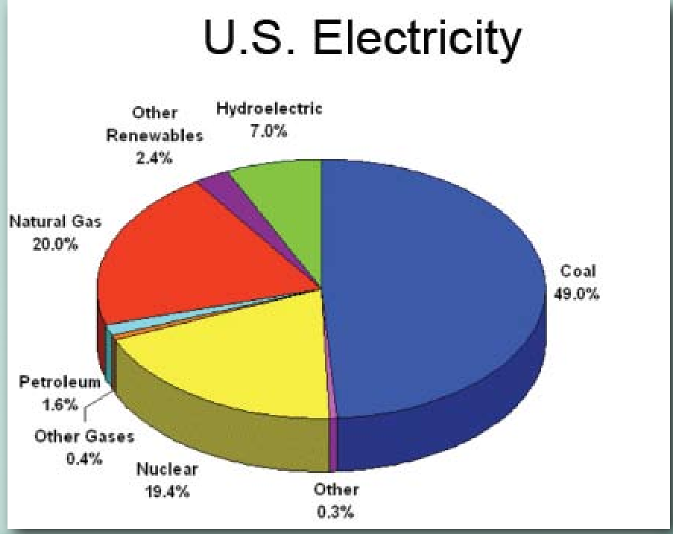
Energy Production

- Warming will be accompanied by significant increases in electricity use and peak demand in most regions, due to increased demand for air conditioning.
- Energy production is dependent upon reliable water supply.
- Rising temperatures decrease power plant efficiency.
- Energy production and delivery systems are vulnerable to sea-level rise and extreme weather events in many regions.
- Climate change is likely to affect some renewable energy sources, especially hydropower.

placeholder for U.S. Energy consumption graph

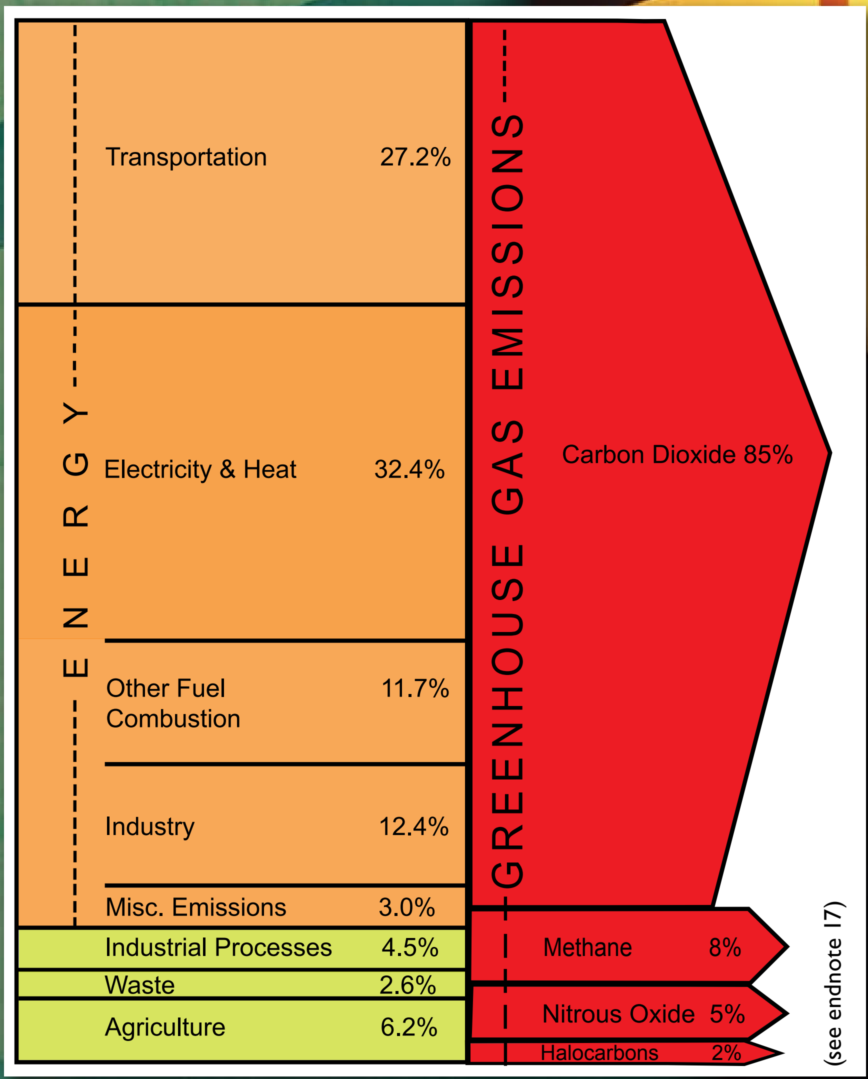


and Use

Energy is at the heart of the global warming challenge. It is humanity's production and use of energy that is the primary cause of global warming, and in turn, warming will impact our production and use of energy. The vast majority of U.S. greenhouse gas emissions, about 87 percent, come from the energy sector[1-a].

At the same time, other U.S. trends are increasing energy use: population shifts to the South and West, an increase in the square footage built per person, increased electrification of the residential and commercial sectors, and increased market penetration of air conditioning.

Global and national energy choices made in the coming years will largely determine the degree of future climate change. Policies to reduce greenhouse gas emissions will have implications for the energy sector, and these will in turn feed back to influence how the energy sector impacts climate.



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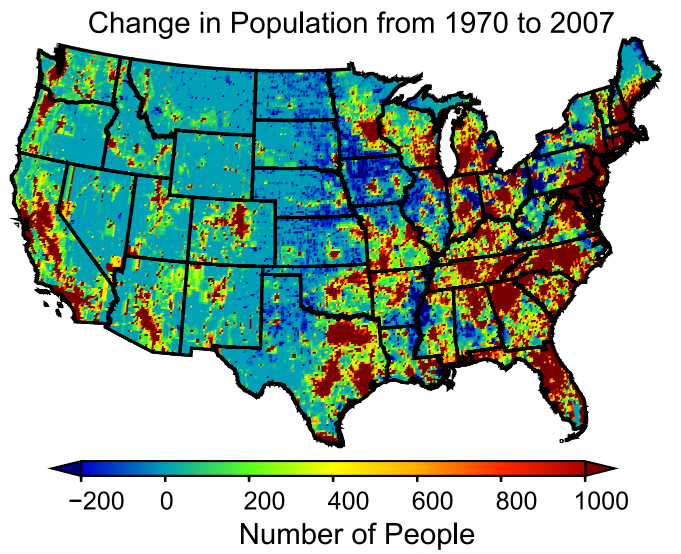
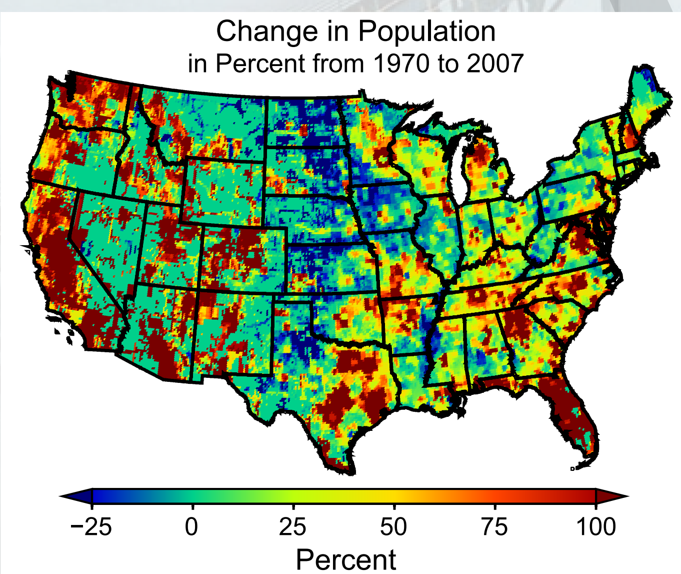


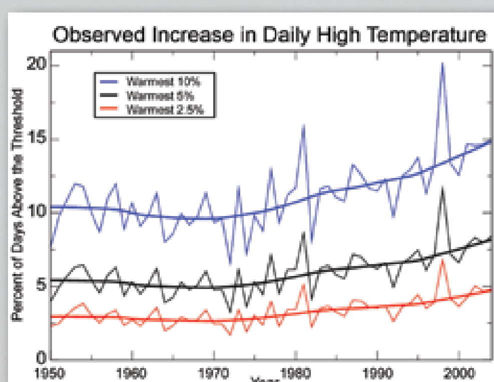
The map above, showing changes in numbers of people, graphically illustrates the large increases in population in places that require air conditioning. Areas with increases of more than 1000 people are all shown in maroon. Some of these places had enormous growth, in the hundreds of thousands of people. For example, parts of Los Angeles, Phoenix, Las Vegas, Dallas, Houston, and Miami all had increases of between 250,000 and 400,000 people.



The map above, showing percentage changes in population, shows the very rapid growth in the South and Southwest. Places with increases over 100% growth are shown in maroon. Some areas, such as those around Orlando, Florida, and Denver, Colorado, had increases of 600%.

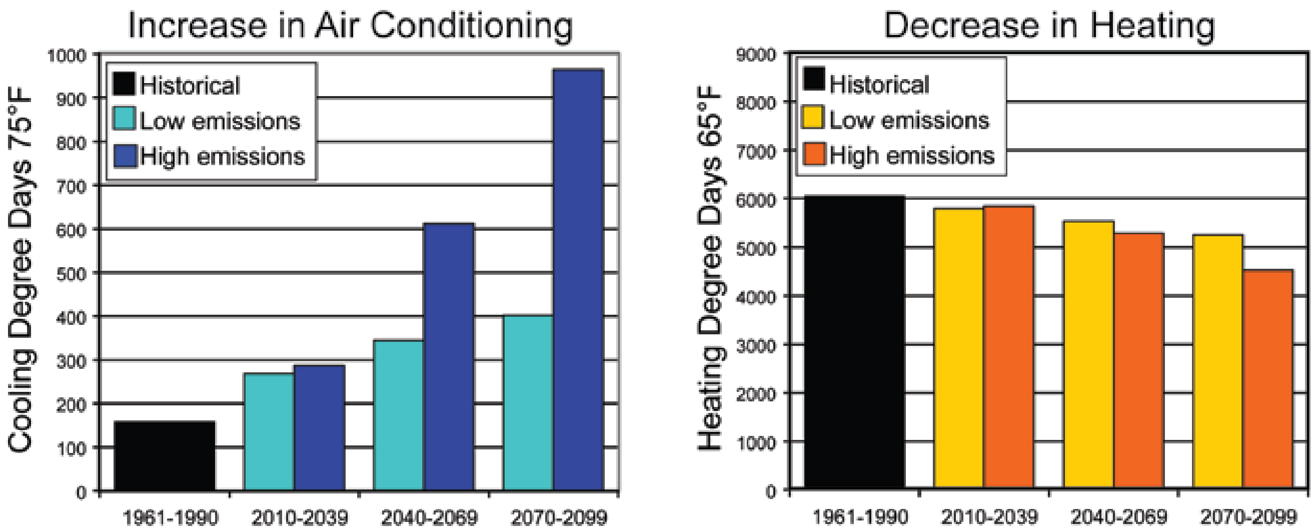
Energy use in U.S. buildings currently accounts for 38 percent of the nation's energy-related heat-trapping gas emissions. Studies that assess future changes in energy use as a result of global warming project an increase in electricity consumption and in the consumption of primary fuels used to generate it, except in the few regions that provide a considerable amount of space heating with electricity, such as the Pacific Northwest. Peak electricity demand is also projected to increase, causing a disproportionate increase in energy infrastructure investment.

In the southern part of the nation, electricity use for air conditioning is expected to increase more than heating fuel use decreases. In the northern part of the U.S., projected warming is expected to reduce consumption of heating fuel more than it increases the consumption of electricity. However, because air conditioning relies entirely on electricity, and the generation, transmission, and distribution of electricity is subject to significant energy losses, national primary energy demand is projected to increase with rising temperatures. And because 50 percent of the nation's electricity is generated with coal, which is the highest carbon fuel, carbon dioxide emissions are also projected to increase (unless concerted measures are taken to change the fuel mix or remove the carbon dioxide from coal-burning processes and store it under ground, as has been proposed). In addition, because population movements are generally toward the southern regions that require more air conditioning and away from those regions that require more heating, population shifts also contribute to an increasing trend in energy use.



Changes in the percentage of days in a year above three thresholds for North America for daily high temperature[15].

Shifting Energy Demand in Chicago



(see endnote 16)

A number of studies have considered effects of warming on energy requirements for heating and cooling in buildings in the United States. They find that the demand for cooling increases from 5 to 20 percent per 1.8°F of warming, and the demand for warming drops by 3 to 15 percent per 1.8°F of warming. The range reflects different assumptions about such factors as the rate of market penetration of improved building equipment technologies.

Since nearly all cooling is provided by electricity use, while much of our heating of buildings is provided by natural gas and fuel oil, the projected changes imply increased demands for electricity, especially in two kinds of areas: (1) where climate change would result in significant increases in the heat index, especially in summers, and (2) where relatively little space cooling has been needed in the past, but demands are likely to increase in the future.

Other effects of climate change on energy consumption are less clear, because little research has been done. For instance, warming would increase the use of air conditioners in highway vehicles, possibly reducing fuel efficiency, and water scarcity in some regions could increase energy demands for water pumping. Improving the information available about these other kinds of effects is a priority.

Energy production is dependent upon reliable water supply

In some regions, reductions in water supply could be significant, increasing the competition for water among various sectors including energy production (see *Water* sector). Operation of existing energy plants and development of future facilities could be restricted by water availability.

The production of energy from fossil fuels (coal, oil, and natural gas) is inextricably linked to the availability of adequate and sustainable supplies of water[3]. While providing the U.S. with the majority of its annual energy needs, fossil fuels also place a high demand on the nation's water resources in terms of both use and quality impacts[4]. Generation of electricity in power plants (coal, nuclear, gas, or oil) is water intensive; on average, each kilowatt-hour of electricity generated in a power plant requires about 25 gallons of cooling water. Power plants rank only slightly behind irrigation in terms of freshwater withdrawals in the United States[5].

Water is also required in the mining, processing, and transportation of coal to generate electricity, all of which can have direct impacts on water quality. Surface and underground coal mining can result in acidic, metal-laden water that must be treated before it can be discharged to nearby river and streams. In addition, in 2000, the mining industry withdrew about two billion gallons per day of fresh water.

There is a high likelihood of water shortages limiting power plant electricity production in many regions, projecting future water constraints on electricity production in power plants for Arizona, Utah, Texas, Louisiana, Georgia, Alabama, Florida, California, Oregon, and Washington state by 2025[5a]. Additional parts of the United States could face similar constraints as a result of drought, growing populations, and increasing demand for water for various uses. The issue of competition among various water uses is dealt with in more detail in the *Water* sector.

In addition to the problem of water availability, there are issues related to an increase in water temperature. Using warmer water as an input for power plants reduces the efficiency of cooling technologies, and warmer water as a receiver of water discharges could present environmental implications. And when power plants use water for cooling, they discharge that water at higher temperatures which has environmental implications. Large coal and nuclear plants have been limited in their operations by temperature-related river water level changes and thermal limits on water discharges[6].

Rising temperatures decrease power plant efficiency.

The efficiency of thermal power plants, fossil or nuclear, is sensitive to ambient air and water temperatures; higher temperatures reduce power outputs by affecting the efficiency of cooling. Although the effect is not large in percentage terms, even a relatively small change could have significant implications for total national electric power supply. For example, an average reduction of one percent in thermal power generation nationwide would mean 25 billion kWh/year, about the amount of electricity consumed by two million Americans, that would need to be supplied in some other way.

Regional Spotlight: Energy Impacts of Alaska's Rapid Warming

Significant impacts of warming on the energy sector can be found in Alaska, where temperatures have risen about twice as much as the rest of the nation. In Alaska, frozen ground and ice roads are an important means of winter travel and warming has resulted in a much shorter cold season. Serious impacts on the oil and natural gas industries on Alaska's North Slope have been one of the results. In addition, the thawing of permafrost, on which buildings, pipelines, airfields, and coastal installations supporting oil and gas development are located, adversely affects these structures and increases the cost of maintaining them.

Different energy impacts are expected in the marine environment as sea ice continues to retreat and thin. These trends are expected to improve shipping accessibility around the margins of the Arctic Basin, though not in a uniform fashion among the different regions. Extensive oil and gas reserves have been discovered in Alaska along the Beaufort Sea coast. Offshore oil exploration and extraction will probably benefit from less extensive and thinner sea ice, although equipment will have to be designed to withstand increased wave forces and ice movement[9].

Energy production and delivery systems are vulnerable to sea-level rise and extreme weather events in many regions.

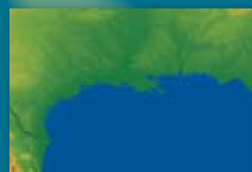
Sea-level rise

A significant fraction of America's energy infrastructure is located near the coasts, from power plants, to oil refineries, to facilities that receive oil and gas deliveries. Rising sea levels are likely to lead to direct losses such as equipment damage from flooding or erosion and indirect effects such as the costs of raising vulnerable assets to higher levels or building new facilities further inland, thus increasing transportation costs[10]. The U.S. East Coast and Gulf Coast have been identified as particularly vulnerable to sea-level rise because the land is relatively flat and also subsiding in some places[11].

Extreme events

Observed and projected increases in a variety of extreme events will have significant impacts on energy. As witnessed in 2005, hurricanes can have a debilitating impact on energy infrastructure. Direct losses to the energy industry in 2005 are estimated at $15 billion[13], with millions more in restoration and recovery costs. As one example, the Yscloskey Gas Processing Plant was forced to close for six months following Hurricane Katrina, resulting in lost revenues to the plant's owners and employees, and higher prices to consumers as alternative gas sources had to be procured.

Regional Spotlight: Gulf Coast Oil and Gas



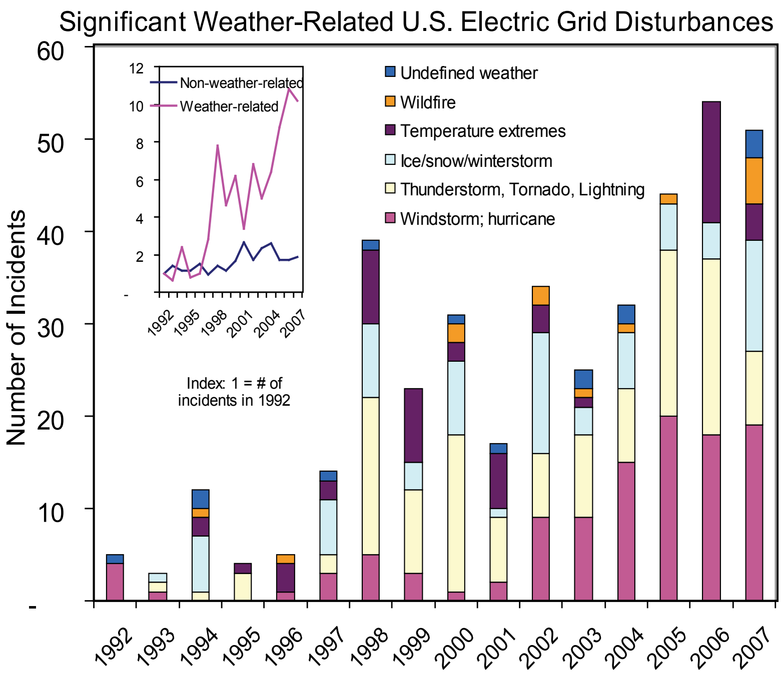
The Gulf Coast is home to the U.S. oil and gas industries, representing nearly 30 percent of the nation's crude oil production and approximately 20 percent of its natural gas production. A third of the national refining and processing capacity lies on coastal plains adjacent to the Gulf. Several thousand offshore drilling platforms, dozens of refineries, and thousands of miles of pipelines are vulnerable to damage and disruption due to sea-level rise and the high winds and storms surge associated with hurricanes and other tropical storms. For example, Hurricanes Katrina and Rita halted all oil and gas production from the Gulf, disrupted nearly 20 percent of the nation's refinery capacity, and closed many oil and gas pipelines[12].

Offshore production is particularly susceptible to extreme weather events. Hurricane Ivan in 2004 destroyed seven platforms in the Gulf of Mexico, significantly damaged 24 platforms, and damaged 102 pipelines. Hurricanes Katrina and Rita in 2005 destroyed more than 100 platforms and damaged 558 pipelines. The photos show Chevron's "Typhoon" platform before and after the 2005 hurricanes. The $250 million platform was damaged beyond repair. Plans are being made to sink its remains to the sea floor.

(see endnote 3)

The incapacitation of energy infrastructure due to the hurricanes of 2005, especially of refineries, gas processing plants, and petroleum product terminals, is widely blamed for driving a price spike in fuel prices across the country, with national consequences. The impacts of more severe weather are not limited to hurricane-prone areas. Rail transportation lines, which transport approximately two-thirds of the coal to the nation's power plants, often follow riverbeds, especially in the Appalachian region. More intense rainstorms, which have been observed and projected, can lead to flooding of rivers that can then wash out or degrade the nearby rail and roadbeds[14].

Flooding and drought can both disrupt the operation of inland waterways, the second-most important method for transporting coal. With utilities carrying smaller stockpiles and projections showing a growing reliance on coal for a majority of the nation's electricity generation, any significant disruption to the transportation network has serious implications for the over reliability of the electric grid (see *Transportation* sector).



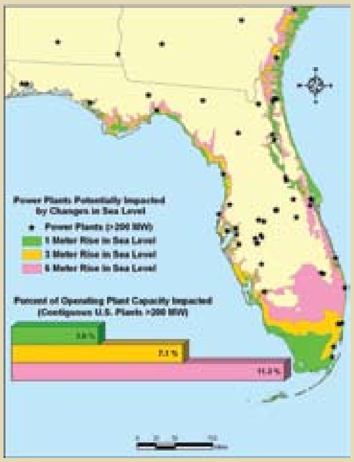
The number of incidents caused by extreme weather is up 10-fold since 1992. The portion of all events that are caused by weather-related phenomena has tripled from about 20 percent in the early 1990s to about 65 percent in recent years. The weather-related events are more severe, with an average of about 180,000 customers affected per event compared to about 100,000 for non-weather-related events (and 50,000 excluding the massive blackout of August 2003)[3].

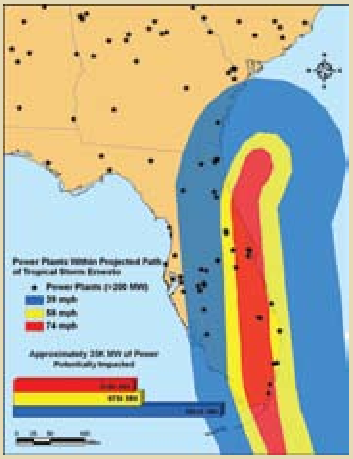
Development of new energy facilities could be restricted by siting concerns related to sea-level rise, exposure to extreme events, and increased capital costs resulting from a need to provide greater protection from extreme events.

The electricity grid is also vulnerable to climate change effects, from temperature changes to severe weather events. The most familiar example is effects of severe weather events on power lines (e.g., from ice storms or tornadoes as well as hurricanes), but in the summer heat wave of 2006 electric power transformers failed in several areas, such as St. Louis and Queens, NY, due to high temperatures, causing interruptions of electric power supply. It is not yet possible to project effects of climate change on the grid, because so many of the effects would be more localized than current climate change models can depict; but weather-related grid disturbances are recognized as a challenge for strategic planning and risk management.

Regional Spotlight: Florida's Energy Infrastructure

Florida's energy infrastructure is particularly vulnerable to sea-level rise and storm impacts. Most of the petroleum products consumed in Florida are delivered by barge to three ports, two on the east coast of Florida and one on the west coast. The interdependencies of natural gas distribution, transportation fuel distribution and delivery, and electrical generation and distribution were found to be major issues in Florida's recovery from recent major hurricanes.





Climate change is likely to affect some renewable energy sources, especially hydropower.

Renewable energy production accounts for 9.4 percent of electricity production in the United States. Hydroelectric power is by far the largest renewable contributor to electricity generation, accounting for about 7 percent of total U.S. electricity. Like many things discussed in this report, renewable energy resources have strong interrelationships with climate change; using renewable energy can reduce the magnitude of climate change, while climate change can affect the prospects for using some renewable energy sources.

Hydropower is a major source of electricity in some regions of the U.S., particularly the Pacific Northwest. It is likely to be significantly affected by climate change. The year-to-year variation in hydropower generation is very high, especially relative to other energy sources. There is a 30 percent difference between recent high and low years for hydropower generation because the amount of water available for hydropower varies greatly from year to year. This amount depends upon weather patterns, local hydrology, and competing water uses such as flood control, water supply, recreation, and requirements for fulfilling downstream water rights, navigation, and the protection of fish and wildlife. Climate variability is the most important factor in the variability of hydropower.

Significant changes are already being detected in the flow regimes of many western rivers, consistent with the predicted effects of global warming. More precipitation coming as rain rather than snow, reduced snow pack, earlier peak runoff, and related effects are beginning to affect hydropower availability. Hydroelectric generation is very sensitive to changes in precipitation and river discharge. For example, every 1 percent decrease in precipitation results in a 1 percent drop in stream flow; every 1 percent decrease in stream flow in the Colorado River Basin results in a 3 percent drop in generation. Such magnifying sensitivities occur because water flows through multiple power plants in a river basin. Climate impacts on hydropower occur when either the total amount or the timing of runoff is altered, for example, when natural water storage in snow pack and glaciers is reduced under hotter conditions. Glaciers, snow pack, and their associated runoff are already declining in the U.S. West, and larger declines are projected.

Hydropower operations are also affected by changes to air temperatures, humidity, or wind patterns due to climate change. These variables cause changes in water quantity, quality, and temperature. Warmer air and water generally increases the evaporation of water from the surface of reservoirs, reducing the amount of water available for power production and other uses. Huge reservoirs with large surface areas, located in arid, sunny parts of the country, such as Lake Mead on the Colorado River, are particularly susceptible to increased evaporation due to warming, meaning less water will be available for all uses, including hydropower. And where hydropower dams flow into waterways that support trout, salmon or other cold-water fisheries, warming of reservoir releases may have unacceptable consequences that require changes in operations that reduce power production. Such impacts will increasingly present competition for resources.

Biomass energy now produces about 4 percent of total U.S. energy, mostly for industrial uses, though it may increase substantially in the future, given the current emphasis on ethanol and other biofuels for transportation.

If there were changes in wind resources and direct solar radiation, it would impact the planning, siting, and financing of wind and solar technologies. For example, some climate models project increases in cloudiness that have the potential to diminish the solar resource barring other counterbalancing effects; preliminary results based on one study suggest a 6 percent decrease in overall solar cell output. Atmospheric pollutant particles could further decrease the solar resource. Wind power could also be affected if there were warming-induced changes in the wind resource. Preliminary results from a limited number of studies suggest significant decreases may be expected in some places in some seasons though others suggest increases in some places and seasons. This is an area that requires much more study (see *Pathways to Improved Understanding*).