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Bill Hardy "Calculator was easy to use and very accurate. I had solar installed a couple of years ago. I wanted to check what the calculator would give as a recommendation and forecast compared to my actual experience. My actual experience was well within the ranges given. GREAT TOOL." Michael Le “Very responsive and helpful. Got a friendly phone call right away after filling out online estimate to gather additional information. Knowledgeable and friendly. Can’t ask for more.” Adrian Uribe "Very helpful with information about cost, effectiveness and options for various solar panel installations. Very quick to reach out to me and explain things clearly so I understood exactly what my obligations would be and what I should expect from the system.” The sun emits solar radiation in the form of light. Solar energy technologies capture this radiation and turn it into useful forms of energy. There are two main types of solar energy technologies—photovoltaics (PV) and concentrating solar-thermal power (CSP). On this page you’ll find resources to learn what solar energy is; how you, your business, or your community can go solar; and find resources for every step of the way. It also shares how the Solar Energy Technologies Office (SETO) and other U.S. Department of Energy (DOE) offices are advancing solar energy technologies. Explore the latest solar market insights and policy updates in all 50 states and Washington, D.C. All market data is current through Q2 2025. Based on the latest data from the EnergySage Marketplace, the average Huntersville, NC homeowner needs a 14.19 kW solar panel system to cover their electric bills. That'll set you back about $32,790 before incentives. Need a bigger (or smaller) system to offset your electricity use? The average price per watt of solar power in Huntersville, NC is $2.31/W. These prices are before incentives. After the federal solar tax credit, the final cost will drop by 30%, down to $22,953 for a 14.19 kW system. Many states even offer local rebates and incentives that lower the price further--sometimes by thousands of dollars. But the federal tax credit is about to end: President Trump’s recently enacted megabill moves up its expiration date from January 1, 2035 to January 1, 2026. If you're considering solar, acting before this new deadline could save you thousands of dollars in California. After the credit expires, the cost of your solar system would increase significantly—from $14,286 to the full $20,409 for an average 8.9 kW system. Imagine a home or business where solar panels capture energy, intelligent batteries store and manage electricity, and your entire property becomes a smart, responsive energy environment. We're making that vision a reality. Enter your address and the cost of your most recent electric bill Our estimator shows how many solar panels your home needs We generate an online cost and savings estimate You choose how many solar companies send you an exact price by email or text When considering a residential solar project, the first step should be to investigate energy efficiency improvements to your home, as many energy efficiency investments have faster paybacks than solar. Visit the State Energy Office's Energy Efficiency webpage for more information.Once energy efficiency has been explored, there are many resources available to help you pursue residential solar. The NC Sustainable Energy Association’s “Consumer Guide for Solar for the NC Homeowner” explains the basics of how solar operates and the factors to consider when deciding on a solar project. Homeowners Associations and SolarIf you live in a community that has a homeowner association, it is important to check to see if that HOA has provisions or covenants affecting solar. While North Carolina’s solar access law prevents HOA’s from completely prohibiting solar panels, there are still ways that an HOA may restrict their installation. See the Southern Environmental Law Center for more information about solar and HOA's. Estimating CostsThere are several online options to get rough estimates for residential solar costs. Energy Sage is an online tool you can use to get a free estimate based on your ZIP code. Solar installers in your area may also be able to provide cost estimates.Community SolarCommunity solar is another option that some homeowners may be able to make use of. In this type of program, a household will typically enroll in a monthly subscription to a community solar project in their area. As part of that subscription, the value of the solar electricity that you have subscribed to is typically credited to your monthly electric bill. In North Carolina, some Electric Membership Co-ops and Municipal Electric Utilities (ElectriCities) have community solar projects. You will need to check if your Co-op or ElectriCity has a community solar project. Duke Energy does not yet have a community solar option. The amount of sunlight that strikes the earth's surface in an hour and a half is enough to handle the entire world's energy consumption for a full year. Solar technologies convert sunlight into electrical energy either through photovoltaic (PV) panels or through mirrors that concentrate solar radiation. This energy can be used to generate electricity or be stored in batteries or thermal storage.Below, you can find resources and information on the basics of solar radiation, photovoltaic and concentrating solar-thermal power technologies, electrical grid systems integration, and the non-hardware aspects (soft costs) of solar energy. You can also learn more about how to go solar and the solar energy industry. In addition, you can dive deeper into solar energy and learn about how the U.S. Department of Energy Solar Energy Technologies Office is driving innovative research and development in these areas.Solar Energy 101Solar radiation is light – also known as electromagnetic radiation – that is emitted by the sun. While every location on Earth receives some sunlight over a year, the amount of solar radiation that reaches any one spot on the Earth’s surface varies. Solar technologies capture this radiation and turn it into useful forms of energy. Learn about the basics of solar radiation. There are two main types of solar energy technologies—photovoltaics (PV) and concentrating solar-thermal power (CSP). You're likely most familiar with PV, which is utilized in solar panels. When the sun shines onto a solar panel, energy from the sunlight is absorbed by the PV cells in the panel. This energy creates electrical charges that move in response to an internal electrical field in the cell, causing electricity to flow. Concentrating solar-thermal power (CSP) systems use mirrors to reflect and concentrate sunlight onto receivers that collect solar energy and convert it to heat, which can then be used to produce electricity or stored for later use. It is used primarily in very large power plants. Solar energy technology doesn’t end with electricity generation by PV or CSP systems. These solar energy systems must be integrated into homes, businesses, and existing electrical grids with varying mixtures of traditional and other renewable energy sources. A number of non-hardware costs, known as soft costs, also impact the cost of solar energy. These costs include permitting, financing, and installing solar, as well as the expenses solar companies incur to acquire new customers, pay suppliers, and cover their bottom line. For rooftop solar energy systems, soft costs represent the largest share of total costs. Solar energy can help to reduce the cost of electricity, contribute to a resilient electrical grid, create jobs and spur economic growth, generate back-up power for nighttime and outages when paired with storage, and operate at similar efficiency on both small and large scales. Solar energy systems come in all shapes and sizes. Residential systems are found on rooftops across the United States, and businesses are also opting to install solar panels. Utilities, too, are building large solar power plants to provide energy to all customers connected to the grid. Learn more about the innovative research the Solar Energy Technologies Office is doing in these areas. Conversion of energy from sunlight into electricity This article is about the conversion of energy from sunlight into electricity. For a broader range of human uses for sunlight, see Solar energy. For the unit of light from stars and galaxies, see Solar luminosity. For other uses, see Solar Power. Rooftop solar in Hong KongThe first three concentrated solar power (CSP) units of Spain's Solnova Solar Power Station in the foreground, with the PS10 and PS20 solar power towers in the background Solar power, also known as solar electricity, is the conversion of energy from sunlight into electricity, either directly using photovoltaics (PV) or indirectly using concentrated solar power. Solar panels use the photovoltaic effect to convert light into an electric current.[2] Concentrated solar power systems use lenses or mirrors and solar tracking systems to focus a large area of sunlight to a hot spot, often to drive a steam turbine. Photovoltaics (PV) were initially solely used as a source of electricity for small and medium-sized applications, from the calculator powered by a single solar cell to remote homes powered by an off-grid rooftop PV system. Commercial concentrated solar power plants were first developed in the 1980s. Since then, as the cost of solar panels has fallen, grid-connected solar PV systems' capacity and production has doubled about every three years. Three-quarters of new generation capacity is solar,[3] with both millions of rooftop installations and gigawatt-scale photovoltaic power stations continuing to be built. In 2024, solar power generated 7% of global electricity and over 1% of primary energy (2.7% by the substitution method), adding twice as much new electricity as coal.[4][5] [6] Along with onshore wind power, utility-scale solar is the source with the cheapest levelised cost of electricity for new installations in most countries.[7][8] China has about half the world’s solar power.[9] Almost half the solar power installed in 2022 was mounted on rooftops.[10] Much more low-carbon power is needed for electrification and to limit climate change.[3] The International Energy Agency said in 2022 that more effort was needed for grid integration and the mitigation of policy, regulation and financing challenges.[11] Nevertheless solar may greatly cut the cost of energy.[5] Solar is important for energy security.[12] Part of a series onSustainable energy Energy conservation Arcology Building insulation Cogeneration Compact fluorescent lamp Eco hotel Eco-cities Ecohouse Ecolabel Efficient energy use Energy audit Energy efficiency implementation Energy recovery Energy recycling Energy saving lamp Energy Star Energy storage Environmental planning Environmental technology Fossil fuel phase-out Glass in green buildings Green building and wood Green building Heat pump List of low-energy building techniques Low-energy house Microgeneration Passive house Passive solar building design Sustainable architecture Sustainable city Sustainable habitat Sustainable refurbishment Thermal energy storage Tropical green building Waste-to-energy Zero heating building Zero-energy building Renewable energy Biofuel Sustainable Biogas Biomass Carbon-neutral fuel Geothermal energy Geothermal power Geothermal heating Hydropower Hydroelectricity Micro hydro Pico hydro Run-of-the-river Small hydro Marine current power Marine energy Tidal power Tidal barrage Tidal farm Tidal stream generator Ocean thermal energy conversion Renewable energy transition Renewable heat Solar Wave Wind Community Farm Floating wind turbine Forecasting Industry Lens Outline Rights Turbine Windbelt Windpump Sustainable transport Green vehicle Electric vehicle Bicycle Solar vehicle Wind-powered vehicle Human-electric Twike Plug-in Human-powered transport Helicopter Hydrofoil Land vehicle Bicycle Cycle rickshaw Kick scooter Quadracycle Tricycle Velomobile Roller skating Skateboarding Walking Watercraft Personal transporter Rail transport Tram Rapid transit Personal rapid transit Category Renewable energy portalvte Geography affects solar energy potential because some places are sunnier than others. In particular areas that are closer to the equator generally receive more sunshine. However, solar panels that can follow the position of the Sun can significantly increase the solar energy potential in areas that are farther from the equator.[13] Daytime cloud cover can reduce the light available for solar cells. Land availability also has a large effect on the available solar energy. Solar power plants use one of two technologies: Photovoltaic (PV) systems use solar panels, either on rooftops or in ground-mounted solar farms, converting sunlight directly into electric power.[14] Concentrated solar power (CSP) systems use mirrors or lenses to concentrate sunlight to extreme heat to make steam, which drives a turbine to generate electricity.[15] Main articles: Photovoltaics and Solar cell Schematics of a grid-connected residential PV power system[16] The photovoltaic effect in solar cells converts light into electric current. The first solar cell was constructed by Charles Fritts in the 1880s.[17] The German industrialist Ernst Werner von Siemens was among those who recognized the importance of this discovery.[18] In 1931, the German engineer Bruno Lange developed a photo cell using silver selenide in place of copper oxide,[19] although the prototype selenium cells converted less than 1% of incident light into electricity. Following the work of Russell Ohl in the 1940s, researchers Gerald Pearson, Calvin Fuller and Daryl Chapin created the silicon solar cell in 1954.[20] These early solar cells cost US$286/watt and reached efficiencies of 4.5–6%.[21] In 1957, Mohamed M. Atalla developed the process of silicon surface passivation by thermal oxidation at Bell Labs.[22][23] The surface passivation process has since been critical to solar cell efficiency.[24] As of 2022[update] over 90% of the market is crystalline silicon.[25] The array of a photovoltaic system, or PV system, produces direct current (DC) power which fluctuates with the sunlight's intensity. For practical use this usually requires conversion to alternating current (AC), through the use of inverters.[16] Multiple solar cells are connected inside panels. Panels are wired together to form arrays, then tied to an inverter, which produces power at the desired voltage, and for AC, the desired frequency/phase.[16] Many residential PV systems are connected to the grid when available, especially in developed countries with large markets.[26] In these grid-connected PV systems energy storage is optional. In certain applications such as satellites, lighthouses, or in developing countries, batteries or additional power generators are often added as back-ups. Such stand-alone power systems permit operations at night and at other times of limited sunlight. In a "vertical agrivoltaics" system, solar cells are oriented vertically on farmland, to allow the land to both grow crops and generate renewable energy.[27] Other configurations include floating solar farms, placing solar canopies over parking lots, and rooftop solar.[27] Main article: Thin-film solar cell A thin-film solar cell is a second generation solar cell that is made by depositing one or more thin layers, or thin film (TF) of photovoltaic material on a substrate, such as glass, plastic or metal. Thin-film solar cells are commercially used in several technologies, including cadmium telluride (CdTe), copper indium gallium diselenide (CIGS), and amorphous thin-film silicon (a-Si, TF-Si).[28] This section is an excerpt from Perovskite solar cell.[edit] A perovskite solar cell (PSC) is a type of solar cell that includes a perovskite-structured compound, most commonly a hybrid organic–inorganic lead or tin halide-based material as the light-harvesting active layer.[29][30] Perovskite materials, such as methylammonium lead halides the all-inorganic cesium lead halide, are cheap to produce and simple to manufacture. Solar-cell efficiencies of laboratory-scale devices using these materials have increased from 3.8% in 2009[31] to 27% in 2025 in single-junction architectures,[32][33] and, in silicon-based tandem cells, to 34.85%,[32][34] exceeding the maximum efficiency achieved in single-junction silicon solar cells. Perovskite solar cells have therefore been the fastest-advancing solar technology as of 2016[update].[29] With the potential of achieving even higher efficiencies and very low production costs, perovskite solar cells have become commercially attractive. Core problems and research subjects include their long-term stability,[35] high sensitivity to moisture[36], and toxicity if lead is used.[37] Managing toxic lead in PSCs is essential, as exposure presents significant health risks, including neurological disorders. Because PSCs are an emerging technology, lead toxicity remains a major hurdle to widespread adoption and commercialization. A parabolic collector concentrates sunlight onto a tube in its focal point. Main article: Concentrated solar power Concentrated solar power (CSP), also called "concentrated solar thermal", uses lenses or mirrors and tracking systems to concentrate sunlight, then uses the resulting heat to generate electricity from conventional steam-driven turbines.[38] As of 2021[update] the levelized cost of electricity from CSP is over twice that of PV.[39] As of 2022, less than 1% of solar power comes from CSP. Main article: Hybrid power A hybrid system combines solar with energy storage or one or more other forms of generation. Hydro,[40][41] wind[42][43] and batteries[44] are commonly combined with solar. The combined generation may enable the system to vary power output with demand, or at least smooth the solar power fluctuation.[45][46] There is much hydro worldwide, and adding solar panels on or around existing hydro reservoirs is particularly useful, because hydro is usually more flexible than wind and cheaper at scale than batteries,[47] and existing power lines can sometimes be used.[48][49] See also: Growth of photovoltaics, Timeline of solar cells, Solar power by country, and Concentrated solar power § Deployment around the worldPer capita solar power usage Share of energy from solar power The early development of solar technologies starting in the 1860s was driven by an expectation that coal would soon become scarce, such as experiments by Augustin Mouchot.[50] Charles Fritts installed the world's first rooftop photovoltaic solar array, using 1%-efficient selenium cells, on a New York City roof in 1884.[51] However, development of solar technologies stagnated in the early 20th century in the face of the increasing availability, economy, and utility of coal and petroleum.[52] Bell Telephone Laboratories' 1950s research used silicon wafers with a thin coating of boron. The "Bell Solar Battery" was described as 6% efficient, with a square yard of the panels generating 50 watts.[53] The first satellite with solar panels was launched in 1957.[54] By the 1970s, solar panels were still too expensive for much other than satellites.[55] In 1974 it was estimated that only six private homes in all of North America were entirely heated or cooled by functional solar power systems.[56] However, the 1973 oil embargo and 1979 energy crisis caused a reorganization of energy policies around the world and brought renewed attention to developing solar technologies.[57][58] Deployment strategies focused on incentive programs such as the Federal Photovoltaic Utilization Program in the US and the Sunshine Program in Japan. Other efforts included the formation of research facilities in the United States (SERI, now NREL), Japan (NEDO), and Germany (Fraunhofer ISE).[59] Between 1970 and 1983 installations of photovoltaic systems grew rapidly. In the United States, President Jimmy Carter set a target of producing 20% of U.S. energy from solar by the year 2000, but his successor, Ronald Reagan, removed the funding for research into renewables.[55] Falling oil prices in the early 1980s moderated the growth of photovoltaics from 1984 to 1996. Yearly solar generation by continent Benefitting from favorable policies and declining costs of modules, photovoltaic solar installation has grown consistently.[60][61] In 2023, China added 60% of the world's new capacity.[62] The growth of solar PV on a semi-log scale since 1996 Electricity production by source In the mid-1990s development of both residential and commercial rooftop solar, as well as utility-scale photovoltaic power stations, began to accelerate again due to supply issues with oil and natural gas, global warming concerns, and the improving economics of PV relative to other energy technologies.[55][63] In the early 2000s, the adoption of feed-in tariffs—a policy mechanism that gives renewables priority on the grid and defines a fixed price for the generated electricity—led to a high level of investment security and to a soaring number of PV deployments in Europe. For several years, worldwide growth of solar PV was driven by European deployment, but it then shifted to Asia, especially China and Japan, and to a growing number of countries and regions all over the world. Chinese manufacturers of solar equipment grew to be the largest.[64][65] Although concentrated solar power capacity grew more than tenfold, it remained a tiny proportion of the total,[66]:51 because the cost of utility-scale solar PV fell by 85% between 2010 and 2020, while CSP costs only fell 68% in the same timeframe.[67] Despite the rising cost of materials, such as polysilicon, during the 2021–2022 global energy crisis,[68] utility scale solar was still the least expensive energy source in many countries due to the rising costs of other energy sources, such as natural gas.[69] In 2022, global solar generation capacity exceeded 1 TW for the first time.[70] However, fossil-fuel subsidies have slowed the growth of solar generation capacity.[71] See also: Solar cell research About half of installed capacity is utility scale.[72] Map of solar resources from World bank Actual annual deployments of solar PV vs predictions by the IEA for the period 2002–2016. Predictions have largely and consistently underestimated actual growth. Solar is forecast to become the largest source of renewable power before the end of the 2020s, exceeding the output of hydropower.[73] Utility scale is forecast to become the largest source of electricity in all regions except sub-Saharan Africa by 2050.[72] See also: List of photovoltaic power stations This section is an excerpt from Photovoltaic power station.[edit] The 40.5 MW Jännersdorf Solar Park in Prignitz, Germany A photovoltaic power station, also known as a solar park, solar farm, or solar power plant, is a large-scale grid-connected photovoltaic power system (PV system) designed for the supply of merchant power. They are different from most building-mounted and other decentralized solar power because they supply power at the utility level, rather than to a local user or users. Utility-scale solar is sometimes used to describe this type of project. This approach differs from concentrated solar power, the other major large-scale solar generation technology, which uses heat to drive a variety of conventional generator systems. Both approaches have their own advantages and disadvantages, but to date, for a variety of reasons, photovoltaic technology has seen much wider use. As of 2019[update], about 97% of utility-scale solar power capacity was PV.[74][75] In some countries, the nameplate capacity of photovoltaic power stations is rated in megawatt-peak (MWp), which refers to the solar array's theoretical maximum DC power output. In other countries, the manufacturer states the surface and the efficiency. However, Canada, Japan, Spain, and the United States often specify using the converted lower nominal power output in MWAC, a measure more directly comparable to other forms of power generation. Most solar parks are developed at a scale of at least 1 MWp. As of 2018, the world's largest operating photovoltaic power stations surpassed 1 gigawatt. At the end of 2019, about 9,000 solar farms were larger than 4 MWAC (utility scale), with a combined capacity of over 220 GWAC.[74] Most of the existing large-scale photovoltaic power stations are owned and operated by independent power producers, but the involvement of community and utility-owned projects is increasing.[76] Previously, almost all were supported at least in part by regulatory incentives such as feed-in tariffs or tax credits, but as levelized costs fell significantly in the 2010s and grid parity has been reached in most markets, external incentives are usually not needed. Main article: List of solar thermal power stations Ivanpah Solar Electric Generating System with all three towers under load Part of the 354 MW Solar Energy Generating Systems (SEGS) parabolic trough solar complex in northern San Bernardino County, California Commercial concentrating solar power (CSP) plants, also called "solar thermal power stations", were first developed in the 1980s. The 377 MW Ivanpah Solar Power Facility, located in California's Mojave Desert, is the world's largest solar thermal power plant project. Other large CSP plants include the Solnova Solar Power Station (150 MW), the Andasol solar power station (150 MW), and Extresol Solar Power Station (150 MW), all in Spain. The principal advantage of CSP is the ability to efficiently add thermal storage, allowing the dispatching of electricity over up to a 24-hour period. Since peak electricity demand typically occurs at about 5 pm, many CSP power plants use 3 to 5 hours of thermal storage.[77] See also: Photovoltaic power station § Economics and finance See also: Cost of electricity by source In many countries, solar power is the lowest cost source of electricity.[78] The typical cost factors for solar power include the costs of the modules, the frame to hold them, wiring, inverters, labour cost, any land that might be required, the grid connection, maintenance and the solar insolation that location will receive. Photovoltaic systems use no fuel, and modules typically last 25 to 40 years.[79] Thus upfront capital and financing costs make up 80% to 90% of the cost of solar power,[80]:165 which is a problem for countries where contracts may not be honoured, such as some African countries.[5] Some countries are considering price caps,[81] whereas others prefer contracts for difference.[82] Expenses of high-power band solar modules has greatly decreased over time. Beginning in 1982, the cost per kW was approximately 27,000 American dollars, and in 2006 the cost dropped to approximately 4,000 American dollars per kW. The PV system in 1992 cost approximately 16,000 American dollars per kW and it dropped to approximately 6,000 American dollars per kW in 2008.[83] In 2025 in the US, residential solar costs around 2.50 dollars/watt[84] (but solar shingles cost much more).[85] As of 2025[update] utility solar costs are around 25 UScent/watt.[86] See also: Solar irradiance The productivity of solar power in a region depends on solar irradiance, which varies through the day and year and is influenced by latitude and climate. PV system output power also depends on ambient temperature, wind speed, solar spectrum, the local soiling conditions, and other factors. Onshore wind power tends to be the cheapest source of electricity in Northern Eurasia, Canada, some parts of the United States, and Patagonia in Argentina whereas in other parts of the world mostly solar power (or less often a combination of wind, solar and other low carbon energy) is thought to be best.[87]:8 Modelling by Exeter University suggests that by 2030, solar will be least expensive everywhere except in some nordic countries.[88] The locations with highest annual solar irradiance lie in the arid tropics and subtropics. Deserts lying in low latitudes usually have few clouds and can receive sunshine for more than ten hours a day.[89][90] These hot deserts form the Global Sun Belt circling the world. This belt consists of extensive swathes of land in Northern Africa, Southern Africa, Southwest Asia, Middle East, and Australia, as well as the much smaller deserts of North and South America.[91] Thus solar is (or is predicted to become) the cheapest source of energy in all of Central America, Africa, the Middle East, India, South-east Asia, Australia, and several other regions.[87]:8 Different measurements of solar irradiance (direct normal irradiance, global horizontal irradiance) are mapped below: North America South America Europe Africa and Middle East South and South-East Asia Australia World In cases of self-consumption of solar energy, the payback time is calculated based on how much electricity is not purchased from the grid.[92] However, in many cases, the patterns of generation and consumption do not coincide, and some or all of the energy is fed back into the grid. The electricity is sold, and at other times when energy is taken from the grid, electricity is bought. The relative costs and prices obtained affect the economics. In many markets, the price paid for sold PV electricity is significantly lower than the price of bought electricity, which incentivizes self-consumption.[93] Moreover, separate self-consumption incentives have been used in e.g., Germany and Italy.[93] Grid interaction regulation has also included limitations of grid feed-in in some regions in Germany with high amounts of installed PV capacity.[93][94] By increasing self-consumption, the grid feed-in can be limited without curtailment, which wastes electricity.[95] A good match between generation and consumption is key for high self-consumption. The match can be improved with batteries or controllable electricity consumption.[95] However, batteries are expensive, and profitability may require the provision of other services from them besides self-consumption increase,[96] for example avoiding power outages.[97] Hot water storage tanks with electric heating with heat pumps or resistance heaters can provide low-cost storage for self-consumption of solar power.[95] Shiftable loads, such as dishwashers, tumble dryers and washing machines, can provide controllable consumption with only a limited effect on the users, but their effect on self-consumption of solar power may be limited.[95] Main article: PV financial incentives The original political purpose of incentive policies for PV was to facilitate an initial small-scale deployment to begin to grow the industry, even where the cost of PV was significantly above grid parity, to allow the industry to achieve the economies of scale necessary to reach grid parity. Since reaching grid parity, some policies are implemented to promote national energy independence,[98] high tech job creation[99] and reduction of CO2 emissions.[98] Net metering is a pricing method for residential solar: the price of the electricity produced is the same as the price supplied to the consumer, and the consumer is billed on the difference between production and consumption.[100] Community solar farm in the town of Wheatland, Wisconsin[101] A community solar project is a solar power installation that accepts capital from and provides output credit and tax benefits to multiple customers, including individuals, businesses, nonprofits, and other investors. Participants typically invest in or subscribe to a certain kW capacity or kWh generation of remote electrical production.[102] In some countries tariffs (import taxes) are imposed on imported solar panels.[103][104] Main articles: Energy storage and Grid energy storage Energy from sunlight or other renewable energy is converted to potential energy for storage in devices such as electric batteries or higher-elevation water reservoirs. The stored potential energy is later converted to electricity that is added to the power grid, even when the original energy source is not available.Salt Tanks provide thermal energy storage[105] so that output can be provided after sunset, and output can be scheduled to meet demand requirements.[106] The 280 MW Solana Generating Station is designed to provide six hours of energy storage. This allows the plant to generate about 38% of its rated capacity over the course of a year.[107] Thermal energy storage. The Andasol CSP plant uses tanks of molten salt to store solar energy.Pumped-storage hydroelectricity (PSH). This facility in Geesthacht, Germany, also includes a solar array. The overwhelming majority of electricity produced worldwide is used immediately because traditional generators can adapt to demand and storage is usually more expensive. Both solar power and wind power are sources of variable renewable power, meaning that all available output must be used locally, carried on transmission lines to be used elsewhere, or stored (e.g., in a battery). Since solar energy is not available at night, storing it so as to have continuous electricity availability is potentially an important issue, particularly in off-grid applications and for future 100% renewable energy scenarios.[108] Solar is intermittent due to the day/night cycles and variable weather conditions. However solar power can be forecast somewhat by time of day, location, and seasons. The challenge of integrating solar power in any given electric utility varies significantly. In places with hot summers and mild winters, solar tends to be well matched to daytime cooling demands.[109] Concentrated solar power plants may use thermal storage to store solar energy, such as in high-temperature molten salts. These salts are an effective storage medium because they are low-cost, have a high specific heat capacity, and can deliver heat at temperatures compatible with conventional power systems. [110] In stand alone PV systems, batteries are traditionally used to store excess electricity. With grid-connected photovoltaic power systems, excess electricity can be sent to the electrical grid. Net metering and feed-in tariff programs give these systems a credit for the electricity they produce. This credit offsets electricity provided from the grid when the system cannot meet demand, effectively trading with the grid instead of storing excess electricity.[111] When wind and solar are a small fraction of the grid power, other generation techniques can adjust their output appropriately, but as these forms of variable power grow, additional balance on the grid is needed. As prices are rapidly declining, PV systems increasingly use rechargeable batteries to store a surplus to be used later at night. Batteries used for grid-storage stabilize electrical grids by leveling out peak loads for several hours.[112] Common battery technologies used in today's home PV systems include nickel-cadmium, lead-acid, nickel metal hydride, and lithium-ion.[113][114][better source needed]Lithium-ion batteries have the potential to replace lead-acid batteries in the near future, as they are being intensively developed and lower prices are expected due to economies of scale provided by large production facilities such as the Tesla Gigafactory 1. In addition, the Li-ion batteries of plug-in electric cars may serve as future storage devices in a vehicle-to-grid system. Since most vehicles are parked an average of 95% of the time, their batteries could be used to let electricity flow from the car to the power lines and back. Retired electric vehicle (EV) batteries can be repurposed.[115] Other rechargeable batteries used for distributed PV systems include, sodium–sulfur and vanadium redox batteries, two prominent types of a molten salt and a flow battery, respectively.[116][117][118] Seasonal cycle of capacity factors for wind and photovoltaics in Europe shown under idealized assumptions. The figure illustrates the balancing effects of wind and solar energy at the seasonal scale (Kaspar et al., 2019).[119] Solar power plants, while they can be curtailed, usually simply output as much power as possible. Therefore in an electricity system without sufficient grid energy storage, generation from other sources (coal, biomass, natural gas, nuclear, hydroelectricity) generally go up and down in reaction to the rise and fall of solar electricity and variations in demand (see load following power plant). Conventional hydroelectric dams work very well in conjunction with solar power; water can be held back or released from a reservoir as required. Where suitable geography is not available, pumped-storage hydroelectricity can use solar power to pump water to a high reservoir on sunny days, then the energy is recovered at night and in bad weather by releasing water via a hydroelectric plant to a low reservoir where the cycle can begin again.[120] While hydroelectric and natural gas plants can quickly respond to changes in load; coal, biomass and nuclear plants usually take considerable time to respond to load and can only be scheduled to follow the predictable variation. Depending on local circumstances, beyond about 20–40% of total generation, grid-connected intermittent sources like solar tend to require investment in some combination of grid interconnections, energy storage or demand side management. In countries with high solar generation, such as Australia, electricity prices may become negative in the middle of the day when solar generation is high, thus incentivizing new battery storage.[121][122] The combination of wind and solar PV has the advantage that the two sources complement each other because the peak operating times for each system occur at different times of the day and year.[123] The power generation of such solar hybrid power systems is therefore more constant and fluctuates less than each of the two component subsystems.[124] Solar power is seasonal, particularly in northern/southern climates, away from the equator, suggesting a need for long term seasonal storage in a medium such as hydrogen or pumped hydroelectric.[125] Further information: Concentrated solar power § Environmental effects Greenhouse gas emissions per energy source. Solar power is one of the sources with the least greenhouse gas emissions. Part of the Senftenberg Solarpark, a solar photovoltaic power plant located on former open-pit mining areas close to the city of Senftenberg, in Eastern Germany. The 78 MW Phase 1 of the plant was completed within three months. Solar power is cleaner than electricity from fossil fuels,[25] and is better for the environment than burning things.[126][127] Solar power does not lead to harmful emissions during operation, but the production of the panels creates some pollution. The carbon footprint of manufacturing is less than 1kg CO2/Wp,[128] and this is expected to fall as manufacturers use more clean electricity and recycled materials.[129] Solar power carries an upfront cost to the environment via production with a carbon payback time of several years as of 2022[update],[129] but offers clean energy for the remainder of their 30-year lifetime.[130] The life-cycle greenhouse-gas emissions of solar farms are less than 50 gram (g) per kilowatt-hour (kWh),[131][132][133] but with battery storage could be up to 150 g/kWh.[134] In contrast, a combined cycle gas-fired power plant without carbon capture and storage emits around 500 g/kWh, and a coal-fired power plant about 1000 g/kWh.[135] Similar to all energy sources where their total life cycle emissions are mostly from construction, the switch to low carbon power in the manufacturing and transportation of solar devices would further reduce carbon emissions.[133] Lifecycle surface power density of solar power varies[136] but averages about 7 W/m2, compared to about 240 for nuclear power and 480 for gas.[137] However, when the land required for gas extraction and processing is accounted for, gas power is estimated to have not much higher power density than solar.[25] According to a 2021 study, obtaining 25% to 80% of electricity from solar farms in their own territory by 2050 would require the panels to cover land ranging from 0.5% to 2.8% of the European Union, 0.3% to 1.4% in India, and 1.2% to 5.2% in Japan and South Korea.[138] Occupation of such large areas for PV farms could drive residential opposition as well as lead to deforestation, removal of vegetation and conversion of farm land.[139] However some countries, such as South Korea and Japan, use land for agriculture under PV,[140][141] or floating solar,[142] together with other low-carbon power sources.[143][144] Worldwide land use has minimal ecological impact.[145] Land use can be reduced to the level of gas power by installing on buildings and other built up areas.[136] Harmful materials are used in the production of solar panels, but generally in small amounts.[146] As of 2022[update], the environmental impact of perovskite is difficult to estimate, but there is some concern that lead may be a problem.[25] A 2021 International Energy Agency study projects the demand for copper will double by 2040. The study cautions that supply needs to increase rapidly to match demand from large-scale deployment of solar and required grid upgrades.[147][148] More tellurium and indium may also be needed.[25] Recycling may help.[25] As solar panels are sometimes replaced with more efficient panels, the second-hand panels are sometimes reused in developing countries, for example in Africa.[149] Several countries have specific regulations for the recycling of solar panels.[150][151][152] Although maintenance cost is already low compared to other energy sources,[153] some academics have called for solar power systems to be designed to be more repairable.[154][155] Solar panels can increase local temperature. In large installation in the desert, the effect can be stronger than the urban heat island.[156] A very small proportion of solar power is concentrated solar power. Concentrated solar power may use much more water than gas-fired power. This can be a problem, as this type of solar power needs strong sunlight so is often built in deserts.[157] Acceptance of wind and solar facilities in one's community is stronger among U.S. Democrats (blue), while acceptance of nuclear power plants is stronger among U.S. Republicans (red).[158] It has been argued that although the economic benefits of the energy transition to solar (and other clean energy) are so great that it cannot be stopped,[159] slowing it would result in more climate damage.[160] The fossil fuels lobby has been accused of delaying the transition.[161] Fossil fuel subsidies are political,[162][163] and impede the transition.[164] Solar generation cannot be cut off by geopolitics once installed, unlike oil and gas, which contributes to energy security.[165] And libertarians may favor it for reducing dependence on government,[166] and reliance on inadequate electricity grids.[167] However some right wing parties are opposed to or split on solar.[168][169] Far right party positions vary by country, with some opposing utility solar as part of their climate change denial.[170][171] Although Green parties may favor solar as part of climate change mitigation some environmentalists oppose new power lines.[172] As of 2022[update] over 40% of global polysilicon manufacturing capacity is in Xinjiang in China,[173] which raises concerns about human rights violations (Xinjiang internment camps).[174] According to the International Solar Energy Society China's dominance of manufacturing is not a problem, both because they estimate solar manufacturing cannot grow to more than 400b USD per year, and because if Chinese supply was cut off other countries would have years to create their own industry.[175] Businesses may lobby government for or against tariffs on panel imports.[176][177] 100% renewable energy Cost of electricity by source Gravity battery Index of solar energy articles List of cities by sunshine duration List of photovoltaic power stations List of solar thermal power stations List of solar-powered products Renewable energy commercialization Solar energy Solar lamp Solar vehicle Sustainable energy Thin-film solar cell Timeline of solar cells

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