Environmental and Energy Study Institute

Fact Sheet

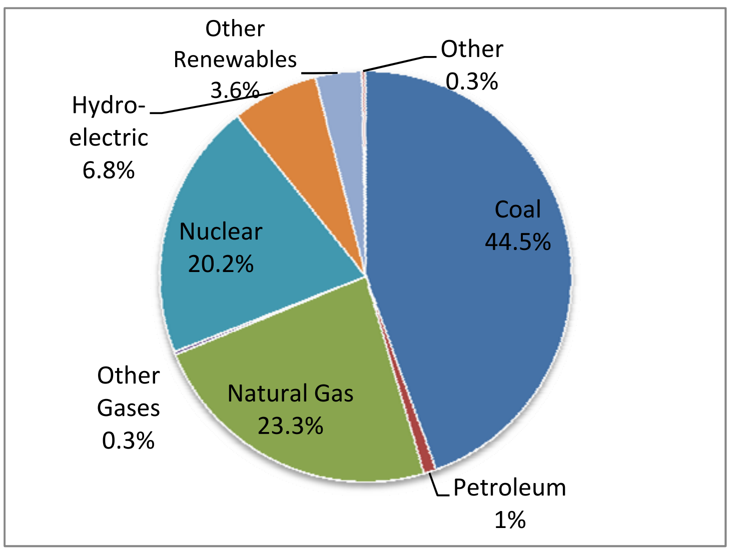
A Snapshot of Renewable Energy Deployment

January 2011

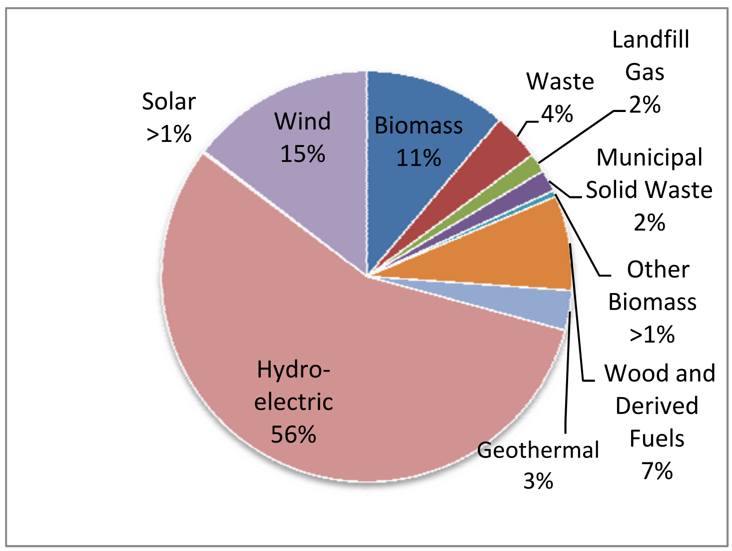
Renewable energy resources – including water, wind, biomass, geothermal, and solar – are abundant and geographically diverse across the United States, and can be used to generate electricity, provide thermal energy, fuel industrial processes, or make transportation fuels. The deployment of renewable energy technologies has grown rapidly in recent years as the nation looks to meet growing demand, diversify its energy supply, and reduce the carbon emissions which cause climate change. But how do the various renewable energy technologies compare to fossil fuels and nuclear power when costs, climate, timing, and flexibility are all imperative?

This fact sheet will focus on renewable electricity, which has grown 86.6 percent since 1998[1] and now comprises 10.6 percent of total U.S. electric generation.[2] Deployment characteristics such as total capacity, project size, cost trends, construction timelines, and impact on carbon emissions of renewable electricity technologies will be compared. Several aspects of renewable thermal (heating and cooling) energy will be addressed as well. It should be noted that about 40 percent of U.S energy is used by buildings for heating and cooling.

U.S. Electricity Net Generation, 2009



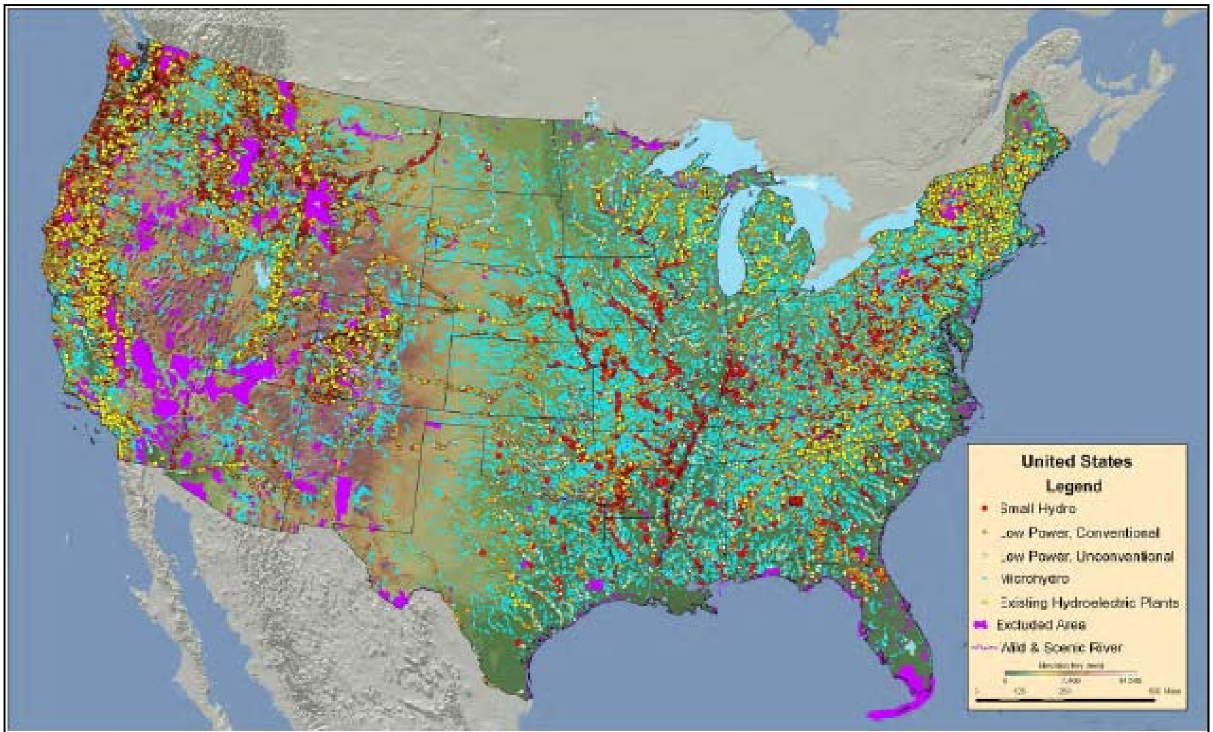
U.S. Electricity Net Generation from Renewables, 2009



Source: Energy Information Administration

WATER

Water technologies harness energy from streams, rivers and ocean currents and convert it to electricity or use it for thermal energy. The most common type of water technology is the hydropower dam, which is used across the country. Ocean currents and tides as well as in-stream hydrokinetic technologies are also sources of energy that can be captured and converted to various uses.



Existing hydroelectric plants and feasible potential hydropower projects in the United States. Source: U.S. Department of Energy - DOE-ID-11263

Map depicts existing hydropower sites in the United States (yellow dots) and potential hydropower sites (red, orange, and blue dots). Purple represents excluded areas. Source: Idaho National Laboratory.

Hydropower's installed capacity is approximately 96,000 megawatts (MW) and represents the largest deployed renewable electricity resource in the country. Though many consider hydropower potential to be already "tapped", less than three percent of the country's dams generate electricity.[3] Additional power also can be gained by installing more efficient turbines at existing hydropower dams. The Department of Energy (DOE) estimated there are approximately 30,000 MW of undeveloped hydropower potential in the United States.[4] Another recent report by Navigant Consulting found that the United States has the potential to add 23,000-60,000 MW of additional hydropower by 2025, including 3,000 MW from new hydrokinetic in-stream technologies, and 10,000 MW from ocean wave energy devices.[5]

Water technologies are largely carbon emissions free, since its electric production does not involve combusting carbon-based fuels. However, studies suggest that conventional hydropower dams cause methane and carbon to be released from decomposing flooded vegetation. In addition, there would be a small carbon footprint involved in the construction of the project from fossil fuels used to manufacture the components. ORNL estimated that the total amount of installed hydropower displaces 54.635 million metric tons of carbon (based on 77,194 MW).[6]

While few hydropower facilities have come on line in recent years, a 2001 Idaho National Lab report estimated the capital cost of a 31 MW hydropower facility to be $1,700-2,300 per kW.[7] The National Renewable Energy Lab (NREL) estimated new hydropower capital costs to be $2,240 per kW.[8] Navigant Consulting estimated conventional hydropower installed costs to be between $1,000 and $6,000 per kW. Most hydrokinetic (ocean and free-flowing river) power facilities are demonstration projects, making cost estimates difficult, but Navigant expects costs to be around $2,500 per kW for ocean energy and $3,000 per kW for tidal energy.[9]

A **kilowatt** is a unit of power usually used for electric power. One kilowatt equals 1000 watts, and one megawatt equals 1000 kilowatts. A traditional type of incandescent light bulb needs 60 watts of power to turn on.

A **kilowatt-hour** is a measure of electricity as a unit of work, measured as 1 kilowatt of power expended for one hour. A traditional incandescent bulb left on for one hour would use 60 watt-hours.

The size of hydropower facilities can range depending on the size of the river and whether the facility uses pumped storage — a method of pumping water from a low elevation to a higher elevation in order to generate more electricity during peak demand. Micro-hydro and low power hydro projects can be between 0.1 and 1 MW, whereas larger projects are between 1 and 6,800 MW.[10,11] Hydrokinetic energy projects could range from less than 1 MW to over 100 MW.[12] In terms of implementation, construction times can be short for small projects, like replacing turbines, and 2-3 years for new facilities.[13]

The tables at the end of each section consist of data compiled from various sources and thus are not entirely consistent with one another. They do not encompass every renewable energy project, but are intended to give a fairly accurate snapshot of each energy resource's characteristics.

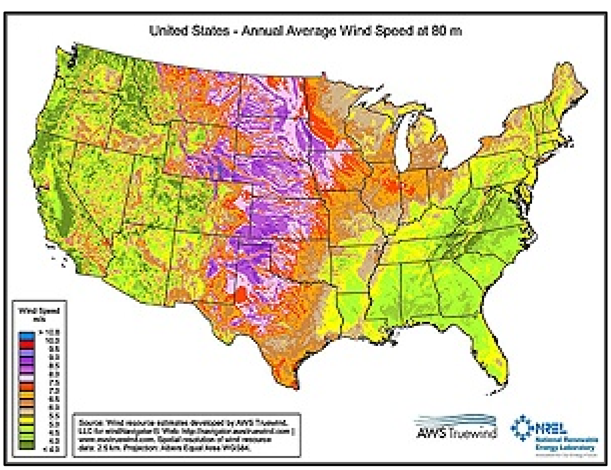
Installed Capacity	Annual Carbon Displacement*	Scale of Projects	Construction Time	Cost
96,000 MW (mostly dams)	54.635 MMTC** (based on 77,194 MW)	100kW - 6,800 MW	2 - 3 years	$1,700 - 2,300/kW

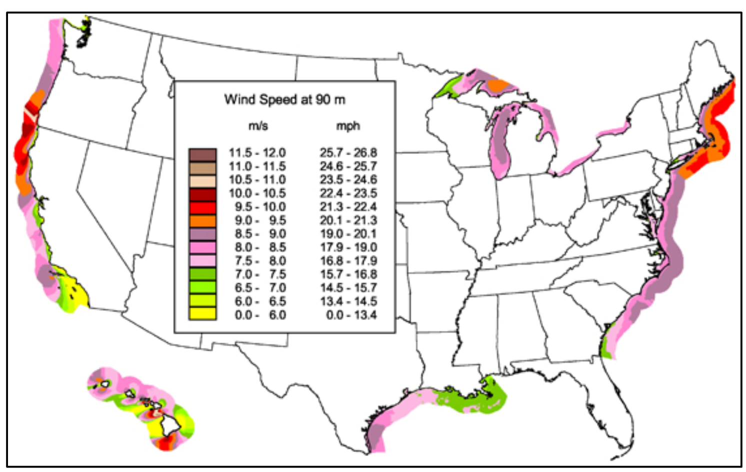
**Carbon displacement, in this context, is an estimate of the amount of carbon an energy resource replaces based on the average carbon content of the U.S. energy portfolio. These estimates do not take into account the amount of emissions displaced over the entire life-cycle of each technology, which would be a larger estimate.*
***Million metric tons carbon*

WIND

Wind energy is the fastest growing renewable energy technology in the United States. From 2000 to 2009, wind energy capacity grew by a factor of 14.[14] Used primarily to generate electricity, wind energy is captured using turbines that are connected to generators.

Wind resources vary across the country (see land-based and offshore resource maps). The areas with the highest potential are the Great Plains (ND to TX), and along the West, East Great Lakes and Gulf of Mexico coastlines. By mid-2010, the total installed wind capacity in the United States reached 36,698 MW. Over 6,300 MW are currently under construction. Although there are no off-shore wind facilities in U.S. waters, approximately 13 projects are either under construction or proposed, ranging from 25 to 468 MW.[15]





Maps depict land-based and offshore wind resources in the United States. Sources: DOE, NREL.

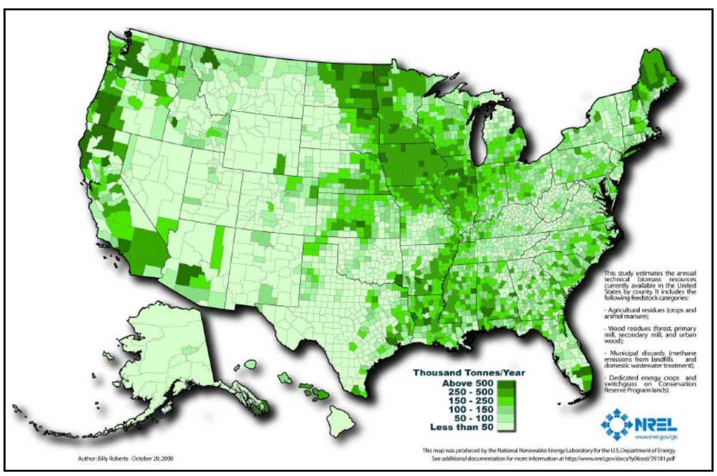
Wind turbines produce no carbon during the energy conversion process. Wind power's small carbon footprint derives mainly from the fossil fuels used to manufacture and construct wind power facilities. ORNL estimated that U.S. wind energy displaced 17.544 million metric tons of carbon in 2009 (based on 31,663 MW).[16]

Despite experiencing an increase in average installed cost in the last few years[17], wind power is now considered to be cost-competitive with most other types of energy resources, having experienced a sharp decline in price in the past three decades.[18] The installed cost of wind power projects varies according to project size, technology, and resource availability, among other things. However, the Department of Energy recently estimated the national average to be approximately $2,000 per kW.[19]

The size of wind power projects varies widely, making it a flexible energy resource. The smallest installations are often just one or a small cluster of turbines used for farms, ranches and homes. Sometimes these installations are not interconnected (i.e., "off the grid") and all the power is used onsite. Individual turbines can be less than 50 kW or as large as 3.5 MW. Grid-connected wind farms also range in size. In 2009, utility scale wind projects ranged from under 2 MW to 280 MW and cumulatively added nearly 10,000 MW.[20] Construction times also differ because size varies widely from project to project, but facilities are generally completed within one year.[21]

Installed Capacity	Annual Carbon Displacement	Scale of Projects	Construction Time	Cost
36,698 MW	17.544 MMTC (31,663 MW)	50kW - 280 MW	<1 year	$2,000/kW

BIOMASS



Map depicts biomass resources in terms of tons per year, where the deeper greens represent larger resource areas. Source: NREL.

Biomass energy comes from plant and animal (organic) matter and has a wide variety of uses. It can be burned to generate electricity or heat, gasified to produce power, heat, or refined into liquid transportation fuels. It is also used in the chemical industry as an alternative to crude oil to produce bio-based products.

Every region of the country has its own biomass resources. Agricultural regions can use dedicated energy crops such as corn, sugar cane, switch grass, soy, rapeseed, and oil palm as well as crop residues such as corn stover, oat hulls, and citrus peels. Forested regions provide low-value woody biomass from residues from wood products industries and ecosystem maintenance activities, while urban areas produce sewage, yard, and food waste, construction debris, and other forms of biogenic municipal solid waste (MSW). Even desert areas can be used to produce algae in manmade ponds.

In 2009, U.S. biomass power capacity reached approximately 10,800 MW.[22] The technologies used to convert biomass into electricity or heat include direct-fired biomass, co-fired biomass with coal power plants, anaerobic digestion (biomass broken down without oxygen), and combined heat and power facilities.[23]

Sustainably produced biomass is inherently carbon neutral over time and landscape. The carbon released by biomass combustion is carbon that was taken from the atmosphere by growing biomass and would be released when the biomass died and decayed. Sustainable biomass energy simply accelerates this natural cycling of carbon. If fossil energy is used in the process of collecting, harvesting, planting, storing, processing, and converting biomass, then the carbon footprint of the bioenergy system becomes positive. However, some bioenergy systems that increase carbon fixed in soils and plants or that prevent the release of methane (which has a global warming potential 21 times that of CO2) from decaying organic matter are actually net carbon negative. ORNL estimated the total installed capacity of biomass power displaces 8.328 million metric tons of carbon (based on 7,024 MW).[24]

Thermal Energy

The diversity of applications for biomass heating — from wood stoves to major industrial processes — is so great that it is difficult to estimate how much the United States uses. However, DOE estimates that, combined with biomass for electricity, biomass energy totaled 3.9 quadrillion Btu (British thermal units), or about **4.1 percent of U.S. energy consumption in 2009**.

http://cta.ornl.gov/bedb/introduction/Biomass_Overview.shtml

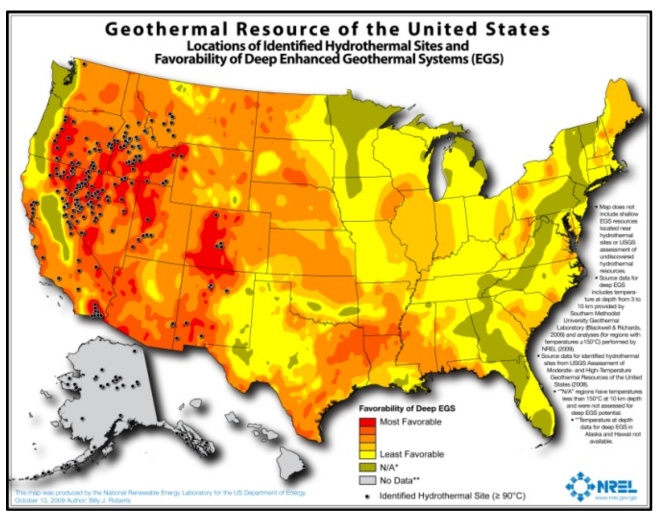
According to an Electric Power Research Institute (EPRI) report, a 50 MW direct-fired biomass plant would cost between \$2,600 and \$3,000 per kW.[25] Converting coal plants to co-fire with biomass has a much lower cost range: \$100 to \$600 per kW of biomass power added. Anaerobic digesters are estimated to cost \$1,650-2,300 per kW.[26] Fuel costs are not included in these cost calculations.

Biomass power plants range in size, typically between 20 and 50 MW, due to the cost of collecting and transporting large volumes of biomass.[27] For a 50 MW facility, installation timelines will typically be 16-18 months, assuming all permits are in place. A retrofit of an existing coal plant may be only 9-12 months.[28]

Installed Capacity	Annual Carbon Displacement	Scale of Projects	Construction Time	Cost
10,800 MW	8.328 MMTC (based on 7,024 MW)	>10 kw - 50 MW	9 - 18 months	\$2,600 – 3,000/kW (new plant)

GEOTHERMAL

Geothermal energy is heat from the earth, naturally stored in underground reservoirs of hot water or steam, which can be used to heat or cool buildings or generate electricity. "Ground source" heat pumps can be installed almost anywhere in the country to heat and cool buildings. The regions with the greatest potential for power production are in the West. In 2009, U.S. geothermal capacity reached 3,086.6 megawatts (MW) with more than 7,000 additional MW under various stages of development, according to the Geothermal Energy Association (GEA).[29]



Map depicts locations of identified geothermal sites and favorability of "deep enhanced" geothermal systems. The most favorable sites are represented in red. Source: NREL.

The carbon footprint of geothermal energy is very small compared to fossil fuel-based energy. In addition to the fossil fuels used to construct geothermal projects, small quantities of CO2 are sometimes released from some geologic formations tapped for geothermal energy.[30] In 2010, Oak Ridge National

Thermal Energy

Ground source heat pumps provide heating and cooling to homes. U.S. heat pumps total 12,000 MW (thermal equivalent) in capacity. Ground source heat pumps are estimated to cost $6,000-7,000 per KW.

John Lund, PE – Ted Clutter/Geothermal Exchange Organization

Labs (ORNL) estimated that the total amount of installed geothermal capacity in the United States displaced 3.172 million metric tons of carbon (based on only 2,440 MW of geothermal capacity that would otherwise have been emitted by fossil fuels).[31]

Major utility-scale projects brought online in 2009 range in size from 0.25 MW to 50 MW.[32] The largest geothermal projects brought online to date are 113 MW.[33]

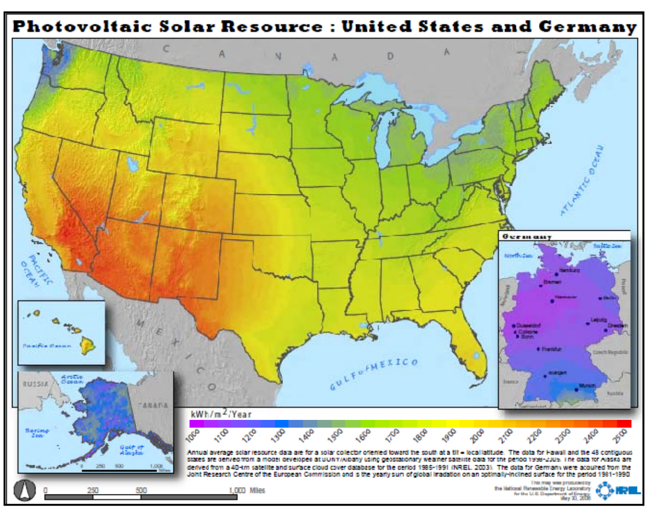
Cost estimates for deploying geothermal energy have trended downward over the last 20 years. The Energy Information Administration (EIA) estimated in 2010 that geothermal power plants cost approximately $4,100 per kilowatt (kW). But this estimate does not include financing costs. Glacier Partners, a financial advisory firm, estimated new geothermal power to cost $4,900 per kW when factoring in financing costs.[34]

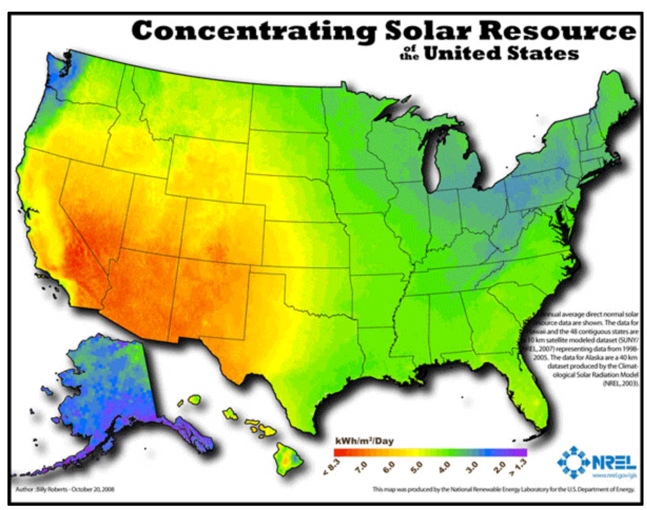
Construction times vary according to size, technology, financing and location, but Glacier estimates 18 months for a 35 MW plant.[35]

Installed Capacity	Annual Carbon Displacement	Scale of Projects	Construction Time	Cost
3,086.6 MW	3.172 MMTC (based on 2,440 MW)	0.25 MW - 133 MW	18 months	$4,100 - 4,900/kW

SOLAR

Solar energy is also a fast growing energy resource in the United States, though it has not yet reached the same level of development as wind energy. Solar energy is used in a variety of ways. It can be converted into electricity with photovoltaic (PV) solar cell panels, which capture the sun's light, or with concentrating solar power (CSP) technologies, which concentrate the sun's heat energy. Solar energy also is used for thermal energy—heating water for buildings and pools, as well as through building design, by incorporating elements such as building orientation and window-to-wall ratios to maximize the direct heat and light from the sun.





Maps depict average annual direct solar resources in the United States for photovoltaic (with Germany) and concentrating solar power in terms of kilowatt-hour per square meter per day (kWh/m²/day). Source: NREL.

The country's solar resources are enormous. The greatest development potential is in the South and West, as the maps above indicate. However, viable solar energy projects exist across the country and globe. Germany, for example, leads the world in installed PV panels with 3,800 MW[36] and has solar resources similar to Alaska. By the end of 2009, there were 2,108 MW of solar power installed in the United States.[37] Photovoltaic panels comprised 1,676 MW of this total. CSP accounted for 432 MW.[38]

Solar energy produces no carbon during conversion to electricity or heat. Carbon emissions attributable to solar energy come from the use of fossil fuels during the manufacture and construction process. ORNL estimated that total installed PV capacity would displace 100,000 metric tons of carbon, and 128,000 metric tons of carbon for CSP (based on 1,378 MW and 608 MW respectively).[39]

Thermal Energy

The total installed capacity of solar water heating and cooling technologies represent the equivalent of 24,000 MW of thermal energy.

http://www.seia.org/cs/about_solar_energy/industry_data

The cost of deployed solar energy continues to trend downward. According to the Solar Energy Industries Association (SEIA), from 2008 to 2009, installed costs of PV systems dropped 10 percent while the prices of the PV modules dropped 40 percent.[40] It is slightly more difficult to assess CSP cost trends because they are typically larger projects and many are currently under construction or in the planning stages. However, SEIA estimated recently that the installed costs of two kinds of CSP to be $3,000-4,500 per kW and $4,500-6,000 per kW.[41] The EIA recently estimated new PV project costs to be $4,755 per kW, and CSP to be $4,692 per kW.[42]

Solar power systems can range dramatically in size due to the scalability of solar power technology. PV panels can become part of a large utility-scale array or be sized to fit on a residential rooftop. Several U.S. cities have so many solar rooftops that, cumulatively, they produce as much electricity as a small power plant. By the end of 2009, the capacity of solar electric systems on businesses and homes totaled 1,124 MW.[43] In 2009, utility scale PV projects ranged in size from 4 MW to 25 MW.[44] CSP systems are also scalable but are typically larger, from 1 MW demonstration projects to 80 MW facilities. CSP projects under construction range from 5-133 MW.[45] There are also projects under development that are as large as 1,200 MW.[46]

Rooftop solar projects are generally installed within a matter of days. Construction (after all permitting and regulatory approval) of a utility-solar power plant can take as little as six months or as long as several years depending on the technology and size of the plant. Also, some plants can be brought online in stages, blurring the concept of construction time.[47]

Solar Technology	Installed Capacity	Annual Carbon Displacement	Scale of Projects	Construction Time	Cost
PV	1,676 MW	0.100 MMTC (based on 1,378 MW)	3kW - 25 MW	Rooftop: 2 days Utility-scale: 2-3 years	$4,755/kW
CSP	432 MW	0.128 MMTC (based on 608 MW)	5 - 1,200 MW	2-3 years	$3,000 - 6,000/kW

CONVENTIONAL POWER

The conventional power source with the largest carbon footprint is coal, accounting for roughly 81 percent of total U.S. carbon dioxide emissions from electricity generation in 2009,[48] followed by natural gas at 17 percent.[49] However, natural gas on average has approximately 45 percent of the carbon intensity of coal. Nuclear power is relatively carbon free in the production of electricity, but there is a footprint for the construction of the power plant and the mining, refinement, and disposal of uranium. Overall, EIA estimated that in 2009, the average carbon intensity of electricity fell by four percent.[50] They attributed this decline to coal's decreased share of overall generation and increases in the share of natural gas and renewable energy — particularly wind.[51]

Coal, natural gas and nuclear power represent the majority of U.S. electric generation. Average-sized coal plants are approximately 500-600 MW per plant.[52] Natural gas plants average 200-300 MW per facility, but individual units can range from 1 MW to more than 500 MW.[53] While no new nuclear reactors have been built in the United States for decades, proposed new nuclear reactors range from 1,100 to 1,700 MW.[54]

Coal plants usually take between four and five years to construct, once licensing and permitting processes have been completed.[55] Natural gas plant construction timelines vary widely due to differences in size, location (whether it is an expansion at an existing facility or at a new site), type of technology, permitting and licensing, and procurement challenges from project to project. Generally speaking, smaller plants that meet electric demand during peak hours are the fastest to construct, generally 6 to 18 months. Larger gas plants can take up to 2-3 years to construct.[56] Construction times are longest for nuclear power plants. Some estimates predict 5-6 years, while others estimate 10 or more years.[57]

The EIA's most recent estimate for the capital costs of constructing new coal plants ranges from $2,844 to $5,348 per kW. This estimate does not include the cost of financing or operations and maintenance (including fuel costs).[58] For natural gas plants, EIA estimated $665 to $2,060 per kW.[59] Early industry and government estimates for new nuclear reactors (around 2001-2005) were between $1,000 and $5,000 per kW, while independent and Wall Street estimates have been between $5,000 and $10,000 per kW.[60,61] More recent estimates are trending higher.

Conventional Power Source	Capacity and Energy Produced[62]*	2009 Carbon Emissions	Scale of Projects	Construction Time	Cost
Coal	314,300 MW (1.758 billion kWh)	1,869 MMTC	500 - 600 MW	4 - 5 years	$2,844 - 5,348/kW
Natural Gas	401,200 MW (920.35 million kWh)	1,221 MMTC	1 - 500 MW	6 months -3 years	$665 - 2,060/kW
Nuclear	101,000 MW (797.9 million kWh)	Minimal**	1,100 - 1,700 MW	5 - 10 years	$5,000 - 10,000/kW

**Energy capacity is expressed in MW, but generation is expressed in kWh (kilowatt-hours) to correspond to the actual amount of electricity produced. This is to illustrate the fact that while there is more natural gas capacity built than coal or nuclear, coal is used more to produce electricity.*

***While there are no carbon emissions emitted at nuclear power plants, there are fossil fuel emissions associated with the construction of nuclear power plants, and mining, enrichment, transportation and storage of uranium.*[63]

FACTORS AFFECTING DEPLOYMENT

Many factors influence the pace of U.S. renewable energy deployment. While it is beyond the scope of this fact sheet to analyze them all in detail, it is important to note a few of the major ones.

- **Financial incentives**: Not only is regularity and predictability essential to the development of renewable energy, it is important to recognize financial government support in a historical context. Conventional power has received substantial financial incentives for decades, establishing a norm that has created challenges to developing alternative energy resources.
- **Licensing and permitting**: Renewable and conventional energy projects require different kinds of permits and licenses based upon location, size, and potential air and water pollution, among other criteria. The length of the

permit and license application process varies widely and affects construction timelines for each technology differently.

- **Capacity factor**: The ratio between the actual output of a power plant versus what it could produce if it were running all the time is capacity factor. Power plants produce a fraction of their capacity depending on the time of day, availability of resource, and economics.
- **Water scarcity**: The availability of water is a growing concern for many energy technologies. Nuclear, coal, natural gas, biomass, and hydropower, to varying degrees, require large amounts of water to produce electricity. As climate change accelerates, water will become an ever-increasing factor in determining which power plants are able to sustain themselves.
- **Transmission infrastructure**: While some renewable energy resources are located near the areas where the energy demand is highest, others are located in areas where transmission infrastructure has yet to be built or is already constrained.
- **Electric grid management**: Particularly for solar and wind, the versatility of the electric grid is a key factor to deploying larger amounts of renewable energy. Versatility is also essential as more and more generation sources are added to the grid. In addition, interconnection and net-metering policies, mechanisms that allow consumers of electricity also to be producers of electricity, affect the deployment of small-scale renewable energy projects.

CONCLUSION

As this fact sheet has shown, renewable energy resources are diverse in terms of costs, deployment characteristics and carbon footprints. On average, as a whole, renewable energy technologies:

- Are generally low in carbon emissions
- Are flexible in terms of tailoring new facility sizes to meet new demand
- Can be built relatively quickly
- Are becoming more cost-competitive with each passing year

It is important to highlight these characteristics because the energy world continues to change rapidly. Companies, utilities, and even customers are required to be more dynamic and flexible in order to meet old and new challenges, such as adjusting to a quickly changing electric demand while keeping costs and carbon as low as possible. This atmosphere has created a new set of values for assessing which resources ought to be developed.

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