of Energy, Energy Efficiency and Renewable Energy, *2008 Solar Technologies Market Report*, January 2010.

[63] National Renewable Energy Laboratory, *The Open PV Project*, 2011, http://openpv.nrel.gov/rankings.

[64] Solar Electric Power Association, *Solar Data & Mapping Tool*, http://www.solarelectricpower.org/solar-tools/solar-data-and-mapping-tool.aspx.

[65] Solar electricity generation may sometimes align with peak power demands in various load centers and distributed generation opportunities.

solar electricity deployment. Possible limitations may include the cost of electricity generation,[66] intermittent operation,[67] and that some solar thermal technologies may require abundant water supplies in areas that are typically water constrained.[68] Among other possible disadvantages are that large-scale solar projects typically require large swaths of land that are not co-located with residential or commercial demand, and transmitting large volumes of solar electricity may be challenged by limited infrastructure.

Policy questions for solar as a qualifying CES energy source could include the following:

- **How will the electricity grid compensate for the intermittent nature of solar electricity?** Grid operators are challenged with maintaining the grid integrity and keeping electricity supply balanced with electricity demand. Stable sources of supply are necessary for reliable grid operations. Electricity generated from solar technologies is, by its nature, variable and can fluctuate based on weather patterns. If solar electricity installations become a large source of electricity, grid operations and reliability might be impacted.
- **Should the federal government fund additional research and development efforts that might reduce the cost of solar electricity production?** In order to reduce the cost of solar electricity, research and development initiatives may be necessary. As a result, solar technology companies may seek additional government assistance to pay for cost reduction R&D activities.[69]
- **Will off-grid solar electricity projects be included in a CES?** Opportunities exist for businesses and homeowners to generate solar electricity that may be completely consumed on-site. These types of projects will be generating electricity, but the electricity may not be sent to the electric grid for sale to other consumers. Determining if off-grid solar generation will receive CES credits and accounting for the role of state metering laws may be policy considerations as legislation is formulated.
- **How might a CES policy interact with natural resource policy?** Solar projects (photovoltaic and thermal) generally require relatively large land areas for utility scale generation. Some solar thermal technologies may also require large volumes of water. Balancing electricity generation with natural resource requirements may be a topic of interest as CES policy is formulated.[70]

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[66] Solar is generally considered the most expensive form of electricity with estimates ranging from $0.16 to $0.34 per kilowatt-hour: estimated natural gas electricity costs are $0.06 - $0.07 per kilowatt-hour. Annual Energy Outlook 2011, Levelized Cost of New Generation Resources in the Annual Energy Outlook 2011, Energy Information Administration, available at http://www.eia.doe.gov/oiaf/aeo/electricity_generation.html

[67] Solar electricity is produced when the sun is shining and weather patterns can impact production.

[68] For more information, see CRS Report R41507, *Energy's Water Demand: Trends, Vulnerabilities, and Management*, by Nicole T. Carter.

[69] DOE's Sunshot Initiative aims to reduce the total system installation cost for solar to $1/watt, with an estimated cost of energy of $0.06/kWhr. On April 8, 2011 DOE awarded $170 million towards solar efficiency improvements and cost reductions. Additional information available at http://www1.eere.energy.gov/solar/sunshot/news_detail.html?news_id=16882

[70] For instance, concentrating solar power technologies can use more water to produce electricity than coal or natural gas. For more information, see CRS Report R40631, *Water Issues of Concentrating Solar Power (CSP) Electricity in the U.S. Southwest*, by Nicole T. Carter and Richard J. Campbell.

Water[71]

Water can be used in various ways to generate electricity. Some water energy technologies include conventional hydropower, small hydropower, low-head hydropower, hydrokinetic, tidal turbines, and ocean thermal energy. Hydropower is the generation of electricity from flowing or falling water. Hydrokinetic electricity is generated by river currents that drive turbines anchored to a river bottom or attached to an existing structure such as a bridge foundation. Tidal turbines capture energy from tidal waves. Ocean thermal energy conversion uses the heat energy stored in the earth's oceans to generate electricity.

The most established form of water energy is conventional hydropower. Conventional hydropower technologies include using turbines at storage facilities, pumped storage, and run-of-river plants.[72] Larger potential for increased hydropower generation lies primarily in the western United States (California, Oregon, and Washington) and Alaska.[73] However, DOE reports that roughly 33 states could increase their hydropower generation by 100% or more, assuming they develop as low-power (less than 1 average megawatt or MWa) projects or small hydro (between 1 and 30 MWa) projects.[74] Moreover, the Bureau of Reclamation identified 70 sites on federal land that could prove economically feasible for development of hydropower based on available data and study assumptions.[75]

The United States has used hydropower for more than 100 years, and at one point hydropower supplied roughly 40% of all electricity generated. Hydropower was the largest renewable energy source for electricity generation in 2010.[76] Approximately 6% of total electricity net generation in 2010 originated from conventional hydropower.[77] The EIA projects that conventional hydropower generation will have an annual growth rate of 0.5% from 2009 to 2035, but is not expected to exceed 7% of total U.S. electricity generating capacity in 2035.[78]

Depending on the technology and site location, there are benefits and drawbacks to expanding hydropower. Some advantages include the generation of electricity as needed to meet demand during peak periods, potentially lower capital costs to upgrade an existing facility or power a non-

[71] This section was written by Kelsi Bracmort.

[72] For more information on hydropower technologies, see CRS Report R41089, *Small Hydro and Low-Head Hydro Power Technologies and Prospects*, by Richard J. Campbell.

[73] For an estimate of natural stream water energy resources available anywhere in the United States for hydropower, see the Idaho National Laboratory (INL) Virtual Hydropower Prospector (VHP) http://hydropower.inl.gov/prospector/index.shtml.

[74] Douglas G. Hall, Kelly S. Reeves, and Julie Brizzee, et al., Feasibility Assessment of the Water Energy Resources of the United States for New Low Power and Small Hydro Classes of Hydroelectric Plants, Department of Energy Office of Energy Efficiency and Renewable Energy, DOE-ID-11263, January 2006, http://www1.eere.energy.gov/windandhydro/pdfs/doewater-11263.pdf.

[75] U.S. Department of the Interior Bureau of Reclamation, *Hydropower Resource Assessments at Existing Reclamation Facilities*, Denver, CO, March 2011, http://www.usbr.gov/power/AssessmentReport/USBRHydroAssessmentFinalReportMarch2011.pdf.

[76] U.S. Energy Information Administration, *Electric Power Monthly*, April 2011, http://www.eia.doe.gov/cneaf/electricity/epm/epm_sum.html.

[77] U.S. Energy Information Administration, *Electric Power Monthly*, April 2011, http://www.eia.doe.gov/cneaf/electricity/epm/epm_sum.html.

[78] Energy Information Administration, *Annual Energy Outlook 2011*, "Electricity Generation," April 2011, http://www.eia.doe.gov/forecasts/aeo/index.cfm.

power dam, and minimal carbon dioxide emissions from energy production in the United States relative to coal power plants. Moreover, certain hydropower facilities may also be used for other purposes, such as irrigation, flood control, and recreation. Disadvantages include relatively high capital costs to construct a new large facility, potential adverse impacts from dams on the environment, and dam safety concerns. Dams can change the natural habitat, affecting wildlife, water quality, and land erosion rates.

One primary natural resource concern for hydropower is adequacy of fresh water supplies. Electricity use and distribution plans must ensure adequate water loads to satisfy energy, human consumption, and agrarian purposes, among others.

Policy questions for water as a qualifying CES energy source could include the following:

- **Should existing hydropower facilities be included as a CES qualifying energy source?** An analysis of EIA data suggests that, if allowed, a few states would currently comply with President Obama's proposed CES mandate of 80% clean energy generation by 2035 largely through the use of existing hydropower facilities.[79] A goal of past CES proposals has been to encourage development of new hydropower facilities.
- **If new hydropower facilities qualify for a CES, will potential licensing issues discourage investment in privately owned facilities?** Privately owned facilities operate under licenses issued by the Federal Energy Regulatory Commission (FERC).[80] The licenses are valid for 30 to 50 years and establish operating parameters for privately owned facilities. Time and cost concerns have arisen in the licensing and relicensing of privately owned facilities.[81] It can take multiple years and millions of dollars to obtain a license.
- **Will small hydro and low-head hydro power facilities be included as "qualifying hydropower" in a CES?** Development of economic small and low-head hydropower resources may be emphasized in a CES.
- **Will new water energy technologies be included as "qualifying hydropower" in a CES?** Hydrokinetic turbines, tidal turbines, and ocean thermal energy conversion are relatively new water energy technologies that might help meet a CES mandate.

Wind[82]

Wind results from uneven heating of the atmosphere by the sun, surface irregularities, and the earth's rotation. Wind is essentially kinetic, or motion energy that can be "harvested" into

[79] For more information, see Figure 3 in CRS Report R41720, *Clean Energy Standard: Design Elements, State Baseline Compliance and Policy Considerations*, by Phillip Brown.

[80] Federal hydropower dams do not require FERC licenses.

[81] For more information, see archived CRS Report RL31903, *Relicensing of Nonfederal Hydroelectric Projects: Background and Procedural Reform Issues*, by Nic Lane.

[82] This section was written by Phillip Brown.

mechanical and electrical energy through a conversion technology.[83] Typically, a turbine and generator are used to capture wind energy and convert it to usable electricity.

Other than hydropower, wind is the largest developed renewable source of electricity in the United States. In 2010, 2.3% of U.S. electricity was generated from wind energy.[84] Wind electricity generation facilities produced more than 70,000 million kilowatt-hours of electricity in 2009.[85] To date, wind electricity generation has come from onshore assets, although abundant offshore wind resources have not been developed and are close to coastal demand loads.

The United States was the largest wind market in the world in 2009, with installed U.S. wind capacity of approximately 35 gigawatts.[86] However, in 2010 China took the lead for the most installed wind capacity, with approximately 44 gigawatts.[87] Total installed wind capacity in the United States at the end of 2010 was approximately 40 gigawatts. U.S. wind capacity is expected to grow by 2.1% from 2009 to 2035, but is not expected to exceed 5% of total U.S. electricity generating capacity in 2035.[88]

Wind is currently one of the lowest-cost renewable electricity options. According to the EIA, the total levelized cost of energy (LCOE) for onshore wind electricity is $97 per megawatt-hour (MWhr) (see **Table 1**).[89] For reference, EIA estimates that solar photovoltaic and solar thermal LCOEs are $210/MWhr and $311/MWhr, respectively.[90]

Proponents for fostering wind development in the United States argue that wind power is clean and emission-free, and that it does not deplete finite resources. In addition, proponents assert that fuel for wind power is essentially free, thus providing a hedge against relatively volatile fossil energy costs. Other suggested advantages are that wind energy may create jobs if the U.S. wind market is expanded and may establish the United States as a global renewable energy leader. Opponents of wind energy development argue that wind energy is an intermittent resource and thus large-scale wind development may result in electricity grid disruptions. They also contend that the best U.S. resources are located in somewhat remote areas with inadequate transmission access to connect the resource with load centers; that wind projects have environmental consequences, including noise and threats to avian species; and that the total system cost of energy for wind is generally higher than for conventional fossil generation, and thus large-scale development of wind projects will ultimately result in higher consumer costs.

[83] Bureau of Land Management, *Wind Energy Guide*, http://windeis.anl.gov/guide/index.cfm.

[84] U.S. Energy Information Administration, *Electric Power Monthly*, April 2011, http://www.eia.doe.gov/cneaf/electricity/epm/epm_sum.html.

[85] *2009 Renewable Energy Data Book*, U.S. Department of Energy, Energy Efficiency and Renewable energy, August 2010.

[86] American Wind Energy Association, *U.S. Wind Industry Market Report*, year ending 2009.

[87] Wind Energy Report 2010, World Wind Energy Association, April 8, 2011, available at http://www.wwindea.org/home/images/stories/pdfs/worldwindenergyreport2010_s.pdf.

[88] Energy Information Administration, *Annual Energy Outlook 2011*, "Electricity Generation," April 2011, http://www.eia.doe.gov/forecasts/aeo/index.cfm.

[89] EIA's LCOE calculations do not include tax credit and other subsidies available for wind projects. Factoring in these subsidies will reduce the cost of energy estimates. Energy Information Administration, "Levelized Cost of New Generation Resources in the Annual Energy Outlook 2011," http://www.eia.doe.gov/oiaf/aeo/electricity_generation.html.

[90] Energy Information Administration, "Levelized Cost of New Generation Resources in the Annual Energy Outlook 2011," http://www.eia.doe.gov/oiaf/aeo/electricity_generation.html.

Policy questions for wind as a qualifying CES energy source could include the following:

- **Could project location and wildlife concerns escalate to a level that might impede large-scale development of wind power projects?** Some opponents of wind argue that rotating wind turbines are a threat to avian species, and some opponents charge that noise from wind turbine operations is considered a nuisance. Others are concerned with radar interference. If wind development continues to increase, these concerns could impact widespread development of wind projects in optimal locations.
- **How will the electric grid compensate for the intermittent nature of wind electricity?** Electricity generated from wind is, by its nature, intermittent and somewhat unpredictable. With grid operators having responsibility for balancing the grid by adjusting supply to accommodate demand, it may be important to have stable and reliable sources of power. Given the intermittent nature of wind electricity generation, grid operators may experience challenges as wind capacity increases.[91]

Potential Demand-Side Source: Energy Efficiency[92]

Energy efficiency is a demand-side resource that could contribute to a CES if reducing future needs for electric energy and power plant capacity is a goal. This section describes the concept of energy efficiency, opportunities for energy efficiency measures, and policy design issues concerning efficiency use in a CES. The section ends with possible policy implications should energy efficiency be included in a CES.

An energy efficiency measure reduces the amount of energy required by specific end-use devices and systems, without reducing the services provided. Energy efficiency is increased when an energy conversion device, such as a household appliance, central air conditioner, or electric motor, undergoes a technical change that enables it to provide the same service (lighting, cooling, motor drive) while using less energy. Energy efficiency involves all aspects of energy production, distribution, and end-use. The energy-saving result of the efficiency improvement is often called "energy conservation."[93]

For an electric utility company, energy efficiency measures are usually packaged into an outreach program that targets demand reductions on the customer's side of the meter. The collective effect of efficiency improvements to a variety of end-use equipment (e.g., lights, refrigerators, air conditioners) provides demand-side power reductions that are equivalent in many ways to supply-side production from new power plants. As a result, energy efficiency can provide power service needs while actually reducing resource use and environmental impacts.

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[91] Bonneville Power Administration (BPA) announced in February 2011 that they were planning to require wind projects in Washington and Oregon to cease operating in order to compensate for "overproduction" expected from BPA's hydropower assets. Wind project owners are appealing BPA's proposed plan. More information is available at http://www.sustainablebusinessoregon.com/articles/2011/04/bpa-pulls-back-on-plan-to-shut-off-wind.html.

[92] This section was written by Fred Sissine.

[93] These ideas of "efficiency" and "conservation" contrast with "curtailment," which decreases output (e.g., turning down the thermostat) or services (e.g., driving less) to curb energy use. That is, energy curtailment occurs when saving energy causes a reduction in services or sacrifice of comfort. Curtailment is often employed as an emergency measure.

There has been considerable debate about the possible role of energy efficiency in a CES. There are at least three key advantages to the use of energy efficiency measures: it is available everywhere that power demand is located; because it cuts energy use, it may reduce environmental impacts; and when it helps avoid growth in power plant capacity, it also reduces the need for additional reserve capacity and may reduce the need for additional transmission infrastructure.

On the other hand, there are at least three disadvantages and/or barriers to the use of energy efficiency measures. First, utility profits generally follow in direct proportion to volume of power sales: the utility has an incentive to increase power sales and a disincentive to reduce power sales. Second, the analytic difficulty of estimating the potential cost savings from energy efficiency measures can deter utility customers (especially residential customers) from using cost-effective efficiency measures.[94] Third, the time requirement and statistical nature of evaluating the impacts of utility energy efficiency programs tends to cause a time delay for the results, and some degree of uncertainty about the magnitude of actual energy savings.

The three main sectors that present opportunities for improving demand-side efficiency in electric energy use are buildings, industry, and transportation. Buildings in the residential, commercial, and industrial sectors present the largest available opportunity.[95] In existing buildings, efficiency improvements can reduce power demanded by hundreds of types of electrical end-use equipment (e.g., lights, refrigerators, air conditioners).[96] Savings may also be available through increased insulation, more efficient windows, and other measures. For new buildings, additional design measures can be incorporated, such as passive heating and cooling features and building integrated solar photovoltaics.

For industry, on-site power generation is another means to reduce demand for electricity generation.[97] Industrial process use of electricity is the next largest opportunity for efficiency. For example, large amounts of electricity are needed to process bauxite into final alloy products in the aluminum industry.

Due to heavy dependence on liquid fuels, the transportation sector currently provides a smaller opportunity for efficiency to reduce electric power use. Currently, most electric power use in this sector supports public transit systems. However, the recent policy focus on increasing the use of electric vehicles and hybrid-electric vehicles could cause the share of power use in this sector to climb significantly.

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[94] "Smart" electronic meters for utility customers are a key part of efforts to transform the national power delivery system into a "smart grid." To the extent that smart meters allow customers to see the potential cost-effectiveness (bill reductions) of energy efficiency measures, increased use of smart meters may help increase use of energy efficiency measures offered through utility programs.

[95] For more about barriers to energy efficiency in buildings, see CRS Report R40670, *Energy Efficiency in Buildings: Critical Barriers and Congressional Policy*, by Paul W. Parfomak, Fred Sissine, and Eric A. Fischer.

[96] Appliance efficiency standards direct manufacturers to improve efficiency, and green labeling programs, such as the Energy Star Program, encourage consumers to use more efficient equipment. As new forms of equipment (e.g., computers, power adapters, cell phones) are introduced into markets, standards may be established to make the equipment more efficient. Also, as technology (e.g., compressors for refrigerators) becomes more efficient, new opportunities arise to increase efficiency levels even further.

[97] The largest amount of on-site power generation is derived from industrial cogeneration power plants. Lesser impacts are derived in the residential and commercial sectors through on-site power generation from renewable energy and combined heat-and-power (CHP) facilities.

There is at least one key issue that would influence the potential contribution from energy efficiency resources. Decoupling of electric utility profits from sales volume is a long-standing issue for the development of energy efficiency resources in power markets. Most utilities have rate structures that encourage greater electricity use by offering lower rates for larger purchases. This practice deters utility use of efficiency because it would reduce profits. Some states (e.g., California) have experimented with innovative rate-making policies that make efficiency profitable. Historically, utilities were designed to make profits in proportion to power sales volume. In the face of growing power demands, that design factor has driven utilities to seek additional supply-side sources and deterred them from seeking demand-side energy efficiency sources that curb sales. Recognition of this key barrier has led to some state regulatory efforts to "decouple" utility profits from sales volume. California, for example, had such an electricity rate-adjustment mechanism in the early 1990s, dropped it during the industry restructuring trend of the mid-to-late 1990s, and re-instated it after the state power shortages of 2001. The mechanism allows rates to increase slightly, to compensate for reduced sales, with the goal of reducing the overall consumer bill.

The role of energy efficiency in a CES depends on potentially conflicting policy goals: use of new, more expensive clean energy technologies or reducing overall demand for electricity. One alternative that has been proposed is to establish a fixed percentage carve-out or "cap" for energy efficiency resources. This was an issue for recent efforts in the debate on renewable energy portfolio standard (RES) legislation. There are at least two purposes of such a cap. One purpose is to provide flexibility to regulated entities that may have a limited amount of clean energy resources. Another purpose is to limit the amount of efficiency resources that could have lower costs in order to avoid diluting the main CES focus on developing new higher-cost forms of power supply.

Policy questions for energy efficiency as a qualifying CES energy source could include the following:

- **Do potential benefits of energy efficiency, such as lower power costs and reduced pollution, justify its inclusion as an eligible resource under a CES?** Many energy efficiency measures are capable of rapid implementation and are available at costs well below those for supply-side resources. In this regard, efficiency may be seen to have less need for new incentives and regulatory policies, such as the CES.
- **If energy efficiency measures were included in a CES, would the relatively low costs inhibit the development and implementation of some clean energy and other supply-side power generation options?** Could a cap on the maximum contribution from efficiency measures help avoid such a concern? Some previous proposals for an RES (i.e., §101 of H.R. 2454 in the 111th Congress) included energy efficiency as a qualified source, but with a cap that set a maximum for its contribution. A key purpose for including efficiency was to increase flexibility for those states or regions that had limited renewable energy resources.
- **If energy efficiency measures were included in a CES, would additional federal funding and regulatory policies (e.g., to help realign utility incentives for profitability) still be needed to help overcome barriers to broader use of energy efficiency measures to defer or displace power plants?** The NAPEE study suggests that efficiency could make a major contribution, effectively

providing the equivalent of up to 20,000 mw of new generating capacity over 10 to 15 years, conditioned on a major increase in efficiency program funding and alignment of the utility profitability incentive.

Unresolved Issues

Legislative examination of a CES could raise multiple questions, including similar questions posed during the renewable fuel standard (RFS) debate.[98] Which sources should be included? Should legislation account for other sources and technologies that are not yet developed? How much clean electricity can be generated in the time frame specified from each qualifying energy source? Should a carbon accounting factor be assigned to each qualifying energy source? Will a time come when some resources (e.g., wind, solar) used to generate clean electricity cease to be considered a "free" resource? If so, what impact might this have on using that resource to meet the CES mandate? Will certain clean energy sources (e.g., natural gas) force out or significantly lower electricity generation from renewable resources? Should energy efficiency be included in a CES, and if so, how should it be included? How would a CES interact with state renewable electricity requirements? Who would assume the costs of new transmission capacity? These questions and other concerns require further exploration to ensure that, if established, a CES would work as intended.

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[98] For more information on the RFS, see CRS Report R40155, *Renewable Fuel Standard (RFS): Overview and Issues*, by Randy Schnepf and Brent D. Yacobucci.