

America's Energy Future: Technology and Transformation: Summary Edition



Committee on America's Energy Future; National Academy of Sciences; National Academy of Engineering; National Research Council

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Executive Summary

This report of the Committee on America's Energy Future addresses a potential new portfolio of energy-supply and end-use technologies—their states of development, costs, implementation barriers, and impacts—both at present and projected over the next two to three decades. The report's aim is to inform policymakers about technology options for transforming energy production, distribution, and use to increase sustainability, support long-term economic prosperity, promote energy security, and reduce adverse environmental impacts. Among the wide variety of technologies under development that *might* become available in the future, this report focuses on those with the best prospects of fully maturing during the three time periods considered: 2008–2020, 2020–2035, and 2035–2050.

Eight key findings emerge:

First, with a sustained national commitment, the United States could obtain substantial energy-efficiency improvements, new sources of energy, and reductions in greenhouse gas emissions through the accelerated deployment of existing and emerging energy-supply and end-use technologies. These options are described in more detail below and in Chapter 2. Mobilization of the public and private sectors, supported by sustained long-term policies and investments, will be required for the decades-long effort to develop, demonstrate, and deploy these technologies. Moreover, actions taken between now and 2020 to develop and demonstrate several key technologies will largely determine options for many decades to come. Therefore, it is imperative that the technology development and demonstration activities identified in this report be started soon, even though some will be expen-

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sive and not all will be successful: some may fail, prove uneconomic, or be overtaken by better technologies.

Second, the deployment of existing energy-efficiency technologies is the near-term and lowest-cost option for moderating our nation's demand for energy, especially over the next decade. The potential energy savings available from the accelerated deployment of existing energy-efficiency technologies in the buildings, industry, and transportation sectors could more than offset the Energy Information Administration's projected increases in energy consumption through 2030. In fact, the full deployment of cost-effective energy efficiency technologies in buildings alone could eliminate the need to construct any new electricity generating plants in the United States except to address regional supply imbalances, replace obsolete power generation assets, or substitute more environmentally benign electricity sources—assuming of course that these efficiency savings are not used to support increased use of electricity in other sectors. Accelerated deployment of these technologies in the buildings, industrial, and transportation sectors could reduce energy use by 15 percent (15–17 quads) in 2020, relative to the Energy Information Administration's "business as usual" reference case projection, and by 30 percent (32–35 quads) in 2030. Even greater energy savings would be possible with more aggressive policies and incentives. Most of these energy-efficiency technologies are cost-effective now and are likely to continue to be competitive with any future energy-supply options; moreover, additional energy-efficiency technologies continue to emerge.

Third, the United States has many promising options for obtaining new supplies of electricity and changing its supply mix during the next two to three decades, especially if carbon capture and storage and evolutionary nuclear technologies can be deployed at required scales. However, the deployment of these new supply technologies is very likely to result in higher consumer prices for electricity.

- Renewable energy sources could provide about an additional 500 TWh (500 trillion kilowatt-hours) of electricity per year by 2020 and about an additional 1100 TWh per year by 2035 through new deployments in favorable resource locations (total U.S. electricity consumption at present is about 4000 TWh per year).

- Coal-fired plants with carbon capture and storage (CSS) could provide as much as 1200 TWh of electricity per year by 2035 through repowering and retrofits of existing plants and as much as 1800 TWh per year by 2035 through new plant construction. In combination, the entire existing coal power fleet could be replaced by CCS coal power by 2035.
- Nuclear plants could provide an additional 160 TWh of electricity per year by 2020, and up to 850 TWh by 2035, by modifying current plants to increase their power output and by constructing new plants.
- Natural gas generation of electricity could be expanded to meet a substantial portion of U.S. electricity demand by 2035. However, it is not clear whether adequate supplies of natural gas will be available at competitive prices to support substantially increased levels of electricity generation, and such expansion could expose the United States to greater import dependence and result in increased emissions of carbon dioxide (CO₂).

Fourth, expansion and modernization of the nation's electrical transmission and distribution systems (i.e., the power grid) are urgently needed. Expansion and modernization would enhance reliability and security, accommodate changes in load growth and electricity demand, and enable the deployment of energy efficiency and supply technologies, especially intermittent wind and solar energy.

Fifth, petroleum will continue to be an indispensable transportation fuel during the time periods considered in this report. Maintaining current rates of domestic petroleum production (about 5.1 million barrels per day in 2008) will be challenging. There are limited options for replacing petroleum or reducing petroleum use before 2020, but there are more substantial longer-term options that could begin to make significant contributions in the 2030–2035 timeframe. Options for obtaining meaningful reductions in petroleum use in the transportation sector include:

- *Improving vehicle efficiency.* Technologies to improve vehicle efficiency are available for deployment now, and new technologies continue to emerge.
- *Developing technologies for the conversion of biomass and coal-to-liquid fuels.* By 2035, cellulosic ethanol and coal-and-biomass-to-liquid

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fuels with carbon capture and storage could replace about 15 percent of current fuel consumption in the transportation sector (1.7–2.5 million barrels per day of gasoline-equivalent) with near-zero lifecycle CO₂ emissions. Coal-to-liquid fuels with carbon capture and storage could replace about 15–20 percent of current fuel consumption in the transportation sector (2–3 million barrels per day; the lower estimate holds if coal is also used to produce coal-and-biomass-to-liquid fuels) and would have lifecycle CO₂ emissions similar to petroleum-based fuels. However, these levels of production would require the annual harvesting of 500 million dry tonnes (550 million dry tons) of biomass and an increase in coal extraction in the United States by 50 percent over current levels, resulting in a range of potential environmental impacts on land, water, air, and human health—including increased CO₂ emissions to the atmosphere from coal-to-liquid fuels unless process CO₂ from liquid-fuel production plants is captured and stored geologically. Commercial demonstrations of the conversion technologies integrated with carbon capture and storage will have to be pursued aggressively and proven economically viable by 2015 if these technologies are to be commercially deployable before 2020. The development of advanced biomass-conversion technologies will require fundamental advances in bioengineering and biotechnology.

- *Electrifying the light-duty vehicle fleet through expanded deployment of plug-in hybrids, battery electric vehicles, and hydrogen fuel-cell vehicles.* Such a transition would require the development of advanced battery and fuel-cell technologies as well as modernization of the electrical grid to manage the increased demand for electricity.

Sixth, substantial reductions in greenhouse gas emissions from the electricity sector are achievable over the next two to three decades through a portfolio approach involving the widespread deployment of energy efficiency technologies; renewable energy; coal, natural gas, and biomass with carbon capture and storage; and nuclear technologies. Achieving substantial greenhouse gas reductions in the transportation sector over the next two to three decades will also require a portfolio approach involving the widespread deployment of energy efficiency technologies, alternative liquid fuels with low CO₂ emissions, and light-duty vehicle electrification technologies.

To enable this portfolio approach in the electricity sector, the viability of two key technologies must be demonstrated during the next decade to allow for their widespread deployment starting around 2020:

- Demonstrate whether carbon capture and storage technologies for sequestering carbon from the use of coal and natural gas to generate electricity are technically and commercially viable for application to both existing and new power plants. This will require the construction of a suite (~15-20) of retrofit and new demonstration plants with CCS featuring a variety of feedstocks, generation technologies, carbon capture strategies, and geological storage locations before 2020.
- Demonstrate whether evolutionary nuclear technologies are commercially viable in the United States by constructing a suite of about five plants during the next decade.

A failure to demonstrate the viability of these technologies during the next decade would greatly restrict options to reduce the electricity sector's CO₂ emissions over succeeding decades. The urgency of getting started on these demonstrations to clarify future deployment options cannot be overstated.

Reducing greenhouse gas emissions from the liquid-fuel-based transportation sector in the 2020–2035 timeframe will also require a portfolio approach that includes cellulosic ethanol and coal-and-biomass-to-liquid fuels. Coal-and-biomass-to-liquid fuels can be produced in quantity starting around 2020 but will not have low carbon emissions unless geologic storage of CO₂ is demonstrated to be safe and commercially viable by 2015. Further reductions in greenhouse gas emissions could potentially be achieved in the transportation sector through electrification of the light-duty vehicle fleet, together with the production of electricity and hydrogen in ways that emit little or no CO₂, assuming the availability of suitable batteries or fuel cells. Although substantial reductions in emissions via these pathways are not likely until late in the 2020–2035 period and beyond, the widespread deployment of hydrogen fuel-cell vehicles during that time also holds some hope for more substantial long-term emission reductions in the transportation sector.

Seventh, to enable accelerated deployments of new energy technologies starting around 2020, and to ensure that innovative ideas continue to be explored, the public and private sectors will need to perform extensive research, development,

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and demonstration over the next decade. Given the spectrum of uncertainties involved in the creation and deployment of new technologies, together with the differing technological needs and circumstances across the nation, a portfolio that supports a broad range of initiatives from basic research through demonstration will likely be more effective than targeted efforts to identify and select technology winners and losers. High-priority technology demonstration opportunities during the next decade include carbon capture and storage, evolutionary nuclear technologies, cellulosic ethanol, and advanced light-duty vehicles. Research and development opportunities during the next decade include advanced batteries and fuel cells, advanced large-scale storage for electrical load management, enhanced geothermal power, and advanced solar photovoltaic technologies.

Eighth, a number of current barriers are likely to delay or even prevent the accelerated deployment of the energy-supply and end-use technologies described in this report. Policy and regulatory actions, as well as other incentives, will be required to overcome these barriers. For technologies to be accepted in the market they must be clearly attractive—in terms of their performance, convenience, and cost—to investors, purchasers, and users. Regulations and standards that target performance characteristics can do a great deal to spur technological development and help improve market attractiveness.

While the committee has done its best to identify those technologies likely to be available over the next two to three decades, many uncertainties remain on the scientific, technological, and policy frontiers and in energy markets. Consequently, the technology options identified in this report should be considered as important first-step technology assessments rather than as forecasts.