7

WIND

7.1 Wind Power Generation

Wind power is the largest renewable energy source in the U.S., surpassing hydroelectric power in 2019; solar ranks third.

In 2023, 425.2 billion kWh of wind power were generated in the U.S., according to the Energy Information Administration (EIA; www.eia.gov). This accounted for 10.2% of total U.S. utility-scale electricity generation and about 48% of total U.S. utility-scale renewable electricity generation.

At year-end 2023, the total installed wind power nameplate generating capacity in the United States was 150,493 MW, including 6,474 MW added in 2023. This is enough wind power to serve the equivalent of 46 million American homes.

As of 2024, more than 72,000 wind turbines had been installed across the U.S., according to the American Clean Power Association (www.cleanpower.org).

Globally, the U.S. ranks third in wind power generation, behind China and the European Union.

7.2 Largest Wind Farms

Ranked by installed capacity, the following are the largest wind farms in the United States:

	Capacity	No. of Turbines
• Alta Wind Energy Center (California):	1,550 MW	600
• Western Spirit (New Mexico):	1,050 MW	377
• Traverse Wind Energy Center (Oklahoma):	998 MW	356
• Los Vientos Wind Farm (Texas):	912 MW	426
• Shepherds Flat Wind Farm (Oregon):	845 MW	338
• Meadow Lake Wind Farm (Indiana):	801 MW	414
• Roscoe Wind Farm (Texas):	782 MW	627
• Javelina Wind Energy Center (Texas):	749 MW	346
• Horse Hollow Wind Energy Center (Texas):	736 MW	421
• Tehachapi Pass Wind Farm (California):	705 MW	3,400
• Capricorn Ridge Wind Farm (Texas):	662 MW	407

The largest wind transmission system is SunZia Wind & Transmission, which represents over 3,500 MW of generation across three counties in New Mexico. SunZia Transmission is a 550-mile, ±525 kV high-voltage direct current (HVDC)

transmission line between central New Mexico and south-central Arizona, with the capacity to transport 3,000 MW of renewable energy. Together, SunZia Wind and SunZia Transmission comprise the largest renewable energy infrastructure project in the U.S.

7.3 Generation by State

The *September 2024 Wind Generation by State Report*, by Choose Energy (www.chooseenergy.com), reported the top states generating electricity from wind as follows (percentage of total U.S. wind energy generation in parenthesis):

- Texas: 11,079 MWh (28.9%)
- Oklahoma: 3,474 MWh (9.1%)
- Iowa: 3,418 MWh (8.9%)
- Kansas: 2,766 MWh (7.2%)
- Illinois: 1,896 MWh (4.9%)
- California: 1,515 MWh (4.0%)
- Colorado: 1,508 MWh (3.9%)
- North Dakota: 1,240 MWh (3.2%)
- New Mexico: 1,178 MWh (3.1%)
- Minnesota: 1,170 MWh (3.1%)

Four states got more than 40% of their electricity supply from land-based wind energy in 2023: Iowa, Kansas, Oklahoma, and South Dakota.

7.4 Offshore Wind Power

Offshore wind power is the process of generating electricity from wind turbines that are placed in bodies of water, usually at sea. Offshore wind farms are considered more efficient than onshore wind farms because of the following advantages:

- Offshore wind speed is typically higher than onshore wind.
- Offshore wind is more consistent than onshore wind.
- There are fewer physical obstructions from land or human-made objects in the water.
- Offshore wind farms are often located far from populated areas, which can reduce noise and environmental impact.
- There is more space for offshore wind farms, which can increase the amount of clean energy available.
- Offshore wind farms can generally be located closer to coastal cities than onshore wind farms, which can reduce the need for expensive transmission infrastructure.

The Biden administration set a goal of installing 30 GW of offshore wind energy capacity by 2030.

According to the U.S. Department of Energy (DOE; www.doe.gov), the potential generating capacity of the U.S. offshore wind energy project development and operational pipeline was 80,523 MW as of January 2024, a 53% increase from one year prior.

In 2023, $2.1 billion was invested in the domestic offshore wind industry to develop ports, vessels, supply chain, and transmission.

As of September 2024, 13 states had policies that collectively supported 115,130 MW of offshore wind by 2050.

The largest offshore wind project in development is the $4 billion Vineyard Wind 1, off the coast of Massachusetts. Scheduled for completion in mid-2024, the project was delayed because of the collapse of a wind turbine blade. The accident is a significant setback for the offshore wind industry.

"The American offshore wind business has struggled to get going because of cost overruns, delays in issuing permits, and opposition from local residents and fishing groups. Several large projects were canceled or postponed even before the blade failure in Massachusetts because their costs increased sharply and developers did not anticipate supply chain problems and higher interest rates. The failure of the blade, which was made by GE Vernova, has also raised concerns about safety and reliability."

The New York Times, 9/12/24

7.5 Distributed Wind Systems

Distributed wind turbines are connected at the distribution level of an electricity system, or in off-grid applications, to serve local energy needs.

According to the DOE, 1,110 MW of distributed wind capacity was installed in the United States from 2003 to 2023.

In 2023, $37 million was invested in new U.S. distributed wind projects.

7.6 Engineering Companies

Ranked by 2023 wind power project revenue, the largest engineering firms in the segment are as follows (source: *Engineering News-Record*):

Design

- Tetra Tech: $135.0 million
- Jacobs: $115.6 million
- Westwood Professional Services: $ 46.0 million
- Burns & McDonnell: $ 30.6 million
- Stantec: $ 25.8 million
- AECOM: $ 23.5 million
- Ulteig Engineers: $ 22.9 million
- RRC Power & Energy: $ 22.8 million
- Barr Engineering Co.: $ 22.4 million
- SWCA Environmental Consultants: $ 18.7 million

Contractors

- Mastec: $1.05 billion
- Mortenson: $ 762.2 million
- AECOM: $ 168.4 million
- The Boldt Co.: $ 52.8 million
- Aristeo Construction Co.: $ 46.8 million
- Black & Veatch: $ 26.2 million
- Kiewit Corp.: $ 16.0 million
- Michels Corp.: $ 12.1 million

7.7 Market Resources

A Decade of U.S. Wind Growth, Climate Central, April 10, 2024. (www.climatecentral.org/climate-matters/a-decade-of-us-wind-growth-2024)

Offshore Wind Power, National Grid Group. (www.nationalgrid.com/stories/energy-explained/what-offshore-wind-power#:~:text=Offshore%20wind%20power%20or%20offshore,into%20the%20electricity%20network%20onshore)

The U.S. Wind Turbine Database, U.S. Geological Survey. (https://eerscmap.usgs.gov/uswtdb/#:)

"U.S. Installed and Potential Wind Power Capacity and Generation," U.S. Department of Energy. (https://windexchange.energy.gov/maps-data/321)

Wind Energy Generation By State, Choose Energy. (www.chooseenergy.com/data-center/wind-generation-by-state/)

Wind Exchange, U.S. Department of Energy. (www.windexchange.energy.gov)

Wind Market Reports, U.S. Department of Energy. (www.energy.gov/eere/wind/wind-market-reports-2024-edition)

Wind Power Facts, American Clean Power Association. (www.cleanpower.org/facts/wind-power/)

8

GEOTHERMAL

8.1 Geothermal Power Generation

Geothermal is the fourth largest source of renewal energy in the U.S., with over 3,000 MW of geothermal electricity connected to the grid. Geothermal energy generated 16 billion kWh of electricity in 2023, accounting for 0.4% of the U.S. total.

Geothermal resources account for about 5% of electricity generation in California. The Geysers, in Sonoma and Lake Counties, are the most productive geothermal field in the world, providing almost 60% of the electricity used in California's North Coast region, which stretches from the Golden Gate Bridge to the Oregon border. Geothermal power plants in this region produce about 1,000 MW, down from about 2,000 MW in the 1980s because of depletion of the aquifer from which the plants draw their steam.

Almost 4,000 MW of new geothermal power plant capacity is under development in the U.S. (this includes projects in the initial development stages). States with projects under consideration or in development include Alaska, Arizona, California, Colorado, Florida, Hawaii, Idaho, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming. Combined, these states have approximately 100 projects in development.

The U.S. generates about 30% of global thermal energy.

8.2 Market Potential

The U.S. Department of Energy (DOE; www.energy.gov) estimates that geothermal could provide up to 120 GW of clean energy, or about 16% of the country's forecasted energy needs by 2050.

8.3 Commercialization

Fervo Energy

- Houston-based Fervo Energy has applied fracking technology to geothermal. The company does this by drilling horizontally into deep rock, then injecting pressurized fluid to fracture the rock. While most geothermal projects need to seek out areas where highly-fractured, highly-permeable hot rocks are easy to get to, the Fervo process itself creates the permeability.

- In partnership with Google, Fervo constructed a 2.4 MW geothermal energy plant in Nevada that became operational and was connected to the grid in 2023. The facility brings water up from 3,250-ft-long (990-m) horizontal bores some 8,000 ft (2,440 m) below the surface, with temperatures up to 191°C (376°F).
- In 2024, Fervo broke ground on the 400 MW Cape Station project, in Utah. The plant is scheduled for grid connection in 2026 and full-scale power production by 2028.

Quaise

- In 2018, MIT's Plasma Science and Fusion Center spun-off Quaise (www.quaise.com), a business focused on ultra-deep geothermal using hybrid systems that combine traditional rotary drilling with gyrotron-powered millimeter-wave technology.
- Quaise plans to drill holes up to 12.4 miles deep, significantly deeper than the Kola Superdeep Borehole, in Russia, which is the deepest human-made hole on earth. But, while the Kola project took nearly 20 years to reach it limit, Quaise expects its gyrotron-enhanced process to take just 100 days.

Other U.S.-based geothermal companies include Eavor (www.eavor.com), Teverra (www.teverra.com), and Zanskar (www.zanskar.com).

8.4 Federal Initiatives

The U.S. Bureau of Land Management has opened about 200,000 acres in Idaho, Oregon, and Utah for geothermal development.

In 2024, the U.S. Air Force awarded contracts for three geothermal pilot projects at three bases: Joint Base San Antonio, Ellington Field Joint Air Reserve Base (Houston, Texas), and Mountain Home Air Force Base (Elmore County, Idaho).

8.5 Resources

Enhanced Geothermal Systems, U.S. Department of Energy.
(www.energy.gov/eere/geothermal/enhanced-geothermal-systems)

Geothermal Electricity Generation, U.S. Department of Energy.
(www.energy.gov/eere/geothermal/electricity-generation#:~:text=Geothermal%20power%20plants%20draw%20fluids,or%20water)%20and%20its%20temperature)

Geothermal Electricity Production Basics, National Renewable Energy Laboratory.
(www.nrel.gov/research/re-geo-elec-production.html)

Geothermal Technologies Office, U.S. Department of Energy
(www.energy.gov/eere/geothermal/geothermal-technologies-office)

International Geothermal Association (www.lovegeothermal.org)

NREL Research, National Renewable Energy Laboratory. (www.nrel.gov/geothermal/index.html)

ThinkGeoEnergy (www.thinkgeoenergy.com)