Invesco

Will solar take the throne?

August 2021

For professional investors and qualified clients/sophisticated investors only.

Executive Summary

Renewable energy developed only incrementally over the previous two decades. However, that may now change completely as major global economies commit to becoming net zero carbon economies in an attempt to curb rising global temperatures. In this paper, we explore the specific catalysts supporting renewable energy and the viability of various sources, including whether solar could become the "king of electricity" in the years ahead.

Government commitment. Following the Paris Agreement, most major nations – particularly the largest economies of the US, China, the EU and the UK – have committed to net zero carbon emissions by 2050 (2060 for China). Each country or economic bloc is developing its own plans for achieving the goal individually, but the common feature is that they will all require transformation of many industries as well as substantial investment. The energy sector is where the greatest challenges and opportunities exist.

Economic improvement. The costs involved with producing energy from both solar and wind have reduced considerably in the past decade and are now among the cheapest sources of electricity. This is in stark contrast to the past, when large government subsidies were needed to make solar and wind worth considering as an alternative to fossil fuels. Financial assistance is no longer needed with solar energy soon set to become the lowest-cost source of electricity in history. Cost reductions have been driven by technological gains, a trend that is predicted to continue.

80 minutes of sunlight hitting the earth's surface is powerful enough to fuel the entire world's energy consumption for a year.[1]

Contrary to fossil fuel energy, solar provides a clean and safe electricity solution, with a cost certainty, despite variable intensity and harnessing limits.

The two main types of solar power technology:

- **Solar photovoltaic** (also known as solar PV) converts sunlight into electricity using a technology known as photovoltaic cell. Solar PV panels are the most common example of this technology.
- **Solar thermal** converts sunlight into heat, which can be used for a variety of purposes like creating steam to drive an electricity generator. This heat energy can also be used for other purposes, like driving a refrigeration cycle, providing solar-based cooling.

In the fight against global warming, solar power is at the forefront of energy transition.

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What are the tailwinds for the solar energy sector globally?

Renewable energy is booming. According to the International Energy Agency (IEA), in 2020, annual renewable capacity additions increased 45% to almost 280 GW – the highest year-on- year increase since 1999. This growth is set to continue, with the IEA forecasting that exceptionally high capacity additions will become the "new normal" in 2021 and 2022, with renewables accounting for 90% of new power capacity expansion globally. Solar PV, in particular, is expected to continue to break records, with annual additional capacity reaching 162 GW by 2022, almost 50% higher than pre-pandemic levels.

The long-term outlook for the renewable energy sector is equally bright, since renewable energy will be essential if the world is to reach Net Zero by 2050 as set out under the Paris Agreement. According to analysis by the IEA, the pathway to Net Zero will mean that two thirds of total energy in 2050 will come from a combination of wind, solar, bioenergy, geothermal and hydro energy, with solar becoming the single largest source, accounting for one-fifth of energy supplies and total capacity increasing 20-fold between now and 2050.

Across the world, governments are setting out their plans on how they will reach Net Zero, as well as their intermediate targets to reduce carbon emissions by 2030. To understand the drivers behind the projected growth of the renewable energy sector, and in particular the solar sector, we take a look in more detail at the EU, China and the US.

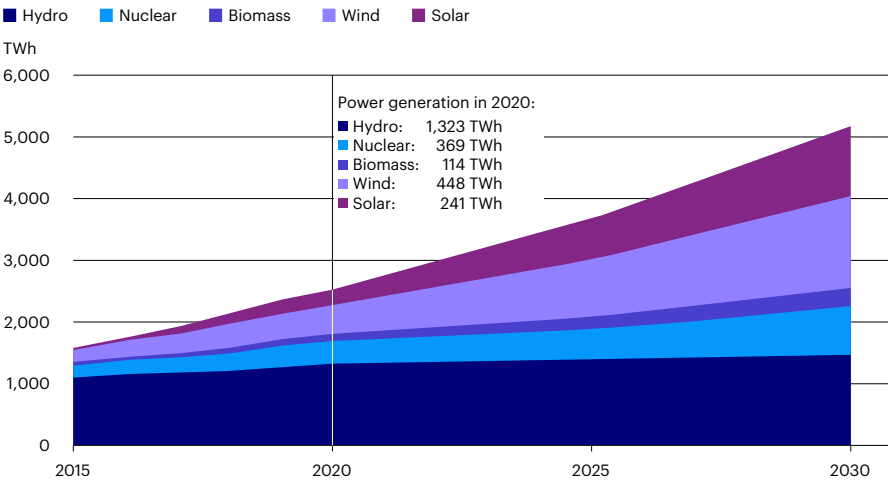
As part of the EU Green Deal, carbon emission in the bloc are set to be cut by 55% by 2030, with vast swathes of EU regulation reviewed to translate the goal into policy. In its recently released "Fit for 55" package in July, the EU outlined expectations for solar energy to grow

Figure 1
Key clean technologíes ramp up by 2030 in the net zero pathway

Solar and wind	Capacity additions set to grow x4 between 2020 and 2030
Electric car sales	Set to increase from around 3.5 million in 2020 to over 55 million by 2030
Energy intensity of GDP	Set to reduce 4% per year between 2020 and 2030

GDP = gross domestic product in purchasing power parity
Source: IEA, Net Zero by 2050 report, May 2021

Figure 2
China's projected non-fossil power generation by source



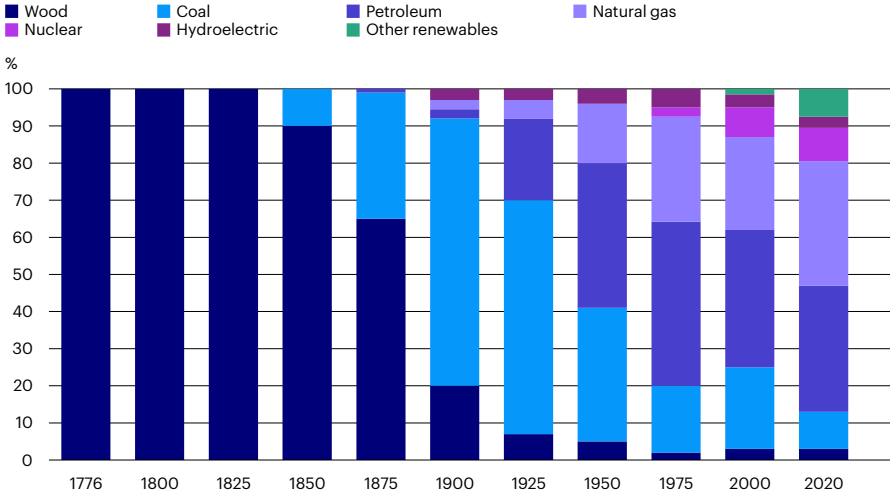
Source: Carbon Brief, data as at 15 December 2020.

from 6% of electricity generation in 2015 to 14% by 2030, with installed solar capacity growing some 380 GW. This extends the growth trend in the EU over the past decade.

In China, the Government announced plans to reach Net Zero in 2060 and for carbon emissions to peak in 2030. As part of the package of measures to achieve this goal, the Chinese government has also announced a target for non-fossil fuels (renewables and nuclear energy) to reach 25% of primary energy and to increase wind and solar power capacity to 1,200 GW, up from the 415 GW of installed capacity at the end of 2019.

In the US, President Biden has announced plans to reduce carbon emissions by 50-52% by 2030. This is complemented by his administration's USD 2 trillion infrastructure plan, which will extend tax credits for clean energy as well as introduce a clean energy standard with the aim of achieving 100% carbon-free electricity by 2035. Such a target would require a significant increase in deployment of renewables, which currently stands at around 20% of total US electricity generation.

Figure 3
Shares of total US energy consumption by major sources in selected years (1776 – 2020)



Note: Wood includes wood and wood waste, other renewables includes biofuels, geothermal, solar and wind.
Source: U.S. Energy Administration, Monthly Energy Review, Appendix D.1, and Tables 1.1 and 10.1, April 2021, preliminary data for 2020.

Why are the economics improving?

Dramatic improvement in solar economics drives sector growth
The steadily falling cost of photovoltaic (PV) solar is the key reason for solar's extremely strong growth rate. Many people still make the mistaken assumption that solar is prohibitively expensive. In fact, solar PV has now become the cheapest source of new electricity generation plants in many cases across the world. Even if the world didn't face a climate crisis, solar would still be winning against fossil fuels.

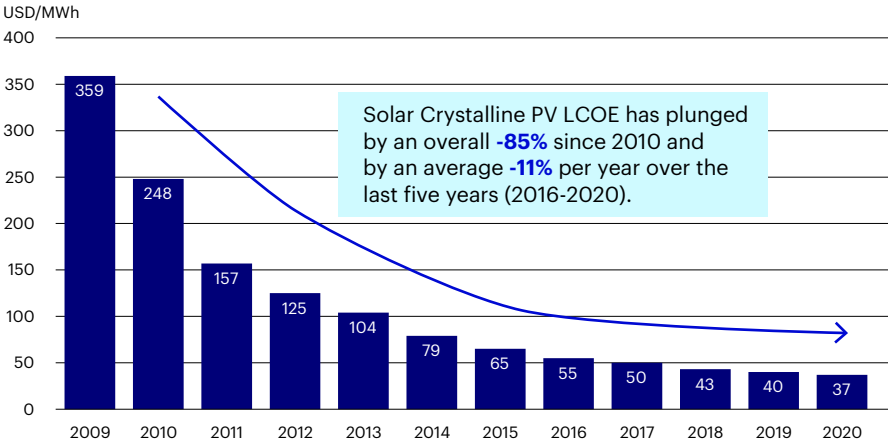
Any perception that the solar industry cannot survive without subsidies is also outdated. Solar plants are being built on a cost-effective basis worldwide without any subsidy benefit, particularly in Europe. When there are subsidies, solar plants have an even more significant cost advantage against competitors.

The fact that the solar sector no longer relies on subsidies for its existence means that the sector's future is secure, regardless of whether governments provide subsidies in the future. Banks, investors and utilities are now willing to dedicate very large sums of capital to the solar sector because its low cost has secured its leading place in the global energy future.

Cheaper utility-scale solar plants vs. fossil fuel and nuclear plants
The investment bank, Lazard, has produced a widely followed annual study of electricity costs since 2015. Its latest Levelized Cost of Energy Analysis report (14.0) found that the unsubsidized levelized cost of utility-scale solar has fallen to an average mid-point level of USD 36.5 per megawatt-hour, down by a staggering 85% since 2010. The levelized cost of energy of solar has fallen by an average 11% per year over the last five years (2016-2020).

The Lazard report shows that utility-scale solar plants, on average, are now substantially cheaper to build than new natural gas, coal or nuclear plants, and are even slightly cheaper than wind. Solar's cost advantage shows why utilities are

Figure 4
Utility-scale solar PV – unsubsidized levelized cost of electricity



Source: Lazard LCOE 14.0, November 2020.

increasingly looking towards solar when they need to build a new electricity-generation plant.

Moreover, solar has become so inexpensive that it is now cheaper to build a new PV utility-scale solar plant from scratch for USD 36.5/MWh than to keep an existing coal plant running at a marginal cost of USD 41/MWh, according to Lazard. Yet, installing a new solar plant does not yet beat the marginal cost of keeping an existing nuclear plant running of USD 29/MWh or a natural gas plant of USD 28/MWh.

Solar has become cheaper than new fossil fuel plants, not just in the US, but also globally. Bloomberg New Energy Finance (BNEF) reports that it is already cheaper for two-thirds of the world's population to get new power from solar or wind than from new fossil fuel plants.

Why are solar costs steadily falling?
Solar PV is a high-technology product where production costs decline due to the technology learning curve, similar to the learning curve seen for computer semiconductor chips.

Due to improved technology, the efficiency of solar cells in converting sunlight to electricity steadily rises, thus reducing the cost of producing the same amount of electricity. Over the past decade, the efficiency of monocrystalline solar modules has increased from about 16% in 2010 to the current level of about 19.6%, for an overall increase of more than 20%, according to the U.S. National Renewable Energy Laboratory (NREL).[2]

Increased solar module efficiency comes from a variety of sources. For example, substantial efficiency gains have been achieved by improving the material composition of the solar cells. Big improvements have also come from increasing the production size of solar cells. On the new technology front, a

Changes in costs of electricity since 2010


-85%
Solar PV


-68%
Wind

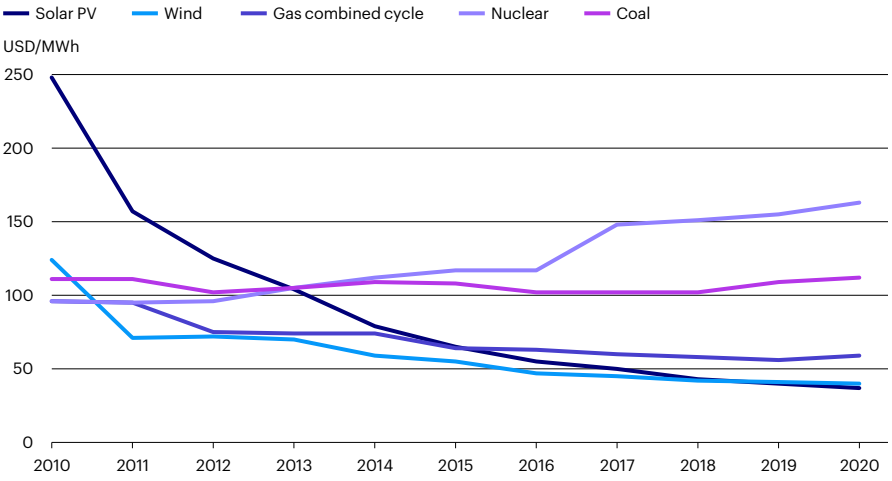

-39%
Gas combined cycle


+70%
Nuclear


+1%
Coal

Source: Lazard LCOE 14.0, November 2020.

Figure 5
Utility-scale levelized cost of electricity (unsubsidized)



Source: Lazard LCOE 14.0, November 2020.

promising area of research involves using a material called "perovskites," rather than silicon, to turn sunlight into electricity.

Solar cell efficiency advanced significantly in recent years due to a new solar cell technology called "Passivated Emitter Rear Cell (PERC)," which allows light that was not absorbed on the first pass through the solar cell to be absorbed after being reflected back for a second pass. The PERC cells then allowed the development of bifacial solar panels, which absorb light from both the front and back of the panel, thus increasing the module's electricity output.

The cost of solar cells and modules has also declined because of improved manufacturing processes. For example, the solar industry now uses high-tech diamond sawing wires to cut solar wafers, which reduces waste. Most solar module manufacturing plants have also become highly robotic, thus reducing labour costs.

Additionally, solar costs fell due to manufacturing economies of scale. As solar cell and module producers increase their output capacity, they can spread their fixed costs out across a larger production base, thus reducing the price per unit. The economy-of-scale factor is substantial since the global solar industry is now eight times bigger than just a decade ago.

The efficiency of solar power increased further due to sophisticated tracking stands that turn the solar panels on an axis to follow the sun as it moves across the sky, thus increasing the amount of electricity that a given solar module can produce. Maintenance costs for solar plants also reduced, driven by anti-soiling coatings that keep the panels cleaner, using robots to periodically clean the panels, and using drones and sophisticated software to monitor a solar plant's performance.

Lastly, solar cell and module economics improved due to the substantial drop in the cost of polysilicon, which is the basic material from which solar cells are produced. Improved technology and manufacturing processes enabled polysilicon prices to plunge from the USD 60 per kilogram area seen a decade ago to last year's record low of USD 6.19 per kilogram, according to Bloomberg New Energy Finance.[3]

Improved balance-of-systems costs
The cost of solar has fallen because of reduced solar cell and module costs, but also from lower other cost components of a solar plant, which are referred to as "balance-of-system" costs.

Balance-of-system costs vary substantially depending on whether the solar system is for a residence or business or a utility-scale solar park. For a utility-scale solar plant, the National Renewable Energy Laboratory (NREL) reports that about 40% of the overall cost of a solar plant comes from the solar modules.[4] Other components of the plant include the DC-AC inverters and other electrical system costs, the structural frame (fixed frame or tracker), land costs, permitting fees, labour and construction expenses, among others.

Most balance-of-system costs have steadily declined because of economies of scale and improved technology, particularly for DC-AC inverters. Also, financing for solar plants fell as solar plants have become attractive investments for institutional funds and infrastructure companies. Major global banks are now heavily involved in financing solar projects, competing with lower interest rates to win financing deals.

Solar-plus-storage costs are dropping
Solar power becomes more valuable when it is paired with batteries for a 24/7 electricity generation solution. Solar power on the grid is worth more when it is spread out over 24 hours as opposed to being loaded into daylight hours.

The sharp drop in the price of batteries has helped slash the cost of PV-plus-storage. Bloomberg New Energy Finance says that utility-scale lithium-ion battery storage systems have plunged by nearly 90% since 2010 and will fall by another 27% by 2023.[5]

IHS Markit reports that virtually all power-purchase agreements to buy solar power in California and Hawaii now involve solar-plus-storage systems rather than PV-only systems. Electricity from these systems is being sold at very low prices. S&P Global Market Intelligence reports that solar-plus-battery power-purchase agreements (PPA) in the U.S. Southwest due to come online in 2021 are priced in the very low range of 2.2–3.2 cents per kilowatt hour.[6]

Positive outlook for solar economics
Bloomberg New Energy Finance (BNEF) predicts that solar costs will fall by a further 71% by 2050.[7]

To assure solar costs continue to decline, the US Department of Energy (DOE) in March 2021 announced a goal of cutting solar costs by 60% by 2030, which is only nine years away.[8] The DOE also announced another USD 128 million in research funding, with USD 40 million of that going to perovskite R&D and USD 20 million for solar thin-film technologies.

The DOE has set a new goal of driving the cost of utility-scale solar down from the current level of 6.4 cents/kilowatt-hour to 3 cents/kWh by 2025 and to 2 cents/kWh by 2030. The pathway to cut costs to 2 cents/kWh by 2030 involves (1) a 1.0 cent cut in costs through module improvements, with efficiency rising to 25% from 19.5%, (2) a 0.7 cent cut in costs through lower balance of systems and soft costs, and (3) a 0.9 cent cut in costs through improvements in performance with lower operations and maintenance costs, reduced module degradation, and higher energy yield.[9]

The outlook for a steady decline in solar costs in coming years ensures that the solar industry will increase its cost advantage against its competitors, meaning its future will likely be even brighter.

What investments can be expected in the coming years?

Solar is set to become the "King of Electricity"
The International Energy Agency (IEA) in its recent flagship "World Energy Outlook" said that solar PV is becoming the "new king of electricity supply and looks set for massive expansion."[10]

In its World Energy Outlook, the IEA considers several different scenarios for forecasting future energy growth.

In the most conservative STEPS scenario, the IEA expects solar PV to set new records for deployment each year through 2030 and average annual growth of 12% per year through 2030.[11]

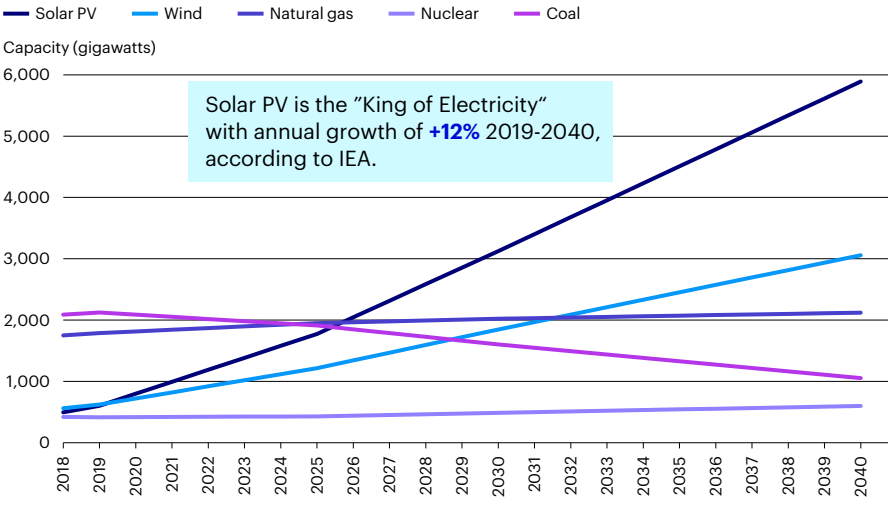
In its mid-range Sustainable Development Scenario, the IEA forecasts that cumulative solar PV capacity would grow by more than three times by 2030 to nearly 3,000 GW from about 800 GW in 2020, and grow by

Figure 6
IEA scenarios for forecasting future energy growth

IEA scenarios	Description	Solar PV capacity by 2030
"Stated Policies Secenario" (STEPS)	Forecast given current country policies and stated target ambitions	More than 2x
"Sustainable Development Scenario" (SDS)	Reverse engineers from shared long-term climate goals to examine "what actions would be necessary to achieve those goals"[12]	More than 3x
"Net Zero Emissions by 2050" case (NZE2050)	Path needed for achieving net-zero carbon emissions by 2050 and avoiding the worst effects of catastrophic climate change	More than 4x[13]

Source: International Energy Agency (IEA), World Energy Outlook 2020.

Figure 7
Global electricity generation capacity forecast to 2040
(IEA "Sustainable Development" scenario forecast)



Source: International Energy Agency (IEA), World Energy Outlook 2020 (Table A.3).

more than seven times to nearly 6,000 GW by 2040, as seen in the nearby graph. Solar in this scenario would show average annual growth of 12% through 2040. In this scenario, the IEA expects cumulative solar PV capacity to exceed coal and natural gas by 2026 and permanently take over the lead as the top electricity generation source.

In the most aggressive "Net Zero Emissions by 2050" case, the IEA sees annual solar PV growth of 20% per year through 2030.[14] The nearby graph shows how the IEA projects electricity capacity sources would change for the world to cut emissions to zero by 2050. In this scenario, fossil fuels have virtually no future, while solar comes out on top with a 43% share of electricity generation by 2050.

The dollar values associated with solar's growth potential are impressive. Bloomberg New Energy Finance (BNEF), in its Economic Transition Scenario, forecasts that solar PV will see an extraordinary USD 4.2 trillion worth of sales through 2050, accounting for 28% of total USD 15.1 trillion of spending on all new power capacity.[15]

Industry track record

The solar industry has already proven that it can sustain very rapid growth. In the five years through 2020, solar PV showed a 5-year compounded annual growth rate of 21%, according to data from Bloomberg New Energy Finance (BNEF). The global solar industry in 2020 installed 143 GW of new solar capacity, which was up by 21% from 2019 and was more than seven times the 18 GW of solar installed a decade ago in 2010, according to BNEF data.

The global solar industry installed a record amount of solar capacity in 2020 despite the obstacles presented by the global Covid pandemic. BNEF is forecasting that solar growth in 2021 will be even stronger at +29% to 185 GW. The solar industry in 2021 is expected to shake off short-term disruptions such as an increase in polysilicon prices, higher prices for steel support structures, and higher shipping costs. Those obstacles are likely to abate by 2022.

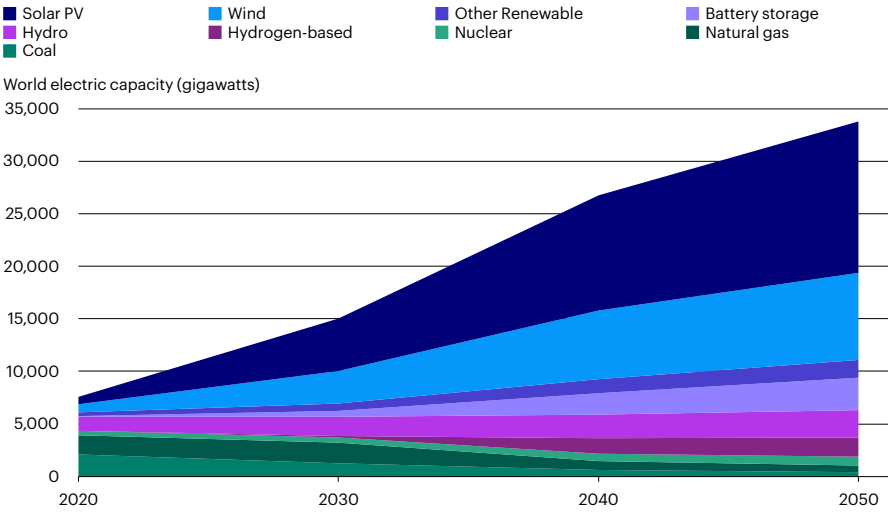
Geographical developments

China continues lead the use of solar energy, accounting for 36% of global solar installs in 2020. However, solar is progressively spreading across the world, and demand is becoming more diversified. In 2020, there were eighteen countries that installed more than 500 megawatts of solar, up from just ten countries as recently as 2017, according to BNEF data.

China's solar installs in 2020 rose sharply by 57% to 52 GW, resuming a strong growth rate after two years of declines in 2018 (-17%) and 2019 (-25%), according to BNEF data. Solar installs in 2018-19 fell when the Chinese government cut back on generous subsidies that had earlier produced a boom in solar installs and caused government subsidy costs to soar to unsustainable levels. The Chinese solar market is now in the latter stages of transitioning to a subsidy-free market, made possible by the sharp decline in solar costs in recent years. Solar installations are expected to remain very strong in China in the coming years given the heavy pressure to expand power capacity, reduce air pollution and meet international climate goals.

The U.S. in 2020 was the second-largest country for solar installs at 18.9 GW, up 64% from 2019, according to BNEF data. Solar growth in the U.S. was led by the utility sector, which saw very strong annual growth of +60% to 14 GW, accounting for about three-quarters of total U.S. solar installs, according to Wood Mackenzie.[16] Utilities are increasingly relying on large-scale solar facilities to produce electricity due to the low cost and the need to meet climate goals.

Figure 8
IEA's "Net Zero by 2050" case – electric capacity



Source: IEA "Net Zero by 2050 – A Roadmap for the Global Energy Sector," Table A.3: Electricity, p. 198.

Strong demand from corporations is also supporting utility-scale solar in the U.S., as companies seek to meet their climate pledges. Corporations can sign power purchase agreements (PPAs) with solar developers to buy electricity from large-scale solar power plants. S&P Global Market Intelligence reports that technology companies are leading the charge for solar PPAs such as Amazon, Facebook, and Google.[17] Other large companies signing solar PPAs include Apple, Microsoft, Walmart, McDonalds, AT&T, Home Depot, Honda, Verizon, PepsiCo, GM, Nucor, and many others. S&P reports that solar corporate PPAs will add over 18.5 GW of solar capacity just in the U.S. from 2020 through 2024.

Europe was the third largest region for solar installs in 2020. European solar installs in 2020 rose by 8.0% to about 17 GW, according to BNEF. Solar has started to grow rapidly again in Europe due to low costs and the attractiveness of subsidy-free solar projects.

In 2018, Europe ended its anti-dumping duties against solar modules imported from China and its associated minimum import price (MIP) scheme. The EU's MIP scheme, implemented in 2013, hurt solar sales by raising the price of solar to end-users and failed to meet its intended purpose of protecting European solar manufacturers from foreign competition. The end of the MIP scheme in 2018 resulted in much lower solar costs and a big jump in European solar demand.

India has impressive solar ambitions with a goal of installing 100 GW of cumulative solar capacity by 2022. However, India's solar installs in the past several years have been hamstrung by a variety of problems, including the high cost of solar panels due to tariffs on imported panels. In addition, some of India's electricity producers saw financial weakness in 2020 due to the pandemic and couldn't afford to invest in solar projects. India's solar installs in 2020 fell sharply by 64% to 4.2 GW, according to BNEF.

However, India's solar installs are expected to show a major recovery in 2021 and 2022 as delayed projects come online and as the government continues to push hard for more solar. Forecasts outline a installations surge of +183% to 11.97 GW, according to forecasts by BNEF.

In Asia, China is not the only country that is seeing strong solar growth. Solar installs in Japan in 2020 rose by 20% to 8.1 GW, according to BNEF. Japanese solar growth was strong as developers sought to meet project completion deadlines in 2020 and 2021 to qualify for the solar feed-in-tariff (FIT), which is progressively stepping down.

South Korea is another bright spot for solar in Asia. Solar installations in South Korea grew sharply by 70% in 2018 and 62% in 2019, before tailing off in 2020 to 5% growth to 3.8 GW, according to BNEF. Corporate demand for solar power is expected to grow sharply after South Korea's government in January 2021 revised its electricity laws to allow clean energy developers to sell electricity directly to corporations under power purchase agreements. In February, the South Korean government also raised its mandate to 25% from the former level of 10% of the amount of electricity that utilities must acquire from renewable sources by 2030.

Conclusion

Solar is set to become the "King of electricity" and the largest source of energy generation by 2032 (Source: Bloomberg new energy Finance). The push from major economies around the world, as well as Solar power's flexibility, speed of deployment and improving costs make it central to decarbonising economies.

Currently, investors looking for exposure to solar power opportunities have several choices:

- individual companies within the solar power industry or with exposure to solar energy,
- solar energy sector or thematic mutual funds,
- solar energy sector or thematic ETFs,
- renewable energy bonds offered by companies to finance the costs of solar energy production,
- install your own solar panels or create a solar energy project.

Notes

1 https://www.energy.gov/eere/solar/how-does-solar-work
2 National Renewable Energy Laboratory (NREL), "U.S. Solar Photovoltaic System and Energy Storage Cost Benchmark: Q1-2020, p. 4.
3 Bloomberg New Energy Finance, polysilicon price data series.
4 National Renewable Energy Laboratory (NREL), "U.S. Solar Photovoltaic System and Energy Storage Cost Benchmark: Q1-2020, p 45.
5 Bloomberg New Energy Finance, "Battery Pack Prices Cited Below USD 100/kWh for First Time in 2020," December 16, 2020.
6 S&P Global Market Intelligence, "Falling US solar-plus-storage prices start to level as batteries supersize," February 20, 2020.
7 Bloomberg New Energy Finance, "Batteries boom enables world to get half of electricity from wind and solar by 2050, June 19, 2018.
8 U.S. Department of Energy, "DOE announces goal to cut solar costs by more than half by 2030," March 25, 2021.
9 U.S. Department of Energy Solar Energy Technologies Office, "Solar Energy Technologies Office Updated 2030 Goals for Utility-Scale Photovoltaics."
10 International Energy Agency (2020), World Energy Outlook 2020, IEA, Paris, p. 214.
11 Ibid, p. 34.
12 Ibid, p. 60.
13 Ibid, p. 133.
14 Ibid, p. 133.
15 Bloomberg New Energy Finance, "New Energy Outlook 2020 – Executive Summary," October 2020, p. 12.
16 Solar Energy Industries Association (SEIA) and Wood Mackenzie, "U.S. Solar Market Insight Executive Summary, 2020 Year in Review," March 2021, p. 14.
17 S&P Global Market Intelligence, "2021 Corporate Renewables Outlook," April 2021, p. 2.

Risk warnings

The value of investments and any income will fluctuate (this may partly be the result of exchange rate fluctuations) and investors may not get back the full amount invested.

Important information