

Solar Energy: Power from the Sun and Its Impact in Tibet and Pennsylvania

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Executive Summary

Purpose & motivation. This report combines hands-on philanthropy (designing and fundraising for an elementary school classroom solar kit) with field observations from a summer trip to Tibet. It explains how solar energy works, why it matters, and compares adoption patterns in Tibet and Pennsylvania.

Global picture. By the end of 2024, the world had more than 2.2 TW of installed solar PV. China exceeds 1 TW, the United States is around 236 GW, and Germany is near 99 GW. Solar led new renewable additions in 2024 as costs continued to fall.¹²³

Tibet (TAR). Tibet's high elevation and strong sunlight have driven rapid growth to ~9.4 GW (2025), including record high-altitude PV-plus-storage projects (e.g., Caipeng at ~5,228 m)⁴⁵. In towns and rural areas, we observed solar on street lights, rooftops, and small off-grid kits for lighting and charging—clear examples of practical, everyday impact.

Pennsylvania. Pennsylvania surpassed ~2 GW of installed solar in 2025, with growth from both distributed rooftops and utility-scale projects. Typical residential costs remain competitive (national benchmarks around \$2.5–\$2.7/W), and average household electric bills are roughly \$150–\$160/month, making well-sited systems financially attractive—especially with available incentives.⁶⁷⁸⁹

Key comparisons. Tibet has a larger installed base and strong off-grid use tailored to high-altitude conditions, while Pennsylvania's growth reflects policy support and market maturation on a modern grid. Both cases show how local geography, policy, and infrastructure shape solar outcomes.

Takeaways. Solar is now mainstream and cost-competitive. The biggest opportunities are in grid modernization, storage, and streamlined permitting. At the community level, small solar kits offer immediate learning and resilience benefits, while large projects continue to push clean-energy goals forward.

¹ IEA-PVPS, Snapshot of Global PV Markets 2025 (global and 2024 country totals; share of new additions).

² IRENA / Our World in Data (historical capacity context).

³ Germany: BNetzA / Fraunhofer ISE end-2024 figure (~99 GW).

⁴ Takshashila Geospatial Bulletin, 2025 (installed capacity ~9.365 GW; project counts).

⁵ PV Magazine article on Caipeng (world's highest-altitude plant; elevation, specs).

⁶ Commonwealth of Pennsylvania / PUC update (2 GW milestone).

⁷ EnergySage 2025 national pricing (cost per watt; typical system costs).

⁸ NREL H2-2024 median benchmarks (cost corroboration).

⁹ Statewide bill references (PA average monthly bill).

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1.Introduction

Solar energy has emerged as one of the most promising and sustainable solutions to meet the world's growing energy demands. Every day, the sun delivers an extraordinary amount of energy to Earth—far more than humanity could ever consume. Harnessing this power not only helps mitigate climate change, but also creates economic opportunities, improves quality of life, and fosters energy independence across communities.

This report was inspired by a dual motivation: a philanthropic initiative to raise funds for a solar energy kit for Pickering Valley Elementary School, and a transformative visit to Tibet, where solar technology is deeply embedded in daily life. In Tibet's remote villages and spiritual centers, I witnessed solar panels powering homes, streetlights, and water heaters—often in places unreachable by traditional power grids. These observations underscored the potential of solar energy to drive equity, resilience, and innovation, especially in underserved regions.

Combining technical analysis with personal experience, this report will explore the fundamentals of solar energy, the technologies used to capture and convert sunlight into electricity, and the environmental and social benefits of solar adoption. It will also present a comparative overview of global solar deployment, with a focused case study on Tibet and its contrast with Pennsylvania in the United States. Through this lens, the report aims to highlight how solar energy can be both a scientific solution and a tool for community empowerment.

2.What Is Solar Energy?

At its core, solar energy is the energy that comes from the sun's light and heat. The sun, a massive ball of burning gas, constantly produces energy through a process called nuclear fusion. This process makes the sun the most important source of energy for life on Earth. Each year, the Earth receives an incredible 174 petawatts of solar energy—so much that, if we could capture it all, we'd never need any other energy source.

Only a tiny portion of the sun's energy actually reaches Earth, but it is still enough to meet all human energy needs many times over. Solar energy can be used in different ways: for heating, lighting, producing electricity, or even powering vehicles. Because it is freely available and renewable (which means it will never run out as long as the sun shines), solar energy is considered one of the best alternatives to fossil fuels like coal, oil, and gas.

How Solar Energy Reaches Us

- The sun creates energy in its core by fusing hydrogen atoms into helium through nuclear fusion.
- The energy travels millions of kilometers from the sun to the Earth, taking about eight minutes to arrive.
- Once it reaches Earth, some of this energy is reflected, some is absorbed by the atmosphere or land, and a small but significant amount is available for us to use.

Types of Solar Energy Technologies

Solar energy can be captured and used by different technologies. The main types are:

a) Photovoltaic (PV) Cells

Photovoltaic cells, or PV cells, are what you see in solar panels on rooftops or large solar farms. These special panels convert sunlight directly into electricity. PV cells are made from materials like silicon that let electrons move when hit by sunlight. When light strikes the cell, it knocks electrons loose, creating an electric current.

- PV cells are joined together to make a solar panel.
- Multiple panels make solar arrays, which can power buildings, street lights, or even entire neighborhoods.
- A standard photo voltaic system includes solar panels, a charge controller, an inverter, and optional batteries. Panels produce DC electricity; the charge controller manages safe battery charging; and the inverter converts DC to AC to run typical appliances. Excess energy can be stored for night use or exported to the grid where allowed.

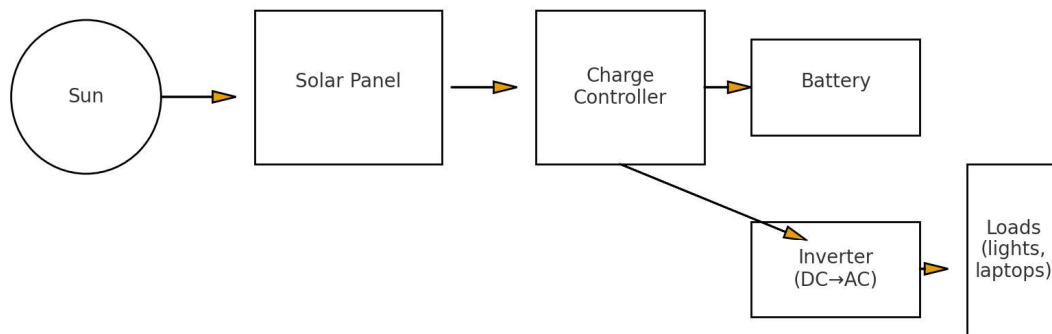


Figure 1: Basic PV system — Sun → Panel → Charge Controller → Battery + Inverter → Loads.

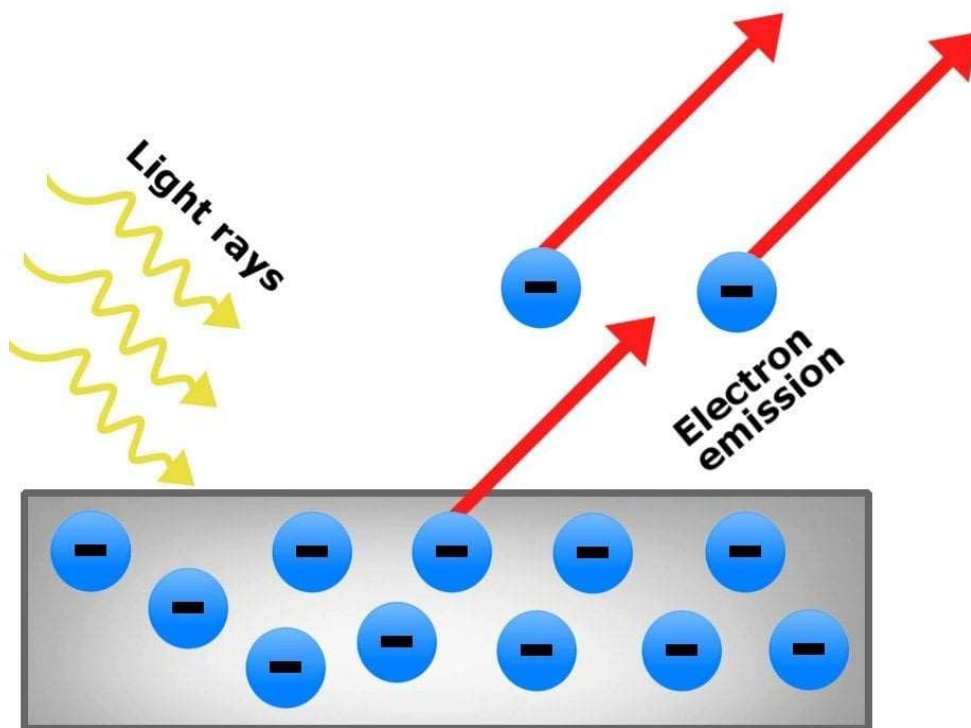


Image- Photons from sunlight hit the cell, creating electricity by moving electrons.

(Source- <https://www.labxchange.org/library/items/lb:LabXchange:8e084a3e:html:1>)

b) Concentrated Solar Power (CSP)

CSP systems use mirrors or lenses to focus sunlight onto a small area. The concentrated sunlight heats up fluids, usually to create steam, which then turns a turbine to produce electricity. This is used mainly in large power plants.

c) Solar Thermal Systems

These systems use the sun's heat to warm water or air. For example:

- Solar water heaters: Use panels to heat water for homes and swimming pools.
- Solar ovens: Cook food using reflected sunlight for heat.

d) Passive Solar Design

This is not a device but a smart way of building homes and structures. For instance, buildings can be designed with big south-facing windows to let in the sun during winter, saving on heating costs.

Comparison of Types of Solar Technologies

Technology	How It Works	Main Uses
Photovoltaic (PV) Cells	Convert sunlight into electricity	Homes, street lights, calculators
Concentrated Solar Power (CSP)	Focuses sunlight to make heat	Large power plants
Solar Thermal Systems	Heats water or air	Water heaters, greenhouses
Passive Solar Design	Building placement/materials	Homes/buildings

Most modern solar panels last 20-30 years and can remain about 80% efficient even after decades in use. Recent advancements such as bifacial solar panels (which collect sunlight on both sides) and AI monitoring have made these systems even more reliable and efficient, especially in places like Tibet.

3.Benefits of Solar Energy- Environment & Social

3.1 Environmental Benefits of Solar Energy

Solar energy is one of the cleanest sources of energy. It produces electricity without releasing harmful gases or pollutants into the air. Here are the main environmental benefits:

a) Reduces Greenhouse Gases

Conventional fuels like coal and oil release carbon dioxide (CO₂) and other pollutants when burned. These gases trap heat in the atmosphere and cause global warming. Using solar panels cuts the need for fossil fuel power plants, directly helping to reduce these emissions.

- In 2022, solar energy offset over 140 million metric tons of CO₂ emissions globally.
- Solar PV's life-cycle emissions are ~6–40 g CO₂e/kWh vs ~820 g CO₂e/kWh for coal (about 100–140× lower).

b) Reduces Air and Water Pollution

- Solar power systems don't release air pollutants, which means fewer cases of asthma, lung disease, and breathing problems.
- Unlike many other power plants, solar does not use water for cooling, saving a vital resource—especially important in dry places. (To be precise, PV systems use minimal water in operation; CSP plants can require cooling water)

c) Limits Resource Use and Supports Recycling

- It takes six months to two years for a solar panel to “pay back” the energy used in its manufacturing process—a small fraction of its total lifespan.
- 90–97% of solar panel materials are recyclable, further reducing long-term waste.

d) Protects Land and Wildlife

- Solar panels can be installed on roofs or “brownfields,” using previously developed land and not disturbing wild habitats. Solar farms, when designed carefully, can coexist with nature, sometimes allowing wildflowers and insects to thrive.

Key Environmental Benefits

Benefit	Solar Energy	Fossil Fuels
CO ₂ Emissions	Very low (6g/kWh)	Very high (up to 820g/kWh)
Air/Water Pollution	None in operation	Significant
Resource Usage	Renewable, recyclable	Finite, polluting
Water Use	Very little	High (for cooling)

Benefit	Solar Energy	Fossil Fuels
End-of-life Impact	90–97% recyclable	Often toxic waste



Employees work at Veolia’s solar panel recycling plant in Rousset, France

Source: <https://www.reuters.com/article/world/uk/europes-first-solar-panel-recycling-plant-opens-in-france-idUSKBN1JL296/>

3.2 Social Benefits of Solar Energy

Besides helping the planet, solar energy offers important social advantages for communities and individuals.

a) Job Creation and Local Economic Growth

- The global solar sector employs ~7 million (2023, IRENA/ILO), including manufacturing, sales, installation, and maintenance jobs.
- In the United States, the “green economy” has created more than 280,000 jobs in the solar industry, making it one of the fastest-growing job markets.
- Solar projects boost local economies by providing work for electricians, engineers, and project managers.

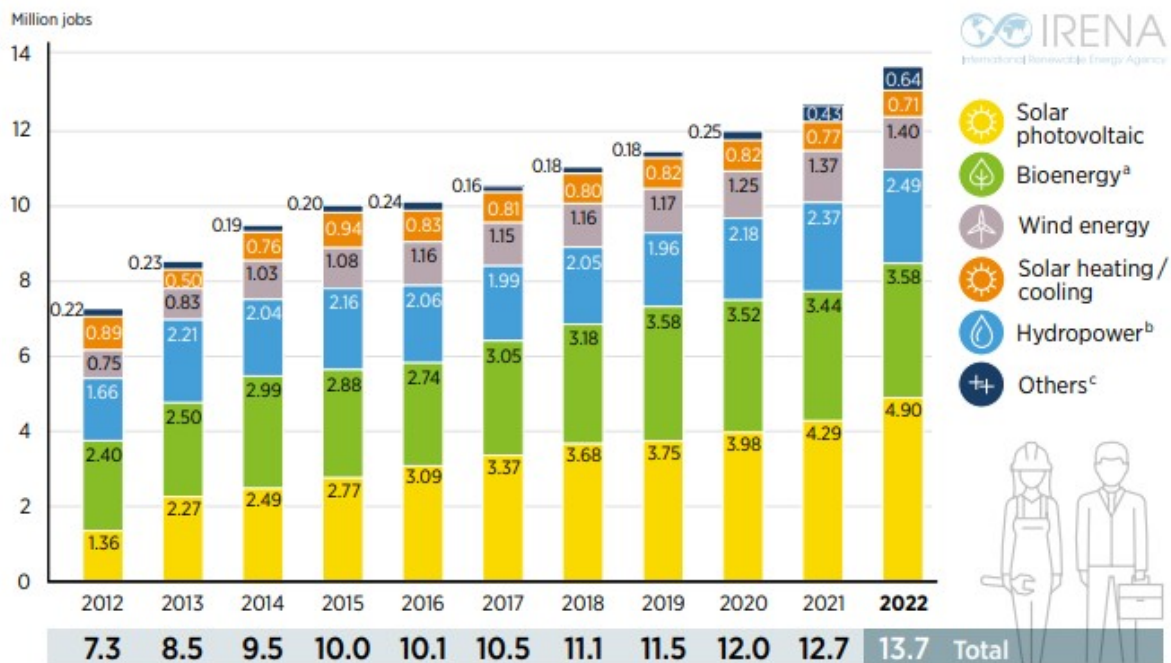


Chart: Global Solar Industry Employment

(Source: Irena, <https://www.irena.org/Publications/2023/Sep/Renewable-energy-and-jobs-Annual-review-2023>)

b) Energy Independence and Security

- Solar energy helps communities rely less on imported oil and gas.
- With solar, even remote areas can have reliable electricity, which helps reduce poverty and increases resilience in natural disasters.

c) Lower Electricity Bills and Community Benefits

- Solar panels can reduce household energy bills by 20–50% on average.
- Programs such as “community solar” share the benefits with families who might not be able to afford their own panels.

d) Public Health Improvements

- Cleaner air means fewer health problems, reduced hospital costs, and a better quality of life for all.
- Improved access to electricity in rural areas also supports health clinics and schools.

e) Educational and Technological Advancement

- Schools, including those in rural or remote regions, can use solar for lighting, computers, and science labs.
- Solar technologies inspire new scientific research and innovation.

f) Equity and Social Justice

- New policies help low-income families afford solar power through rebates, grants, and community programs.
- The US “Solar for All” program aims to expand solar access for over 900,000 low-income households by 2025

Summary: Environmental & Social Benefits of Solar Energy

Environmental Benefits	Social Benefits
No greenhouse-gas emissions	Lower energy bills for families and schools
No air or water pollution	Clean jobs in manufacturing & installation
Renewable, needs no fuel	Reliable power in remote areas
Helps prevent climate change	Energy independence & security
Uses existing rooftops, less land	Improved public health from cleaner air

Solar energy stands out for its unmatched dual role—protecting the planet while improving lives, particularly for those most in need.

4. Global Overview of Solar Energy Adoption

Solar energy use is rising rapidly across the world, with new records set each year. The cost of solar panels has dropped by over 70% in the last decade, making solar cheaper and more accessible.

Key Worldwide Statistics

- By the end of 2024, global solar energy capacity reached >2.2 TW (gigawatts)—the largest share of any renewable energy source.¹⁰
- More than 2.2 terawatts (2,200 GW) installed worldwide by mid-2025.
- In 2024, solar accounted for 75–81% of all new renewable energy capacity added globally.
- Over 600 GW of solar installed in 2024 alone—mostly in China, the US, and the European Union¹¹.

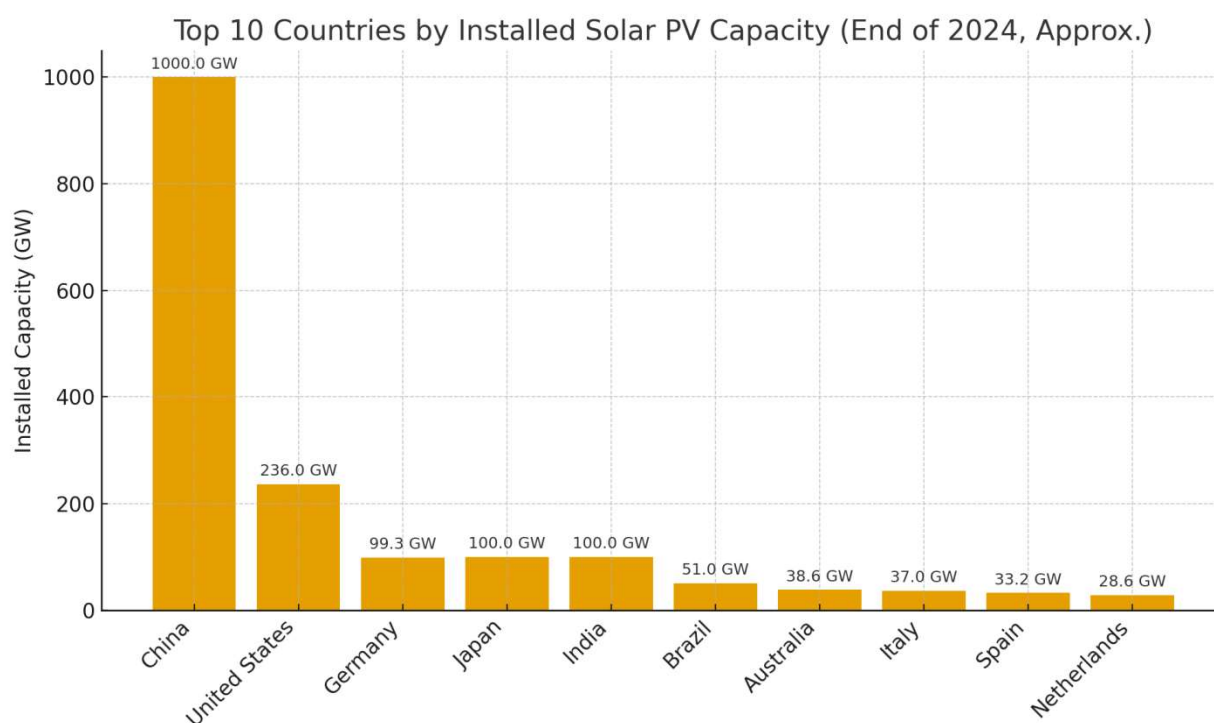


Figure – Top 10 countries by Installed Solar Capacity (Source: IEA-PVPS Snapshot 2025; IRENA/OWID 2000–2024)

¹⁰ Global totals and country rankings based on IEA-PVPS *Snapshot of Global PV Markets 2025* (for 2024 values) and IRENA/Our World in Data (2000–2024 historical)

¹¹ Germany ~99.3 GW by end-2024 (BNetzA / Fraunhofer ISE)

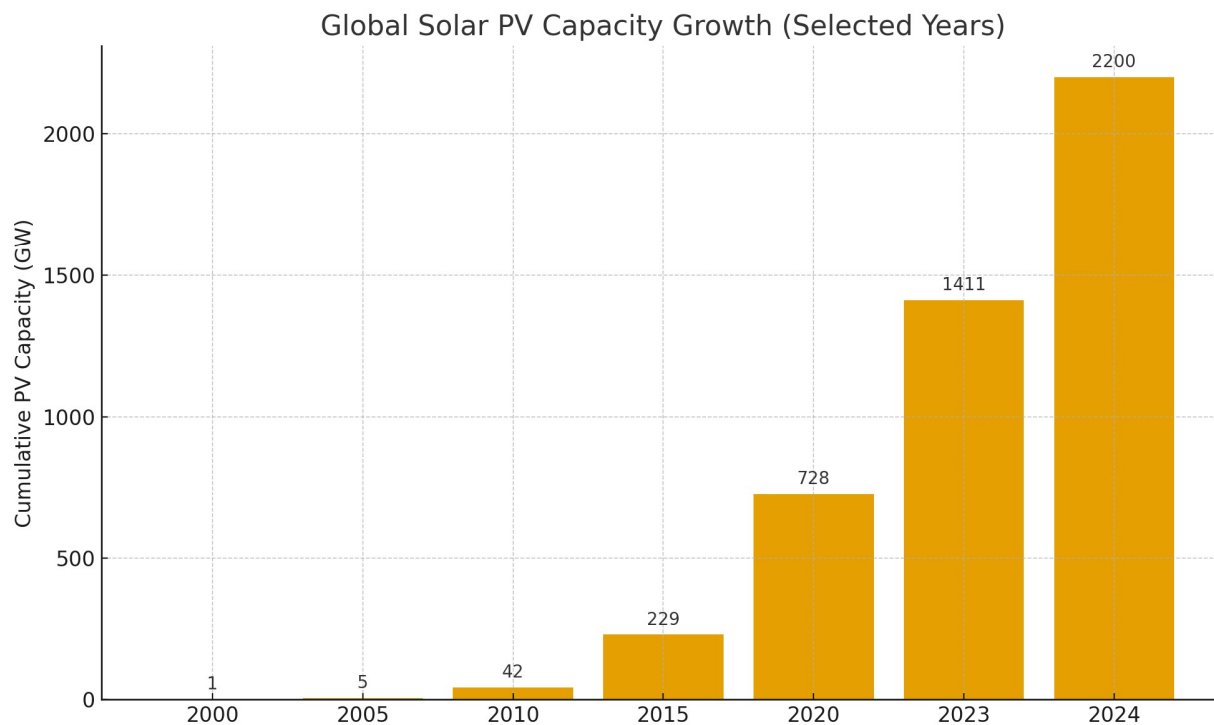


Figure: Global solar PV cumulative capacity growth (selected years, 2000–2024). (IEA-PVPS Snapshot 2025; IRENA/OWID 2000–2024 global capacity datasets.)

Key Trends and Projects

- Rooftop solar systems, community solar, large solar farms, and off-grid installations are all part of the solar boom.
- The cost to generate electricity from solar panels is now as low as \$0.03–\$0.06 per kWh, competing with or beating fossil fuels.
- Emerging markets, such as Tibet and other high-altitude sunny regions, are capitalizing on their natural advantage.

Major Policies and Incentives

- Many countries and states offer tax credits, rebates, and net metering, making solar more affordable for homeowners.
- The US Inflation Reduction Act (IRA) set aside billions for solar incentives, benefiting families and local businesses.
- China’s government has supported solar adoption through large infrastructure investments, making it the world leader in both manufacturing and installation.

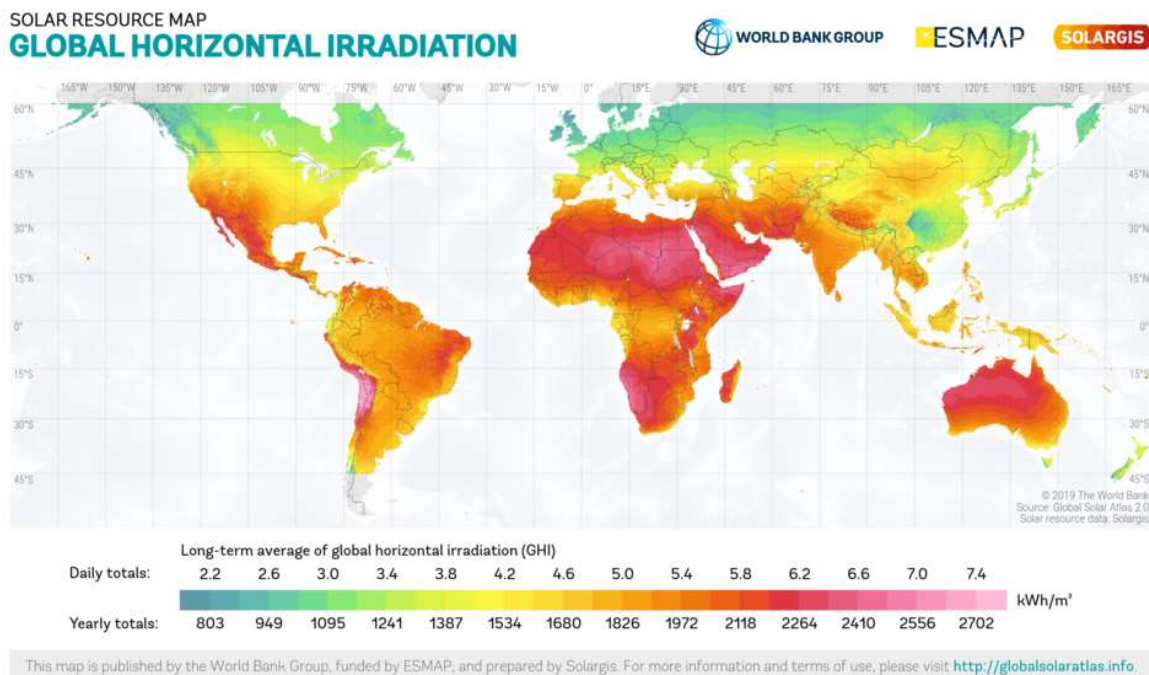
5.Solar Energy in Tibet: High-Altitude Excellence

Solar Resource and Potential

- Tibet receives an annual solar radiation of 5,852–8,400 MJ/m², ranking it among the highest globally.
- Lhasa, Tibet's capital, enjoys over 3,000 hours of sunshine each year.
- The plateau's dry, clear air and high elevation (average: 4,500 meters) further increase the effectiveness of solar power.

Unique Challenges

- Tibet's extreme altitude, cold, and mountain climate require robust solar equipment and careful installation.
- Large-scale grid integration still faces hurdles—winter/spring energy shortages, need for more energy storage, and the vast area of the plateau.
- Environmental rules ensure that large solar farms don't harm key wildlife migration routes or sacred land.



Map: Average Solar Irradiance

(Source: Wikimedia, https://commons.wikimedia.org/wiki/File:World_GHI_Solar-resource-map_GlobalSolarAtlas_World-Bank-Esmap-Solargis.png)

Recent Developments and Projects

- More than 109 large-scale solar projects (over 20 MW each) have been built across Tibet, with a total installed capacity of over 9.365 GW (as of 2025).¹²
- In 2023, the region added 700 MW from new projects; in 2024, another 860 MW came online, and a remarkable 2,600 MW came from just 2 mega-projects in 2025.
- Smaller solar projects (1–20 MW) dot the landscape, suitable for rural villages and individual communities.

Statistics Summary: Tibet ¹³

Metric	Value (Most Recent Data)
Total installed PV capacity (2021)	1,390 MW (1.39 GW) in 2021. (Note - Tibet grew from 1.39 GW (2021) to ~9.4 GW (2025))
% of total electric power from clean energy	~90%
Households served by solar home systems	200,000+
Rural people benefiting from PV	600,000+
Solar resource average (kWh/m ²)	1,816 (average); up to 2,023 in Lhasa
Sunshine hours per year	3,000+
Large-scale solar project (Caipeng PV)	150 MW (world's highest altitude)

(Tibet's energy data compiled from Sustainability Journal, TechScience Energy, and news sources)

Key Innovations

- Bifacial solar panels capture sunlight from both sides, increasing efficiency by up to 20%.
- Battery storage systems ensure stable electricity supply, even after sunset or during cloudy periods.
- Some projects combine solar and hydroelectric power for a more reliable "round-the-clock" energy supply.

Impact on Local Communities

- Solar has brought electricity to more than 600,000 people who previously lived off the grid.
- Over 70,000 households in remote areas like Ngari use solar energy for lighting and cooking.
- Streetlights, homes, schools, and mobile phone towers now run on solar power.

Social and Environmental Considerations

- Projects have raised living standards for farmers, nomads, and herders, enabling better access to education, clean water, and communications.

¹² Tibet (TAR) cumulative solar ~9.365 GW; 100+ projects identified (Takshashila Geospatial Bulletin, 2025)

¹³ Source (Tibet): Takshashila Geospatial Bulletin, 2025

- There are concerns about the loss of grasslands and traditional grazing areas due to large solar installations. Community groups have asked for better protection of fragile ecosystems.

High-Altitude Solar Project Case Study



Image: World's Highest Solar Plant The Caipeng Solar-Storage Station at 5,228 meters in Shannan, Tibet—the highest altitude solar project globally ¹⁴.

Source: <https://www.pv-magazine.com/2024/12/17/worlds-highest-solar-plant-by-elevation-goes-online-in-china/>

Huadian Tibet Caipeng PV-Storage Project

- Location: Shannan, Naidong District, elevation 5,228 m.
- Size: 170,000 solar panels, 20 MW/80 MWh battery storage.
- Output: 150 MW (powers up to 40,000 homes), with the first phase generating 60 million kWh in less than a year.
- Features: Bifacial panels, advanced storage, built in just 115 days.
- Environmental benefit: Reduces CO₂ by over 100,000 tonnes per year.

¹⁴ World's highest-altitude PV-plus-storage project in Tibet (Caipeng) at ~5,228 m (PV-Tech, Dec 2024)

Pictures from my trip to Tibet





Images depict solar panels powering individual street lights and residential homes, while also contributing energy to the main power grid.

6.Solar Energy in Pennsylvania

Pennsylvania is making rapid progress in adopting solar energy, although it faces different conditions compared to Tibet. The state has moderate sunlight (about 160–200 sunny days per year) and a more humid, forested landscape, but supportive policies have allowed solar to flourish in recent years.

State of Solar in 2025

- Installed solar capacity: Pennsylvania now has over 2 GW (2,000 MW)—enough to power 350,000 homes.¹⁵
- In just 17 months, the state doubled its solar capacity, signaling accelerating adoption.
- Most of the growth comes from rooftop and distributed solar systems owned by homeowners and small businesses, as well as utility-scale solar farms in rural counties.



Image: Solar Panels in Pennsylvania

(Source: Wikimedia, https://commons.wikimedia.org/wiki/File:Cleaning_solar_panels,_Palmyra,_Pennsylvania.jpg)

¹⁵ Pennsylvania surpassed ~2 GW of installed solar on July 22, 2025 (Commonwealth of Pennsylvania / PUC)

Policies and Incentives

- A 30% Residential Clean Energy Credit (25D) is available for qualifying residential solar placed in service through December 31, 2025 (per IRS/Treasury commissioning rules).
- The Pennsylvania Sunshine Program offers rebates for both residential and small business solar projects.
- Solar Renewable Energy Certificates (SRECs): Homeowners can earn one SREC for each megawatt-hour of solar electricity produced and sell it back to utilities for extra income.
- Net metering allows solar users to sell extra electricity to the grid for bill credits.

Costs and Economics

- Average cost per watt: \$2.62 (typical system size: 5–10 kW)
- System cost: Around \$13,000–\$18,000 before tax credits; as low as \$9,100 after credits for a 5 kW system.
- With incentives and competitive pricing, homeowners can see a payback period of about 8–10 years.

System Size	Cost Before Credit	Cost After 30% Credit
5 kW	\$13,093	\$9,165
6 kW	\$15,712	\$10,998
8 kW	\$20,949	\$14,664
10 kW	\$26,186	\$18,330

Table: Typical Solar System Costs in Pennsylvania(Source: EnergySage 2025 national pricing; NREL H2-2024 median; 2025 statewide bill references.)

Local Benefits

- Solar helps lower average household electricity bills (average monthly bill ~\$150-\$160/month).¹⁶
- Solar industry supports thousands of jobs in manufacturing, installation, engineering, and project management across the state.
- Solar panels are found in homes, schools, commercial buildings, and even state parks, providing both clean energy and shaded parking.

Growth and Challenges

- Pennsylvania still lags behind solar leaders (like California and Texas), but is gaining ground each year.
- The state aims to generate at least 10% of its electricity from in-state solar by 2030.

¹⁶ Average Pennsylvania household electricity bill ≈ **\$150–\$160/month** in 2025 (statewide references)

- Ongoing challenges include upfront installation costs for some families, limited state-level rebates, and the upcoming end of the federal residential tax credit.

Comparative Table: Solar Energy in Tibet vs. Pennsylvania

Category	Tibet	Pennsylvania
Geographic Conditions	High-altitude, strong solar radiation	Temperate climate, moderate sunlight
Annual Sunshine Hours	3,000+	2,150–2,400
Average Solar Irradiance	6.0 kWh/m ² /day (peak), 1,816–2,189 kWh/m ² /yr	~3.5 kWh/m ² /day
Installed Solar Capacity	9.4 GW (2025)	2 GW+ (2025)
Per Capita Capacity	High (Tibet: strong rural/off-grid use)	Lower, but climbing quickly
Number of Projects	>109 large projects, plus many small	Hundreds of distributed sites
Typical Uses	Homes, street lights, off-grid, rural farms	Rooftop, utility, community solar
Main Incentives	National, regional support	Federal tax credit; state programs, SRECs
Financing / Access	Central investment, donor programs	Loans, leases, rebates, net metering
Local Impact	600,000+ gained electricity; quality of life	350,000+ homes served; job growth, savings
Environmental Concerns	Ecosystem, grassland impacts	Minimal; some land use for large solar farms

(Source: EnergySage 2025 national pricing; NREL H2-2024 median; 2025 statewide bill references.)

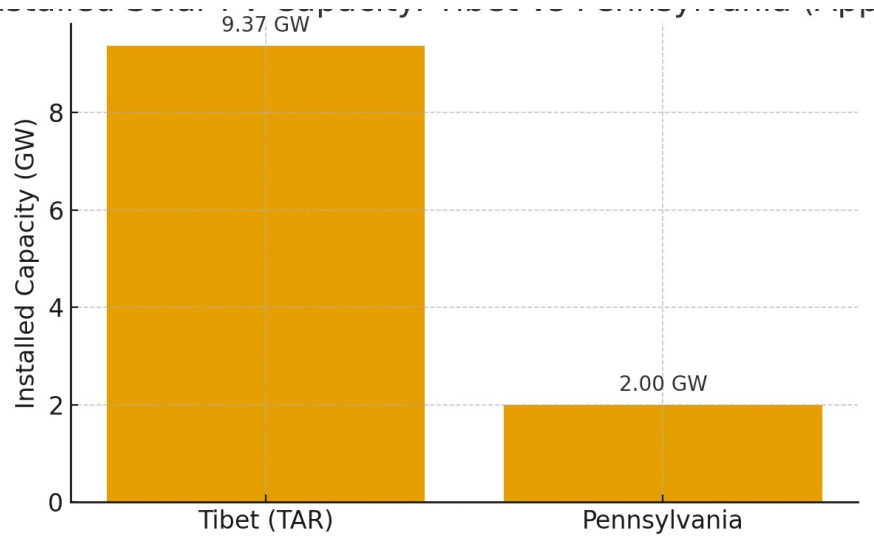


Figure: Installed PV capacity — Tibet vs Pennsylvania (approximate)

7.Solar Power: Challenges and Looking Forward

Despite its advantages, solar energy faces challenges—especially as adoption skyrockets.

Main challenges:

- Intermittency: Solar only generates during the day (clouds and weather affect this). Solutions: Combine with batteries or other power sources.
- Storage: Battery technology is improving, but storing enough for entire nights or cloudy stretches is still costly.
- Upfront Cost: Even though prices are way down, a solar system is still a big investment for many families (though loans, tax credits, and rebates help a lot).
- Grid upgrades: The electric grid needs to be modernized to handle large amounts of renewable energy.
- Waste & Recycling: Aging solar panels will eventually need to be recycled or managed responsibly.
- Equitable Access: Not all communities (including low-income and remote areas) benefit equally yet—programs are growing to close this gap.

Global Solar Energy: What's Next?

The future of solar is bright:

- Costs are predicted to fall further.
- Home batteries and electric vehicles will help match supply with demand.
- Smart grids and “virtual power plants” will allow millions of small solar systems to work together.
- Solar is a pillar of national “net zero” plans and climate agreements.
- Innovation continues in panel efficiency, recycling, and integration with agriculture.

Major organizations, like the International Renewable Energy Agency (IRENA), project that solar could supply 20–50% of global electricity by 2050 if these trends keep up.

8. Conclusion

Solar energy is transforming how people across the globe generate and use electricity. It is clean, powerful, and increasingly affordable. Around the world, countries are turning to solar energy to replace polluting fossil fuels, tackle climate change, and help communities have better lives.

Tibet is a special example—using its natural sunshine at high altitudes, the region has embraced solar energy for homes, streetlights, and major power plants. The spread of advanced technologies, such as bifacial solar panels and battery storage, is making these systems even better suited to Tibet's demanding climate.

Pennsylvania is making steady progress, using incentives and new technologies to bring solar power to more people. While the state faces different climate and economic challenges, solar is becoming a bigger part of its electricity mix every year, creating new jobs and saving families money.

Ultimately, both Tibet and Pennsylvania show that solar energy is not just a solution for the future—it is already improving lives, protecting the environment, and opening opportunities today. By learning more, sharing experiences, and continuing to innovate, everyone can be part of the solar revolution.