Appendix A: History and Context of Sustainable Energy

I. Selected Summary Descriptions of Sustainable Energy Investment Areas

The following sections highlight a limited number of sustainable energy investment areas that may be part of an RD3E strategy.

Advanced, Sustainable Nuclear Power

Nuclear power offers the possibility of providing continuous and dependable base-load electricity without the greenhouse gas emissions produced from fossil-fueled power plants. All commercial nuclear power plants currently operating in the United States (and most nuclear power plants operating worldwide) are light water reactors that use a "once-through" fuel cycle. Proposed advanced (generation IV) nuclear power plants aim to incorporate a suite of new technologies that will produce nuclear power in a manner that is sustainable, economical, reliable, and proliferation-resistant.[1] Despite the potential advantages associated with reduced greenhouse gas emissions, additional research, development, and analysis of advanced nuclear power are needed. Specifically, further information and data are required to demonstrate the possibility of achieving enhanced safety, proliferation resistance, economical cost, and appropriate waste storage solutions. Twelve countries, including the United States, Russia, and China, as well as the European Atomic Energy Community, have agreed on a framework for international cooperation in research for Generation IV systems.[2] In the longer term, fusion energy systems may also offer a sustainable path to nuclear energy. Further research in enabling engineering aspects of fusion reactors, particularly with regards to materials to withstand plasma and neutron bombardment is essential before viable, economic, fusion reactors will be possible.

Alternative Vehicles and Transportation Technologies

Transportation plays a vital role in the U.S. economy, allowing for timely and affordable movement of goods, services, and people. The U.S. transportation sector ranks high in both energy consumption and carbon dioxide emissions. A number of existing and emerging technologies can reduce energy consumption, carbon dioxide emissions, and dependence on foreign oil in the transportation sector. Technologies include hybrid and electric vehicles, smaller and more efficient cars, and advanced hydrogen fuel cell vehicles. There are also transportation infrastructure improvements that can reduce energy usage. Examples include improved public transit, congestion pricing, dedicated high-occupancy vehicle lanes, and urban planning that encourages walking and biking. Transportation infrastructure improvements also address the relationship between land use and greenhouse gas emissions.

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[1] U.S. Department of Energy, Nuclear Research Advisory Committee, and Generation IV International Forum. *A Technology Roadmap for Generation IV Nuclear Energy Systems: Ten Nations Preparing Today for Tomorrow's Energy Needs*. (December 2002).

[2] For more information, see: *http://www.gen-4.org/*.

Basic Science and Engineering (S&E) Research

The objective of basic S&E research is to "gain more comprehensive knowledge or understanding of the subject under study without specific applications in mind."[3] Advances in basic S&E research are critical in driving applied research and innovation in sustainable energy. For example, basic S&E research may lead to the practical development of a carbon-neutral process for producing hydrogen from sunlight and water[4] catalyzed by certain

microbes. The National Science Foundation is a leader in supporting basic S&E research across all disciplines, and the agency has an important role in driving basic research that leads to sustainable energy innovation. The U.S. Department of Energy's Office of Science and its Energy Efficiency and Renewable Energy office also support basic S&E research that will help build a sustainable energy future.

Behavioral and Social Sciences Research

Behavioral and social sciences research builds knowledge of human behavior, human interactions, social and economic systems, and organizations and institutions.[5] Research in these fields is critical to understand the basis for human attitudes and actions toward sustainability, as well as to understand methods for constructing appropriate incentives that align human behavior with a sustainable energy future.[6] Behavioral and social sciences analyses are important components of life cycle analyses and "systems" approaches to solving sustainability challenges.

Behavioral and social sciences research can be used to construct strategies to motivate appropriate individual consumer action. Consumer behavior related to sustainable energy includes decisions about driving and using public transit systems, buying and operating appliances, and energy conservation actions (e.g., turning off the lights when leaving a room). Decisions related to energy usage are a part of daily American life, and helping consumers make sustainable energy choices is an integral part of achieving a sustainable energy future. Economic incentives and education (both formal and informal) can influence consumer behavior; examples include real-time electricity pricing, the use of "smart appliances," and ad campaigns encouraging conservation. Specific areas of behavioral and social sciences research that could help to illuminate influences on consumer behavior

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[3] National Science Board. *Science and Engineering Indicators 2008*. (Arlington, VA: National Science Foundation (Volume 1, NSB 08-01; Volume 2, NSB 08-01A), 2008). Available online at: *http://www.nsf.gov/statistics/seind08/c4/c4s.htm#c4sb1*.
[4] U.S. Department of Energy, Basic Energy Sciences Advisory Committee. *New Science for a Secure and Sustainable Energy Future*. (Washington, DC: U.S. Department of Energy, December 2008). Available online at: *http://www.sc.doe.gov/BES/reports/files/NSSSEF_rpt.pdf*.
[5] National Science Foundation (NSF), Directorate for Social, Behavior, & Economic Sciences (SBE). *About SBE*. (Arlington, VA: NSF). Available online at: *http://www.nsf.gov/sbe/about.jsp*.
[6] G.D. Brewer and P.C. Stern, eds. *Decision Making for the Environment: Social and Behavioral Science Research Priorities.* (Washington, DC: The National Academies Press, 2005).

include consumer response to incentives and information, attitudes and social interactions regarding energy, the effect of social values on consumption, social organization of energy pricing, micro-behavior in consumption environments, and macro-social patterning of consumption.[7],[8],[9]

Carbon Capture, Sequestration, and Utilization

The process of carbon capture (CC), sequestration, and utilization involves the capture, long-term storage, and/or utilization of carbon dioxide from energy systems, especially power generation plants.[10] The captured carbon dioxide may be stored in locations such as deep saline aquifers or depleted oil and gas reservoirs. By capturing a waste stream of carbon dioxide, transporting and compressing the gas, and channeling the gas underground, CC technology has the potential to reduce the amount of carbon dioxide released into the atmosphere. However, the long-term effects of CC technologies and of storing carbon dioxide underground are unknown. Effective demonstration of CC includes overcoming technological, economic, and safety challenges associated with effective transport and storage of compressed carbon dioxide. Many regulatory hurdles and risk management issues exist that must be considered prior to large-scale deployment of CC technology. Despite these challenges, CC may be an important component of the technology solutions required to achieve a sustainable energy future.

In addition to the permanent storage of carbon dioxide in geologic structures, carbon dioxide can be utilized to produce chemical feedstocks, fuel, and raw materials. For example, carbon dioxide can be reduced to formic acid, which has potential to power fuel cells for electricity generation and automobiles. Ponds of genetically modified algae could also convert power-plant carbon dioxide emissions into biodiesel. Bulk chemicals produced from carbon dioxide include urea to make nitrogen fertilizers, salicylic acid as a pharmaceutical ingredient, and polycarbonate-based plastics. Carbon dioxide is also used as a solvent – supercritical carbon dioxide offers advantages in terms of stereochemical control, product purification, and environmental issues for synthesizing fine chemicals and pharmaceuticals.

Economic Models and Assessments

Economic models and assessments for projecting environmental and economic effects of sustainable energy-related technologies and policies are important to arrive at a trans-disciplinary analysis of complex policy issues. Policies that benefit from the use of economic models and assessments include taxing carbon dioxide, renewable energy production tax credits, cap and trade systems, and renewable fuel standards. Some areas for improvement in economic assessments include refining the

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[7] National Research Council, Committee on Behavioral and Social Aspects of Energy Consumption and Production, Assembly of Behavioral and Social Sciences. *Behavioral and Social Aspects of Energy Consumption and Production: Preliminary Report*. (Washington, DC: The National Academies Press, 1982). Available online at: *http://www.nap.edu/catalog/10458.html*.

[8] L. Lutzenhiser. "Social and Behavioral Aspects of Energy Use," *Annual Review of Energy and Environment*, 18(1993): 247-289.

[9] National Science and Technology Council, Subcommittee on Social, Behavioral and Economic Sciences. *Social, Behavioral, and Economic Research in the Federal Context*. (Washington, DC: National Science and Technology Council, January 2009). Available online at: *http://www.ostp.gov/galleries/NSTC%20Reports/SBE%20in%20the%20Federal%20Context.pdf*.

[10] Massachusetts Institute of Technology. *The Future of Coal: An Interdisciplinary MIT Study*. (Cambridge, MA: MIT, 2007). Available online at: *http://web.mit.edu/coal/*.

definition of underlying assumptions, simplifying model structures for faster computational times, and finding better ways to define model parameters.[11] Improved economic models and assessments could provide greater accessibility to policymakers.

Energy Efficiency

From a mechanistic perspective, increased energy efficiency means "energy inputs are reduced for a given level of service, or there are increased or enhanced services for a given amount of energy inputs."[12] Increased energy efficiency may also refer to end-use energy conservation measures that reduce total energy consumption. Increases in energy efficiency may lead to decreased energy costs (for providers and consumers), as well as reduced levels of carbon dioxide emissions. Opportunities exist for improving the efficiency of energy generation (e.g., converting fuels into energy with less waste), transmission (e.g., transmitting electricity from power plant to load center with fewer losses), and distribution (e.g., use by infrastructure, buildings, and transportation vehicles). Consumers can reduce energy consumption and energy costs by making energy efficiency decisions such as weatherizing their homes and using Energy Star® appliances.

Energy Storage

Inexpensive, efficient, and safe methods for storing electrical energy are critical elements of a sustainable energy economy. Electricity storage technologies include pumped hydropower, batteries, and compressed air, which all convert electricity to potential energy and retrieve it when demand for electricity is high. Research in thermal management will ensure a safe and reliable operating temperature for energy storage devices such as batteries. Another research challenge is to increase the number of life cycles for batteries. Emerging sustainable energy technologies that will benefit from advances in energy storage include fuel cells, hybrid electric vehicles, and plug-in electric vehicles.[13] Plug-in hybrid electric vehicle batteries provide a means of energy storage for the electric grid and replace carbon-emitting internal combustion engines from many automobiles. Improvements in energy storage will also facilitate the incorporation of intermittent sources such as wind and solar to the electricity grid.

Information and Communication Technology (ICT)

The ICT sector is defined as "a combination of manufacturing and services industries that capture, transmit, and display data and information electronically."[14] Though ICT services are critical to our nation's productivity and economic well-being, they are large contributors to global greenhouse gas

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[11] Bob Van der Zwaan. "Endogenous Learning in Climate-Energy-Economic Models: an Inventory of Key Uncertainties," *International Journal of Energy Technology and Policy*, 2(1-2, 2004): 130-142. Available online at: *http://belfercenter.ksg.harvard.edu/files/ijetpzwaan.pdf*.

[12] U.S. Department of Energy, Energy Information Agency. "Energy Efficiency: Definition." Available online at: *http://www.eia.doe.gov/emeu/efficiency/definition.htm*.

[13] U.S. Department of Energy, National Renewable Energy Laboratory. "Energy Storage: Research & Development." Available online at: *http://www.nrel.gov/vehiclesandfuels/energystorage/research_development.html*.

[14] Organisation for Economic Co-operation and Development. *Measuring the Information Economy*. (Paris, France: Organisation for Economic Co-operation and Development, 2002). Available online at: *http://www.oecd.org/dataoecd/34/37/2771153.pdf*.

emissions.[15] The ICT sector can be made more efficient by renovating old data centers with new energy-efficient equipment, moving data centers near renewable energy sources, and putting data centers underground to utilize passive cooling potential. In addition to possible efficiency gains within the ICT sector, the use of advanced ICT services (e.g., Smart Motor Systems, Smart Logistics, Smart Buildings, and Smart Grids) has the potential to reduce energy consumption and carbon dioxide emissions in power generation and other end use sectors by as much as 15 percent by 2020.[16]

Renewable Energy Supply Technologies

The Energy Information Administration defines renewable energy as "energy sources that are naturally replenishing but flow limited."[17] Such energy sources are virtually inexhaustible, but often require advanced technologies to be efficiently captured and utilized. Renewable energy sources include solar technologies, wind, geothermal, biomass, and traditional (dams) and non-traditional (tidal, wave, and ocean thermal energy) hydropower. Renewable energy technologies produce little or no greenhouse gas emissions, but are often economically unattractive in the private sector and lack market investment incentives than traditional fossil energy technologies. Therefore, making R&D investments and establishing market conditions will help to make renewable energy cost-competitive with fossil fuels. The following summary descriptions are selected examples of renewable energy sources and technologies.

- **Biomass**
  Biomass is any plant-derived organic matter. Biomass available for sustainable energy includes herbaceous and woody energy crops, agricultural food and feed crops, agricultural crop wastes and residues, wood wastes and residues, aquatic plants, and other waste materials including some municipal wastes.[18] Biofuel is a liquid transportation fuel (e.g., ethanol and biodiesel) that can be produced from biomass.[19] First generation feedstocks for biofuel production include corn (for ethanol) and soybeans (for biodiesel).[20] Bioethanol and biodiesel are commercially available, and researchers are focused on improving crop yields. Second generation feedstocks include crop residues (e.g., corn stover), which are available but will require breakthroughs in cellulosic conversion technology or subsidies to become cost-competitive with corn ethanol and gasoline. Significant R&D gains will be required to commercialize biofuels from third generation feedstocks, which include algae and additional cellulosic feedstocks such as perennial grasses.

[15] The Climate Group and the Global e-Sustainability Initiative. *Smart 2020: Enabling the Low Carbon Economy in the Information Age*. (London, United Kingdom: The Climate Group, 2008). Available online at: *http://www.theclimategroup.org/assets/resources/publications/Smart2020Report.pdf*.
[16] Ibid.
[17] U.S. Department of Energy, Energy Information Administration. *Renewable Energy Consumption and Electricity Preliminary 2006 Statistics*. (Washington, DC: Energy Information Administration). Available online at: *http://www.eia.doe.gov/cneaf/solar.renewables/page/prelim_trends/rea_prereport.html#_ftn20*.
[18] U.S. Department of Energy, National Renewable Energy Laboratory. "Glossary of Biomass Terms." Available online at: *http://www.nrel.gov/biomass/glossary.html*.
[19] U.S. Department of Energy, National Renewable Energy Laboratory. "FAQs on Biomass Basics." Available online at: *http://www.nrel.gov/biomass/faqs/topic.cfm/topic_id=4*.
[20] Biomass Research and Development Board. *National Biofuels Action Plan.* (October 2008).

- **Geothermal**
  Geothermal energy utilizes heat beneath the earth's surface. Geothermal reservoirs of hot water and steam are used to spin turbine-generators to create electricity.[21] Accessing the very high temperature rock located hundreds of meters below the surface of the earth to use as a heat exchanger is a proposed second generation geothermal energy technology, but physical drilling limitations pose a barrier to implementation.[22] Additionally, geothermal heat pumps use the relatively constant earth temperature at very shallow depths as a thermal energy source to heat buildings or as a thermal energy sink to cool buildings. These heat pumps provide an alternative to traditional home heating and air-conditioning systems.

- **Ocean Thermal Energy Conversion (OTEC)**
  OTEC technology takes advantage of the temperature difference between shallow and deep ocean water to produce electricity. The scientific principles behind OTEC have been demonstrated in prototypes, but the technology is not widely used.[23] Challenges to commercialization include substantial upfront capital investment, as well as practical implementation concerns (e.g., there are a limited number of sites where deep-ocean water is located close enough to shore to utilize OTEC technology).[24]

- **Solar**
  Renewable solar energy technologies capture energy from the sun in the form of light or heat, and use it for a variety of applications, such as electricity generation.[25] Photovoltaic (PV) cells capture energy from sunlight and convert the energy directly into electricity. First generation PV devices were made from silicon and were characterized by relatively high costs and moderate efficiency.[26] Second generation PV devices are built to reduce production costs by using thin film semiconductor materials. Although these devices have lower efficiency, they also have lower production costs. Third generation PV aims to combine lower cost with higher efficiency. "Concentrating PV technologies" use lenses or mirrors to concentrate sunlight onto high-efficiency solar cells; they are used in large-scale installations that require large amounts of energy to be harnessed from devices covering a relatively small area. In contrast to PV technologies that convert sunlight to electricity, solar thermal technologies harness the heat energy from the sun to produce electricity. Concentrated solar thermal power technologies use mirrors in a variety of geometries in order to concentrate sunlight and transfer solar heat to be used in electricity generation. In addition to solar electricity generation, solar heat can be utilized for building climate control, cooking, and heating hot water.

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[21] U.S. Department of Energy, National Renewable Energy Laboratory. "Geothermal Technologies." Available online at: *http://www.nrel.gov/geothermal/*.

[22] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. "Geothermal Technologies Program." Available online at: *http://www1.eere.energy.gov/geothermal/geothermal_basics.html*.

[23] U.S. Department of Energy, National Renewable Energy Laboratory. "OTEC." Available at: *http://www.nrel.gov/otec*.

[24] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. "Energy Savers: Ocean Thermal Energy Conversion." Available online at: *http://apps1.eere.energy.gov/consumer/renewable_energy/ocean/index.cfm/mytopic=50010*.

[25] U.S. Department of Energy, National Renewable Energy Laboratory. "Solar Research." Available online at: *http://www.nrel.gov/solar/*.

[26] Martin A. Green. *Third Generation Photovoltaics: Advanced Solar Energy Conversion*. (New York, NY: Springer, 2003).

- **Tidal power**
  Tidal power is generated by forcing water in tidal regions through turbines to generate electricity, typically through the use of a barrage or dam.[27] Tidal power generation is not widespread because of high capital costs and site difficulties, but there is potential for using this technology in the United States.

- **Traditional hydropower**
  Hydroelectric power plants convert the kinetic energy of flowing water to electricity by running the water through a turbine-generator.[28] Several types of hydropower plants exist; some simply divert running river water into a channel where the water flows through a turbine, while others use dams to store river water in a reservoir. Water stored in reservoirs can be released to flow over turbines and generate electricity when demand for electricity is high. Research and development in hydropower is required to improve energy efficiency, as well as to minimize the environmental impacts of the dams used in some hydroelectric power plants.

- **Wave power**
  There are multiple technological approaches to capturing the energy at or below the surface of ocean waves and converting it into electricity. The first commercial wave power plant (which opened in Portugal in 2008) uses the attenuation method of running a hydraulic motor by using the wave to create pressure differentials between sections.[29] Though wave power cannot be harnessed in all coastal areas, the Pacific Northwest is one region in the United States where the potential does exist. Upfront capital costs of building wave power plants are a significant barrier to making wave energy cost-competitive with other energy sources.[30]

- **Wind**
  The kinetic energy in wind can be harnessed and converted by wind turbines into mechanical power or electricity. Wind turbines can operate independently or can be connected to a utility power grid. Utility-scale wind energy generation requires a large number of wind turbines built close together to form a wind plant. Small wind systems can be used as distributed energy resources. Current research in wind technology involves working toward improved efficiency and materials for utility-scale wind turbines and smaller turbines used for distributed power generation.[31] Additional research and development is vital to assess resource-rich locations for new energy facilities, prediction of their intermittent weather-sensitive output at a variety of time scales, storage of their produced power, and transmission to regions of high demand.

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[27] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. "Energy Savers: Ocean Tidal Power." Available online at: *http://apps1.eere.energy.gov/consumer/renewable_energy/ocean/index.cfm/mytopic=50008*.

[28] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. "Wind and Hydropower Technologies Program: Types of Hydropower Plants." Available online at: *http://www1.eere.energy.gov/windandhydro/hydro_plant_types.html*.

[29] Pelamis Wave Power Website. For more information, see: *http://www.pelamiswave.com/*.

[30] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. "Energy Savers: Ocean Wave Power." Available online at: *http://apps1.eere.energy.gov/consumer/renewable_energy/ocean/index.cfm/mytopic=50009*.

[31] U.S. Department of Energy, National Renewable Energy Laboratory. "Wind Research." For more information, see: *http://www.nrel.gov/wind/*.

Smart Grid

A "Smart Grid" encompasses a system of technologies designed to make the electricity grid more efficient, reliable, and capable. Updating and improving the current antiquated electric grid involves many challenges because its critical infrastructure is deteriorating and is unable to handle increased electricity load to accommodate projected increases in U.S. energy demand. Failure to adequately address these challenges by developing an advanced Smart Grid could lead to severe economic disturbance from increasing interruption of electricity distribution and vulnerability from threats and natural disasters. Smart Grid technologies aim to reduce operating costs for both utilities and consumers by easing congestion and increasing capacity utilization through transmission corridors to accommodate the demand for electricity. In addition, Smart Grid technologies reduce the environmental impact of electricity production by reducing load during peak demand as well as making it easier to integrate clean energy sources into the grid. Aspects of a Smart Grid include:

- Integration of digital, control, and cyber-security technologies that allow the grid to perform more reliably and securely;
- Utilization of advanced storage technologies, including plug-in hybrid electric vehicles, to mitigate peak load and integrate intermittent energy sources, such as wind and solar; and
- Deployment of intelligent appliances in homes and offices, as well as smart meters that can communicate price signals and demand response from the power provider to consumers.

Achieving these measures will require new communication standards for appliances and grid-connected equipment, as well as the removal of barriers to adopt Smart Grid technologies and protocols.[32] Various technological components and protocols required to achieve a Smart Grid are currently under development in the public and private sectors. Technological areas requiring further development include sensing and measurement technologies, communication technologies, and energy storage.

Systems Approach to Sustainability Solutions

A systems approach to sustainability involves interdisciplinary work among technologists, behavioral scientists, regulatory experts, and policy analysts in addition to the development of life cycle assessment tools, in order to understand the full environmental impact of sustainable energy solutions. Investment in systems approaches and life cycle assessment tools will allow government and industry to consider economic, environmental and social costs of sustainable energy solutions in order to optimize their utilization. These approaches and analyses will ultimately help decision makers sift through conflicting benefits and consequences of sustainable energy technologies. For example, compact fluorescent light bulbs use less energy than incandescent light bulbs, but they also contain toxic chemicals (e.g., mercury), making disposal hazardous for humans and the environment. A systems approach would include incorporating environmental considerations into product design. Beyond evaluating specific sustainable energy technologies, using systems approaches would also benefit residential and commercial developments: investing in energy efficiency during the construction phase reduces energy costs throughout the operational life of buildings and infrastructure.

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[32] U.S. Congress. *Energy Independence and Security Act of 2007*, 110th Congress, 2nd session, P.L. 110-140. For more information, see: *http://www.oe.energy.gov/DocumentsandMedia/EISA_Title_XIII_Smart_Grid.pdf*.

Zero-Energy Buildings

Buildings currently consume about one-third of the world's energy and account for 40 percent of primary energy use in the United States.[33] Projections indicate that buildings will be the primary consumer of energy worldwide by as early as 2025.[34] Most of the energy consumed in buildings is delivered in the form of electricity, which incurs heavy efficiency losses during generation and transmission. Support for zero-energy buildings can therefore have a substantial impact on global energy consumption and greenhouse gas emissions.

The term "net-zero energy" represents a vision for buildings that independently produce and fulfill their energy requirements, while minimizing greenhouse gas emissions. Zero-energy buildings utilize highly efficient appliances; lighting; heating, ventilating, and air conditioning (HVAC) systems; and advanced building materials. Zero-energy buildings also incorporate options such as daylighting (i.e., strategic placement of windows in order to maximize the use of natural sunlight as lighting), and evaporative cooling and passive ventilation. In addition, they minimize energy losses by generating electricity on-site using renewable technologies such as solar photovoltaic, solar hot water, and wind energy.

Many of the technologies needed to implement zero-energy buildings are currently available. However, because of the long average lifespan of a commercial building, major renovations are often needed to implement energy saving changes. Currently, NSF, the National Institute for Standards and Technology, the U.S. Department of Agriculture, and the Smithsonian Institution are all funding RD3E activities related to zero-energy buildings. One critical focus area is developing measurement science to enable the development of zero-energy buildings. In addition, there is a range of Federal deployment programs executed by the Environmental Protection Agency, the Department of Energy, and other Federal agencies. The private sector, consumers, and Federal and state governments can all implement zero-energy building technologies to increase energy efficiency and reduce greenhouse gas emissions.

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[33] Office of Science and Technology Policy, National Science and Technology Council. *Federal Research and Development Agenda for Net-Zero Energy, High-Performance Green Buildings*. (Washington, DC: Office of Science and Technology Policy, 2008).

[34] Ibid.

II. Current State of U.S. Energy Supply and Consumption

In 2007, the United States consumed energy through four end-use sectors: residential, commercial, industrial, and transportation.[35] The Energy Information Agency (EIA) records data for primary energy consumption in those four sectors, but separates energy consumed as electricity in a fifth sector. Total energy consumption, sources of energy consumption, and carbon dioxide emissions for all five sectors are described in this section.

U.S. energy consumption varies by economic sector and by energy source. About one-third of energy delivered in the United States is consumed by the industrial sector, and one-half of that is consumed by three industries (bulk chemicals, petroleum refining, and paper products).[36] The transportation sector accounts for the second-highest share of total end-use consumption at 29 percent, followed by the residential sector at 21 percent and the commercial sector at 18 percent (Figure 1).[37] Figure 2 depicts primary consumption of energy by end-use sector and separately categorizes energy used in electricity production, transmission, and distribution. Electricity provides the greatest proportion of energy consumed in the United States, and the transportation sector accounts for the next largest share of U.S. energy consumption. Figure 3 depicts energy-related carbon dioxide emissions by end-use sector. Transportation is the largest contributor to total U.S. carbon dioxide emissions followed by the industrial, residential, and commercial sectors, respectively.

Across all sectors, petroleum is the largest primary energy source at around 40 percent of total U.S. energy consumption. Other energy sources include natural gas (23 percent), coal (22 percent), nuclear electric power (8 percent), and renewable energy (7 percent), according to 2007 data.[38] The transportation sector has historically consumed the most petroleum, with its petroleum consumption dramatically increasing over the past few decades. In 2007, petroleum accounted for 95 percent of the transportation sector's energy consumption.[39]

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[35] U.S. Department of Energy, Energy Information Administration. "Energy Consumption by Sector, 1949-2007," Table 2.1a in *Annual Energy Review 2007*. (Washington, DC: U.S. Department of Energy, 2008).

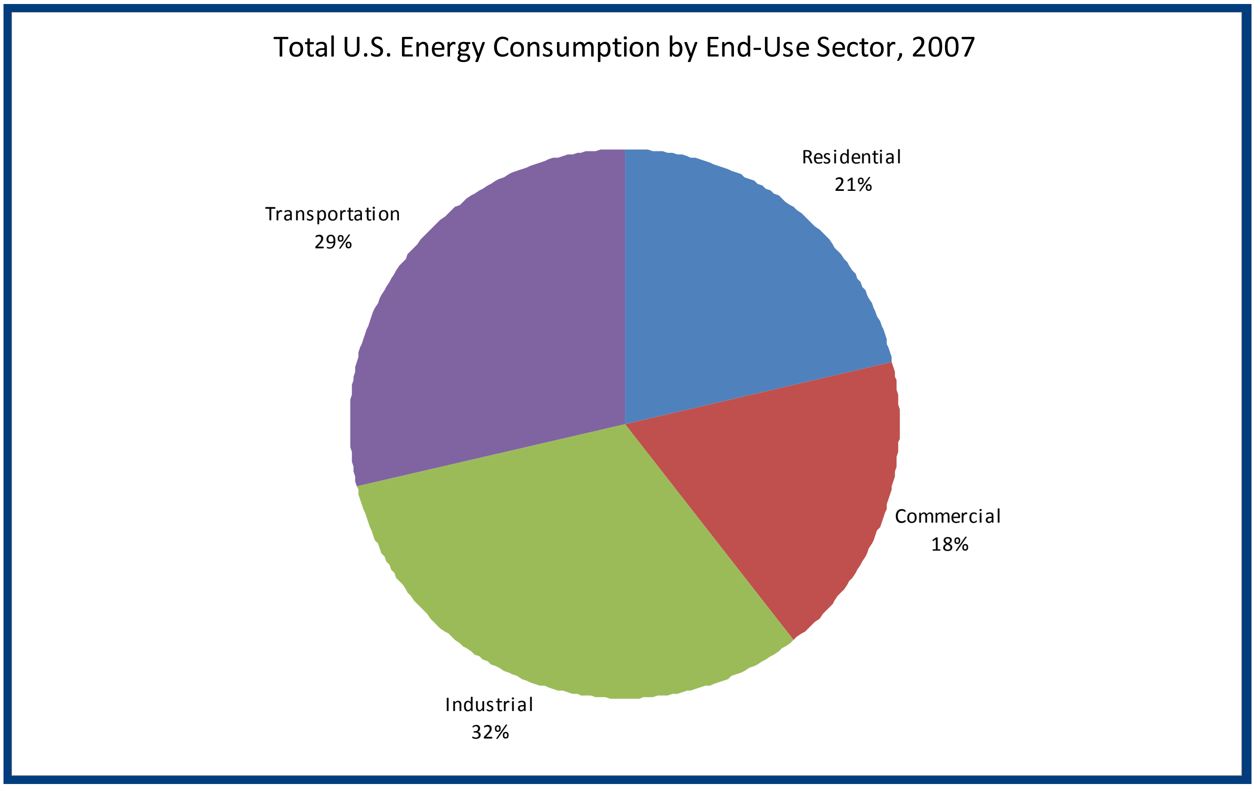
[36] U.S. Department of Energy, Energy Information Administration. *Annual Energy Review 2007*, DOE/EIA-0384(2007). (Washington, DC: U.S. Department of Energy, 2008).

[37] Ibid.

[38] Ibid.

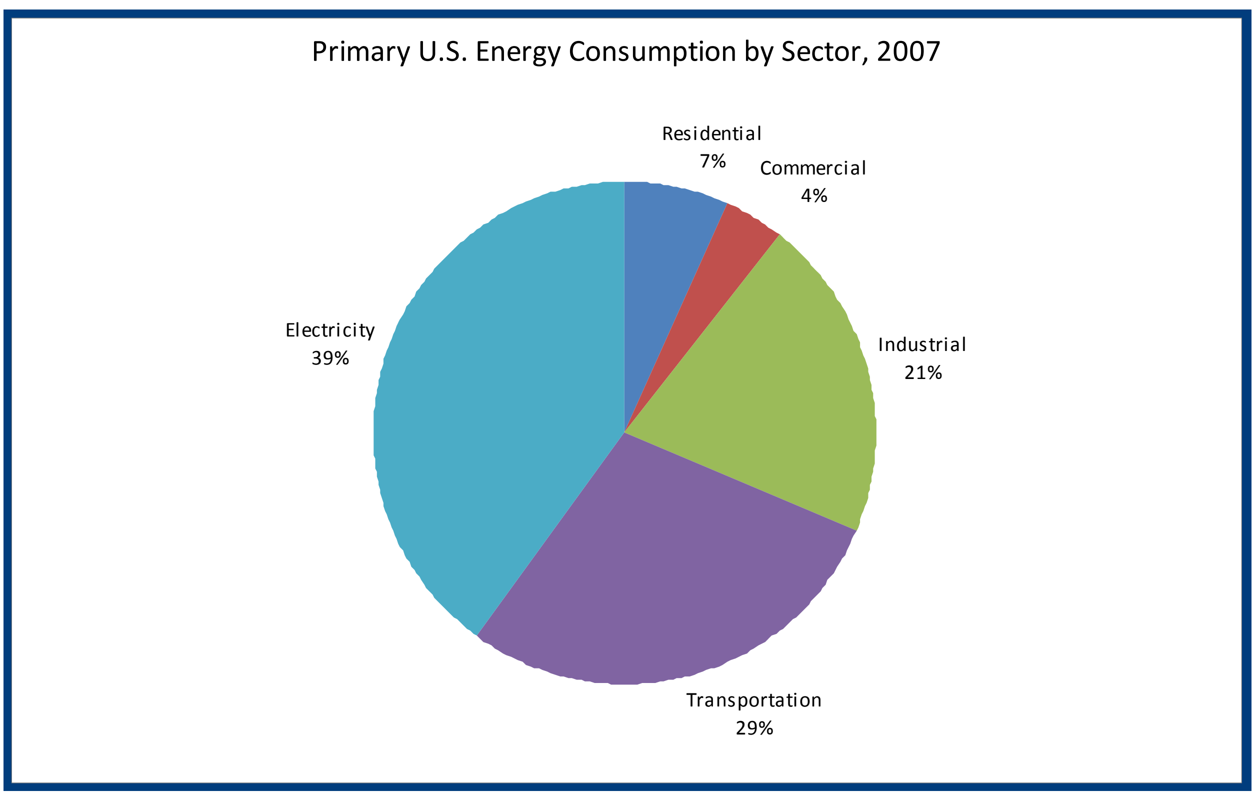
[39] Ibid.

Figure 1. Total U.S. Energy Consumption by End-Use Sector, 2007



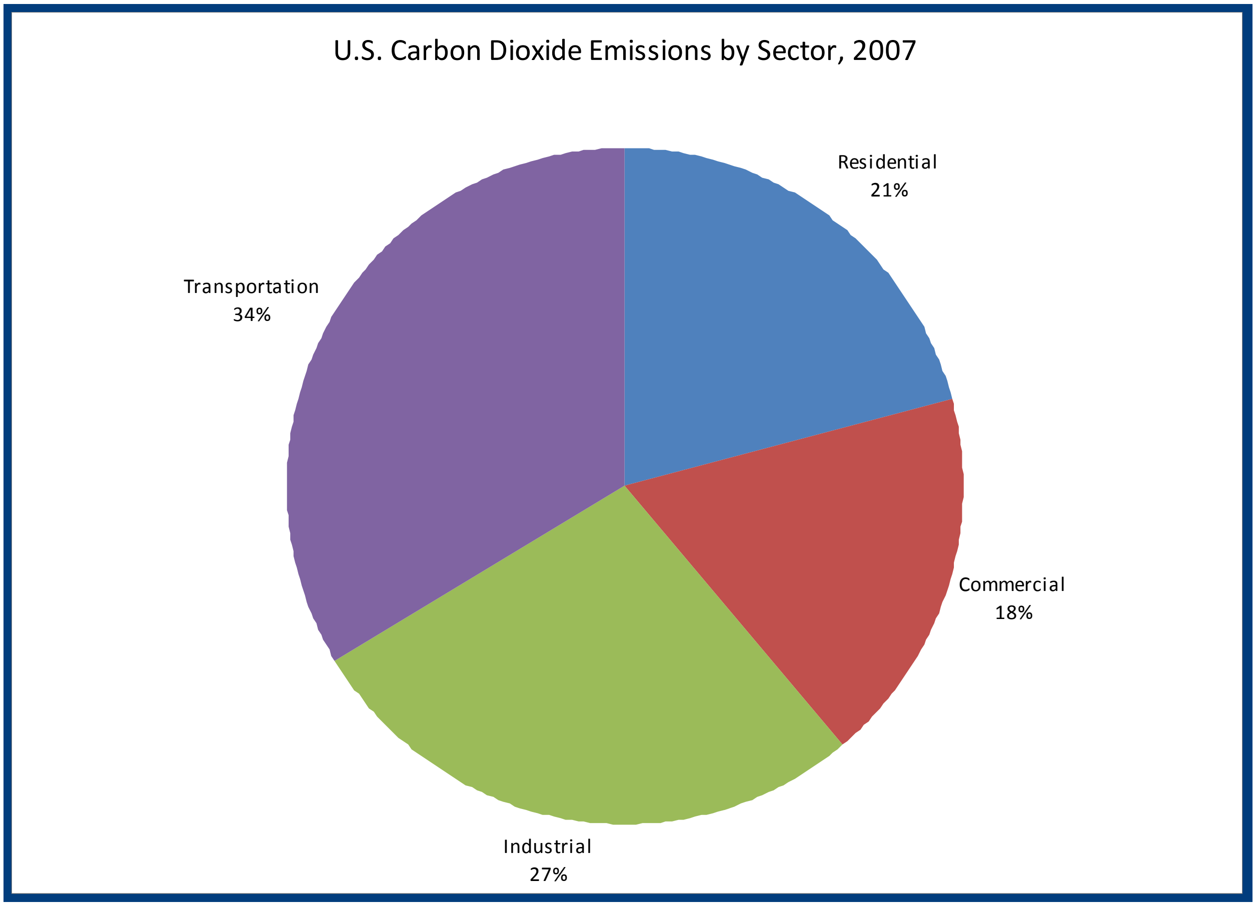
Source: EIA. Annual Energy Review 2007. Table 2.1a, "Energy Consumption by Sector, 1949-2007."

Figure 2. Primary U.S. Energy Consumption by Sector, 2007



Source: EIA. *Annual Energy Review 2007*. Table 2.1a, "Energy Consumption by Sector, 1949-2007."

Figure 3. U.S. Carbon Dioxide Emissions by End-Use Sector, 2007



Source: EIA. *Emissions of Greenhouse Gases Report*. Table 6, "U.S. Energy-Related Carbon Dioxide Emissions by End-Use Sector, 1990-2007."

U.S. Industrial Sector

The U.S. industrial sector includes manufacturing enterprises such as producers of bulk chemicals, refineries, paper products, primary metals, food, glass, and cement. Collectively, these energy-intensive manufacturing industries produce about one-fifth of the dollar value of industrial shipments, while accounting for more than two-thirds of delivered energy consumption.[40] The industrial sector also includes three non-manufacturing categories: agriculture, mining, and construction. Energy is mainly consumed through industrial processes, assembly lines, and building operations. The industrial sector generates most of its own power produced through methods that utilize boilers, steam, and cogeneration.[41] Most energy sources in the industrial sector come from fossil fuels (e.g., petroleum, natural gas, and coal). Fossil fuels are responsible for nearly all of carbon dioxide emissions from this sector.

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[40] U.S. Department of Energy, Energy Information Administration. *Annual Energy Review 2007*. (Washington, DC: U.S. Department of Energy, 2008).
[41] U.S. Department of Energy, Energy Information Administration. "Industrial Sector Demand Module." Available online at: *http://tonto.eia.doe.gov/FTPROOT/modeldoc/m064(2001).pdf*.

Because of the high energy intensity of many industrial subsectors, inexpensive fuels are a priority for this sector. Non-intermittent renewable sources, such as biomass, geothermal, and hydro, could be introduced in greater shares if prices were competitive with fossil fuels and in cases in which those resources are located in close geographic proximity to industrial sites. Increasing consumption of non-intermittent renewable sources would directly displace fossil fuel consumption.

U.S. Transportation Sector

The U.S. transportation sector includes all modes of transportation (i.e., automotive vehicles, rail, marine vessels, aircraft, and mass transit). Transportation is an important component in military and freight operations, as well as personal and commercial travel.[42] Petroleum is the primary source of energy and carbon dioxide emissions in the transportation sector—it supplies 96 percent of the energy consumed and accounts for 98 percent of the carbon dioxide emissions produced by the sector. The remaining 4 percent of energy consumed in the transportation sector is supplied by natural gas and biomass.

Currently, vehicles and associated infrastructure in the United States are designed for a petroleum-based transportation sector. The United States imported 65 percent of the crude oil and petroleum products it used in 2007, mainly from Canada (18 percent of imports), Saudi Arabia (11 percent), Mexico (11 percent), Venezuela (10 percent), and Nigeria (8 percent).[43] The United States could significantly reduce its dependence on imported oil by increasing its use of domestically produced electricity to fuel the transportation sector. Shifting to electricity as the main transportation fuel would affect carbon dioxide emissions, but more research is needed to determine its specific effects. Biofuels, specifically corn and cellulosic ethanol, are expected to achieve increased market penetration as the Federal Renewable Fuel Standard[44] is implemented. Corporate Average Fuel Economy[45] standards will reduce the carbon intensity of the transportation sector by increasing the efficiency of cars and light-duty trucks.

U.S. Residential Sector

The U.S. residential sector includes single- and multi-family homes and mobile homes. Energy in this sector is consumed for heating, cooling, refrigeration, lighting, and powering electric appliances.[46] Fossil fuels supply the majority of energy in the residential sector, with domestic coal

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[42] U.S. Department of Energy, Energy Information Administration. "Transportation Sector Demand Module." Available online at: *http://www.eia.doe.gov/bookshelf/models2002/tran.html*.

[43] Data extrapolated from the U.S. Department of Energy, Energy Information Administration. *Petroleum Navigator*. Available online at: *http://tonto.eia.doe.gov/dnav/pet/pet_cons_psup_dc_nus_mbbl_a.htm* and *http://tonto.eia.doe.gov/dnav/pet/pet_move_impcus_a2_nus_ep00_im0_mbbl_a.htm*.

[44] As legislated by the Energy Independence and Security Act of 2007, the EPA will increase the volume of renewable fuels in the nation's motor fuel supply from 9 billion gallons in 2008 to 36 billion gallons in 2022. For more information, see: *http://www.epa.gov/OMS/renewablefuels/*.

[45] Corporate Average Fuel Economy Standards, first implemented in 1975 was updated in 2007 with the Energy Independence and Security Act to raise the average fuel economy of vehicle fleets to 35 miles per gallon by 2020. Recently, President Obama announced a new national fuel efficiency policy that requires an average fuel economy standard of 35.5 miles per gallon in 2016. This policy would surpass the 2007 law passed by Congress.

[46] U.S. Department of Energy, Energy Information Administration. "Residential Sector Demand Module." Available online at: *http://www.eia.doe.gov/bookshelf/models2002/rsdm.html*.

sources converted into electricity accounting for an additional 36 percent.[47] For every unit of energy delivered to the residential sector in the form of electricity, over two units of energy are lost as waste heat in electric power generation and transmission.[48] Natural gas provides over 20 percent of the primary energy used in this sector, while less than five percent of residential primary energy comes from sustainable sources, (largely biomass, followed by solar and geothermal). Carbon dioxide emissions from the residential sector correlate closely with its energy consumption percentages: 72 percent of residential carbon dioxide emissions result from electrical power generation, transmission, and end-use. Natural gas and petroleum used in home heating and cooking contribute 21 percent and 7 percent, respectively, to residential carbon dioxide emissions.

The residential sector can increase its on-site consumption of renewable energy by using solar heating, solar photovoltaic, and geothermal (ground source) heat pumps. Solar photovoltaic roof panels produce electricity that can be utilized on-site and, in some cases, sold back to the electricity grid if production exceeds demand. Ground source heat pumps circulate a working fluid through pipes buried underground at very shallow depths to utilize the relatively constant temperature as a thermal energy source to heat buildings or as a thermal energy sink to cool buildings, displacing some of the need for electricity and for natural gas or other fuels.

U.S. Commercial Sector

The U.S. commercial sector consists of retail and service buildings (e.g., for food, healthcare, lodging, and business services), warehouses, assembly buildings, and educational facilities. Energy is consumed by these buildings and facilities for heating, cooling, ventilation, lighting, and powering office equipment.[49] The commercial sector consumes nearly 80 percent of its energy in the form of electricity and associated electrical system losses. Natural gas provides about 17 percent of energy to this sector.[50] Biomass, hydropower, and geothermal sources provide a small amount of sustainable energy for the commercial sector. Most carbon dioxide emissions in the commercial sector are due to using fossil fuel sources to generate electricity and its extensive associated losses. In 2007, the commercial sector accounted for 18 percent of total U.S. carbon dioxide emissions. Approximately 21 percent of carbon dioxide emissions in the commercial sector are attributable to electric power generation, transmission, and end-use consumption.

The commercial sector is similar to the residential sector in that consumption of renewable energy can be increased by using on-site technologies such as roof-based solar water heating, solar photovoltaic panels on roofs, and geothermal ground source heat pumps.

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[47] U.S. Department of Energy, Energy Information Administration. *Annual Energy Review 2007*, DOE/EIA-0384(2007). (Washington, DC: U.S. Department of Energy, 2008).

[48] Power generation involves the combustion of fossil fuels to generate heat, which is then used to boil water and create steam. The steam powers a turbine connected to a generator, which produces electricity. At each stage of the process, some heat is lost to the environment, therefore reducing the efficiency of the operation. Similarly, heat losses occur as a result of resistance in power transmission lines. If these electrical system losses are included, about 70 percent of total energy consumption for the residential sector is attributable to electricity generation, transmission, and end-use.

[49] U.S. Department of Energy, Energy Information Administration. "Commercial Sector Demand Module." Available online at: http*://www.eia.doe.gov/bookshelf/models2002/csdm.html*.

[50] U.S. Department of Energy, Energy Information Administration. "Natural Gas Consumption by End Use." Available online at: *http://tonto.eia.doe.gov/dnav/ng/ng_cons_sum_dcu_nus_a.htm*.

U.S. Electric Power Sector

The U.S. electric power sector is made up of electric utilities and independent power producers.[51] The electric power sector generates and delivers electricity and useful heat (in the case of combined heat and power plants) to all other economic sectors. Three energy sources account for almost 90 percent of energy consumption in the U.S. electric power sector: coal accounts for 51 percent of energy consumed in the electric power sector, nuclear power accounts for 21 percent (of which 91 percent of uranium used comes from foreign sources[52]), and natural gas accounts for 17 percent.[53] Coal accounts for 81 percent of carbon dioxide emissions in the electric power sector, and natural gas accounts for 16 percent of carbon dioxide emissions.

Electric power contributes to every end-use sector of the economy. Higher capacity and improved transmission lines, electricity storage capacity, and Smart Grid[54] implementation could help to integrate more sustainable energy into the electric power sector. Undertaking action only to increase sustainable energy in the electricity sector may not reduce total carbon dioxide emissions or dependence on foreign energy suppliers, due to expected increases in demand and the high proportion of domestically produced energy sources already powering this sector.

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[51] U.S. Department of Energy, Energy Information Administration. "Total Electric Power Summary Statistics." Available online at: *http://www.eia.doe.gov/cneaf/electricity/epm/tablees1a.html*.

[52] U.S. Department of Energy, Energy Information Administration. "Uranium Purchased by Owners and Operators of U.S. Civilian Nuclear Power Reactors." Available online at: *http://www.eia.doe.gov/cneaf/nuclear/umar/summarytable1.html*.

[53] U.S. Department of Energy, Energy Information Agency. *Annual Energy Review 2007*, DOE/EIA-0384(2007). (Washington, DC: U.S. Department of Energy, 2008).

[54] "Smart Grid" encompasses a system of technologies designed to make the electricity grid more efficient, reliable, and capable. For more information, see: *http://www.oe.energy.gov/DocumentsandMedia/EISA_Title_XIII_Smart_Grid.pdf*.

III. U.S. Legislative Timeline: Key Policy Actions Related to Sustainable Energy[55]

Year	U.S. Policy Actions Related to Sustainable Energy
1946	President Truman signs the Atomic Energy Act (McMahon Act), transferring control of atomic energy activities from the military to the Atomic Energy Commission (AEC), a civilian agency. The transfer took effect in 1947.
1950	President Truman signs the National Science Foundation (NSF) Act of 1950, authorizing the creation of the new Federal agency and the National Science Board (NSB).
1951	The Experimental Breeder Reactor - 1 (near Arco, Idaho) produces the first electric power from a nuclear reactor.
1954	President Eisenhower signs the Atomic Energy Act of 1954, providing a foundation for the development of a civilian nuclear power program.
1956	The AEC authorizes the construction of world's first two privately owned nuclear power plants.
1957	The Shippingport Atomic Power Station (located in Beaver County, Pennsylvania), the world's first full-scale nuclear power plant, becomes operational.
1958	GE produces the first commercially successful fuel cell, used by NASA in the Gemini program.
1960	First large-scale geothermal power plant in United States begins operation at The Geysers (located in the Mayacamas Mountains, north of San Francisco, California).
1968	President Johnson signs the Wild and Scenic Rivers Act, which restricts dam building and hydropower along designated segments of some U.S. rivers.
1970	President Nixon signs the National Environmental Policy Act, requiring Federal agencies to integrate environmental values into their decision-making processes
1970	President Nixon signs the Clean Air Act, defining EPA's responsibilities for protecting and improving the nation's air quality and the stratospheric ozone layer.
1970	President Nixon signs the Geothermal Steam Act, which governs lease of geothermal steam resources on public lands.
1972	The Atomic Energy Commission announces a cooperative agreement with industry to build a Liquid Metal Fast Breeder Reactor on the Clinch River in Tennessee. (The Clinch River Breeder Reactor project is later discontinued in 1983.)
1973	The Yom Kippur War spurs the Organization of Petroleum Exporting Countries (OPEC) to raise oil prices by 70 percent and impose an embargo on the United States. The embargo was lifted later that year.
1973	President Nixon establishes the Energy Policy Office (renamed the Federal Energy Office in 1973). The office is assigned the tasks of allocating reduced petroleum supplies to refiners and consumers and of controlling the price of oil and gasoline.
1974	President Nixon signs the Federal Administration Act of 1974, creating the Federal Energy Administration to replace the Federal Energy Office.

[55] Information in this table is drawn from various sources including historical timelines generated by the National Science Foundation and the U.S. Department of Energy. Available online at: *http://www.nsf.gov/about/history/overview-50.jsp* and *http://www.energy.gov/about/timeline.htm*.

1974	President Ford signs the Energy Reorganization Act, which splits the AEC into the Nuclear Regulatory Commission (NRC) and the Energy Research and Development Administration (ERDA). The NRC is charged with regulating the nuclear power industry, and the ERDA is given responsibility for management of nuclear weapons and energy development programs.
1974	President Ford initiates the Energy Resources Council, which is charged with insuring "communication and coordination among the agencies of the Federal Government which have responsibilities for the development and implementation of energy policy or for the management of energy resources."
1974	President Ford signs the Solar Energy Research, Development, and Demonstration Act, which establishes the Solar Energy Research Institute in Golden, Colorado.
1974	The Hydrogen Economy Miami Energy (THEME) Conference, the first international conference on hydrogen-based energy, is held in Miami Beach, Florida.
1975	President Ford signs the Energy Policy and Conservation Act, which establishes Corporate Average Fuel Economy (CAFE) standards.
1975	The U.S. Geological Survey (USGS) releases the first national estimate and inventory of geothermal resources.
1976	Congress enacts the Electric and Hybrid Vehicle Research, Development, and Demonstration Act, despite veto by President Ford. The Act enables ERDA to address research and development (R&D) issues in energy storage, vehicle control systems, vehicle design, etc.
1977	President Carter signs the Department of Energy (DOE) Organization Act, replacing ERDA with the DOE. This Act also establishes the Federal Energy Regulatory Commission (FERC).
1977	President Carter issues Executive Order 12003, which orders energy audits and new standards for energy conservation in Federal facilities and fleets.
1977	President Carter signs the Food and Agricultural Act, which authorizes the U.S. Department of Agriculture (USDA) to guarantee loans for biomass-fired power plants and provides funding for renewable energy.
1977	President Carter installs solar panels on the White House. President Reagan later removes the panels.
1977	Congress abolishes the Joint Committee on Atomic Energy, which was established to oversee activities of the AEC.
1977	The first hot dry rock reservoir is developed in Fenton Hill, New Mexico to mine geothermal energy.
1977	The Solar Energy Research Institute in Golden, Colorado becomes operational.
1978	President Carter signs the National Energy Act, which includes the National Energy Conservation Policy Act, the Power Plant and Industrial Fuel Use Act, the Public Utilities Regulatory Policy Act, the Energy Tax Act, and the Natural Gas Policy Act.
1978	President Carter issues Executive Order 12038 to supplement the DOE Organization Act by transferring functions to the newly created position of Secretary of Energy.
1978	President Carter signs the United States Public Utility Regulatory Policies Act (PURPA), which creates a market for independent power producers.

1978	President Carter signs the Energy Tax Act, which creates Federal ethanol tax incentives.
1979	NASA completes the world's first village photovoltaic (PV) system in Schuchuli, Arizona.
1979	President Carter signs the Interior and Related Agencies Appropriation Act, which provides funding for alternative fuels and alternative fuel power plants.
1980	A solar cell power plant demonstration is dedicated at Natural Bridges National Monument in Utah. The project is a result of collaboration between the Massachusetts Institute of Technology (MIT), DOE, and National Park Service (NPS).
1980	President Carter signs the Supplemental Appropriation and Rescission Act, which provides funding for ethanol feasibility studies.
1980	President Carter signs the Crude Oil Windfall Tax Act, which intends to recover revenues earned by oil producers after the sharp rise in oil prices resulting from the OPEC oil embargo.
1980	President Carter signs the Energy Security Act, including the U.S. Synthetic Fuels Corporation Act, Biomass Energy and Alcohol Fuels Act, Renewable Energy Resources Act, Solar Energy and Energy Conservation Act and Solar Energy and Energy Conservation Bank Act, Geothermal Energy Act, and Ocean Thermal Energy Conversion Act.
1981	President Reagan signs Executive Order 12287, which provides for the decontrol of crude oil and refined petroleum products.
1981	President Reagan signs the Nuclear Waste Policy Act of 1982, the Nation's first comprehensive nuclear waste legislation. The act provides for the development of repositories for disposing high-level radioactive waste and spent nuclear fuel, and establishes a program of research, development, and demonstration with respect to waste disposal.
1983	President Reagan signs the Surface Transportation Assistance Act, which raises the gasoline excise tax to 9 cents per gallon and increases the tax exemption for gasohol to 5 cents per gallon.
1983	DOE establishes an Office of Civilian Radioactive Waste Management, which is charged with safely managing and disposing of the Nation's spent nuclear fuel and high-level radioactive waste.
1984	The Federal Advisory Act establishes the National Coal Council (NCC) as a private, nonprofit advisory body chartered by the U.S. Secretary of Energy. The NCC's mission is to advise both government and industry on ways to improve cooperation in areas of coal research, production, transportation, marketing, and use.
1984	President Reagan signs the Tax Reform Act as part of the Deficit Reduction Act of 1984; the Act raises the level of the gasohol tax exemption.
1987	The United Nations (UN) World Commission on Environment and Development publishes the Brundtland Report (*Our Common Future*), defining the concept of sustainable development.
1987	President Reagan signs the National Appliance Energy Conservation Act of 1987, which establishes Federal minimum efficiency standards for many household appliances.
1987	Congress amends the Nuclear Waste Policy Act, designating Yucca Mountain, Nevada, as the only site to be considered as a high-level nuclear waste repository.

1990	President George H.W. Bush signs into law the Omnibus Budget Reconciliation Act, which decreases the gasohol tax exemption.
1990	President George H.W. Bush signs into law the Clean Air Act Amendments, which contain regulatory provisions to address acid rain, urban air emissions, and toxic air pollutants.
1990	President George H.W. Bush signs into law the U.S. Global Change Research Act, creating a U.S. Global Change Research Program that is "aimed at understanding and responding to global change, including the cumulative effects of human activities and natural processes on the environment, to promote discussions toward international protocols in global change research, and for other purposes."
1991	President George H.W. Bush issues Executive Order 12759, which mandates energy conservation at Federal facilities.
1991	The Solar Energy Research Institute is renamed the National Renewable Energy Laboratory.
1992	The UN Conference on Environment and Development (also known as The Earth Summit) is held in Rio de Janeiro, Brazil. The conference results in the establishment of The United Nations Framework Convention on Climate Change (UNFCCC), an international environmental treaty.
1992	President George H.W. Bush signs the Energy Policy Act of 1992, which addresses a variety of issues including energy efficiency, alternative fuels, and storage of radioactive waste material.
1993	President Clinton releases a Climate Change Action Plan, which states the United States will stabilize greenhouse gas emissions at 1990 levels by the year 2000.
1993	President Clinton issues Executive Order 12844, which authorizes Federal acquisition and use of alternative fueled vehicles.
1993	President Clinton issues Executive Order 12845, which requires agencies to purchase energy-efficient computer equipment.
1994	President Clinton issues Executive Order 12902, which requires all Federal agencies to develop and implement 30 percent energy use reduction plans and to increase use of solar and alternative sources.
1994	A favorable Internal Revenue Service ruling extends the excise tax exemption and income tax credits to ethanol blenders producing the fuel oxygenate ethyl tert-butyl ether (ETBE).
1994	EPA enacts a Renewable Oxygen Standard (ROS) that requires that 30 percent of the oxygenates contained in fuels be produced from renewable sources. A year later, a U.S. court rules that the EPA's ROS was an unconstitutional constraint on commerce.
1996	DOE announces the creation of the National Center for Photovoltaics, combining research efforts at the National Renewable Energy Laboratory (NREL) and Sandia National Laboratories.
1998	DOE announces the award of a contract that will result in the world's first high temperature superconductor power cable, which will deliver electricity in a utility network owned by Detroit Edison.
1999	DOE and the U.S. Department of Interior (DOI) launch the Green Energy Parks Program, designed to increase the use of sustainable energy technology in the nation's parks.

1999	President Clinton issues Executive Order 13123, which sets new goals for Federal energy management.
1999	President Clinton issues Executive Order 13134, which establishes an Interagency Council on Biobased Products and Bioenergy.
1999	The United States withdraws from the International Thermonuclear Experimental Reactor after Congress eliminates funding for participation in the project.
2000	President Clinton signs the Biomass Research and Development Act, which establishes a Biomass R&D Board to coordinate Federal activities related to biobased fuels and biobased products. The Board is co-chaired by DOE and USDA.
2000	President Clinton introduces the Climate Change Technology Initiative to develop renewable energy resources and efficient technologies.
2000	DOE and the American Institute Of Architects announce a national design competition for the largest solar energy system on a U.S. Government building.
2000	The global theme for Earth Day 2000 is "Clean Energy Now." Power for the event on the National Mall in Washington, DC is provided entirely by renewable energy sources.
2001	The United States and the European Union (EU) sign agreements to conduct joint research in the areas of fusion energy and non-nuclear energy.
2001	President George W. Bush announces the Climate Change Research Initiative (CCRI) and the National Climate Change Technology Initiative.
2001	The United States withdraws from the Kyoto Protocol.
2001	The United States and France sign an agreement to jointly fund research in advanced reactors and fuel cycle development.
2001	Governments of leading nuclear nations sign formal charter that established the Generation IV International Forum dedicated to the development by 2030 of the next generation of nuclear reactor and fuel cycle technologies.
2002	DOE, in partnership with the automobile industry, announces the FreedomCar Initiative to develop hydrogen cars.
2002	President George W. Bush signs an economic stimulus bill that includes tax credits for power generators using renewable sources and consumer purchasing of electric vehicles.
2002	The Generation IV International Forum agrees on six nuclear energy systems to be pursued for joint development.
2003	President George W. Bush announces the Climate VISION program to reduce greenhouse gas emissions.
2003	President George W. Bush announces FutureGen, a $1 billion initiative to build a near-zero atmospheric emissions coal fired power plant using carbon capture and sequestration and other advanced technologies. The FutureGen mission is restructured in 2008.
2005	The Asia-Pacific Energy Initiative is announced as a response to the Kyoto Protocol.
2005	President George W. Bush signs the Energy Policy Act of 2005, which includes tax incentives for energy production and procurement guidelines for energy-efficient products by Federal agencies.
2006	President George W. Bush announces the Advanced Energy Initiative, which includes research in alternative energy, nuclear energy, hybrid and electric cars.

2006	Secretary of Energy Bodman announces the Global Nuclear Energy Partnership, designed to promote safe use of nuclear power worldwide and to close the nuclear fuel cycle.
2007	President George W. Bush issues Executive Order 13423, which orders the reduction of Federal energy facility use by 3 percent per year through 2015.
2007	The G8+5 countries agree on the Washington Declaration, the outline of a successor to the Kyoto Protocol.
2007	President George W. Bush signs the Energy Independence and Security Act of 2007, which orders reductions in Federal energy use.
2008	DOE restructures the FutureGen mission due to escalating costs, and changes its approach to fund multiple commercial clean coal projects.
2008	President George W. Bush and Prime Minister Singh grant final approval to a U.S.-India civilian nuclear deal. The agreement creates a strategic partnership between the United States and India with respect to nuclear cooperation and prohibits India from reprocessing nuclear fuel.
2008	President George W. Bush signs the Emergency Economic Stabilization Act, which contains tax incentives for energy efficient homes and commercial buildings, as well as an extension of wind and solar investment and production tax credits.
2008	Secretary of Energy Bodman and Secretary of Agriculture Schafer release the National Biofuels Action Plan developed by the Biomass Research and Development Board.
2009	President Obama signs the American Recovery and Reinvestment Act, which includes funding for energy efficiency and renewable energy programs and research throughout the Federal government.