The Investment Case for Solar Energy

Executive Summary

As the renewable energy revolution enters an important inflection point this decade, the case for solar energy investing is more compelling than ever amid two potential catalysts: the commitment from many countries to promote a clean-energy future and the significant decline in renewable energy costs. Together, these factors may lead to increased adoption of solar and other clean energy sources.

On the policy side, governments of more than 100 countries have pledged to achieve net-zero carbon emissions by 2050 due to climate-change mitigation and economic considerations.[1] Affordable and clean energy technologies will have meaningful benefits for the world over the long term, according to the International Energy Agency (IEA). These benefits include improved energy security among countries through reliance on an indigenous, inexhaustible, and mostly import-independent resource, enhanced sustainability, reduced pollution, as well as lower costs of alleviating global warming and keeping fossil fuel prices lower.[2]

On the cost side, it is important to note that conventional energy from fossil fuels (i.e., coal, oil, and natural gas) has dominated the global power supply because until recently, electricity from fossil fuels, especially coal, was far cheaper than electricity from renewables (i.e., solar, wind, hydro, and geothermal heat). This has dramatically changed within the last decade. In most places across the globe, power from new renewable energy sources is now cheaper than power from new fossil fuels.[3]

In fact, solar energy is now the cheapest new source of global electricity in most developed countries. With solar less expensive today than fossil fuels, this may serve as a key driver of rapid wide-scale adoption.[4]

In the United States, there has been an ongoing trend away from conventional toward renewable energy. The U.S. Energy Information Administration (EIA) forecasts that the share of renewables in the U.S. electricity generation mix will increase from 21% in 2020 to 42% in 2050. Wind and solar are responsible for most of that growth. The renewable share is projected to increase as nuclear and coal-fired generation decrease and the natural gas-fired energy generation share remains relatively constant.[5]

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1 Sources: Bloomberg Energy & Climate Intelligence Unit; Wikipedia https://en.wikipedia.org/wiki/Renewable_energy; *Net-zero refers to new annual carbon emissions on a net basis.*
2 Source: Wikipedia, *Solar Energy* https://en.wikipedia.org/wiki/Solar_energy; Fossil fuels contain high percentages of carbon and include petroleum, coal and natural gas.
3 Source: Our World in Data, *Why did renewables become so cheap, so fast? And what can we do to use this global opportunity for green growth?* Max Roser, Dec. 1, 2020 https://ourworldindata.org/cheap-renewables-growth
4 Source: Bloomberg Energy & Climate Intelligence Unit; Net-zero refers to new annual CO2 emissions on a net basis.
5 Source: U.S. Energy Information Administration, *Annual Energy Outlook 2021,* Feb. 8, 2021
https://www.eia.gov/todayinenergy/detail.php?id=46676#:~:text=In%20its%20Annual%20Energy%20Outlook,for%20most%20of%20that%20growth.

According to the EIA, solar electric generation, which includes photovoltaic (PV) and thermal technologies, as well as both small-scale and utility-scale installations will surpass wind energy by 2040 as the largest source of renewable energy generation in the United States.[6]

For investors, the pivotal shift toward renewable energy this decade and the continued development of the technology to support it may present an appealing investment opportunity. Now may be a good time to invest in companies within the solar energy supply chain that provide solutions and enable the transition from fossil fuels to clean energy.[7]

Solar energy is now the cheapest new source of global electricity in most developed countries. With solar less expensive today than fossil fuels, this may serve as a key driver of rapid wide-scale adoption.

Solar Energy 101[8]

Solar energy is derived from the sun's radiant light and heat. It is an essential source of renewable energy. The sun bathes the earth with enough energy in one hour to satisfy the world's energy needs for an entire year.

Solar Energy Source: 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.

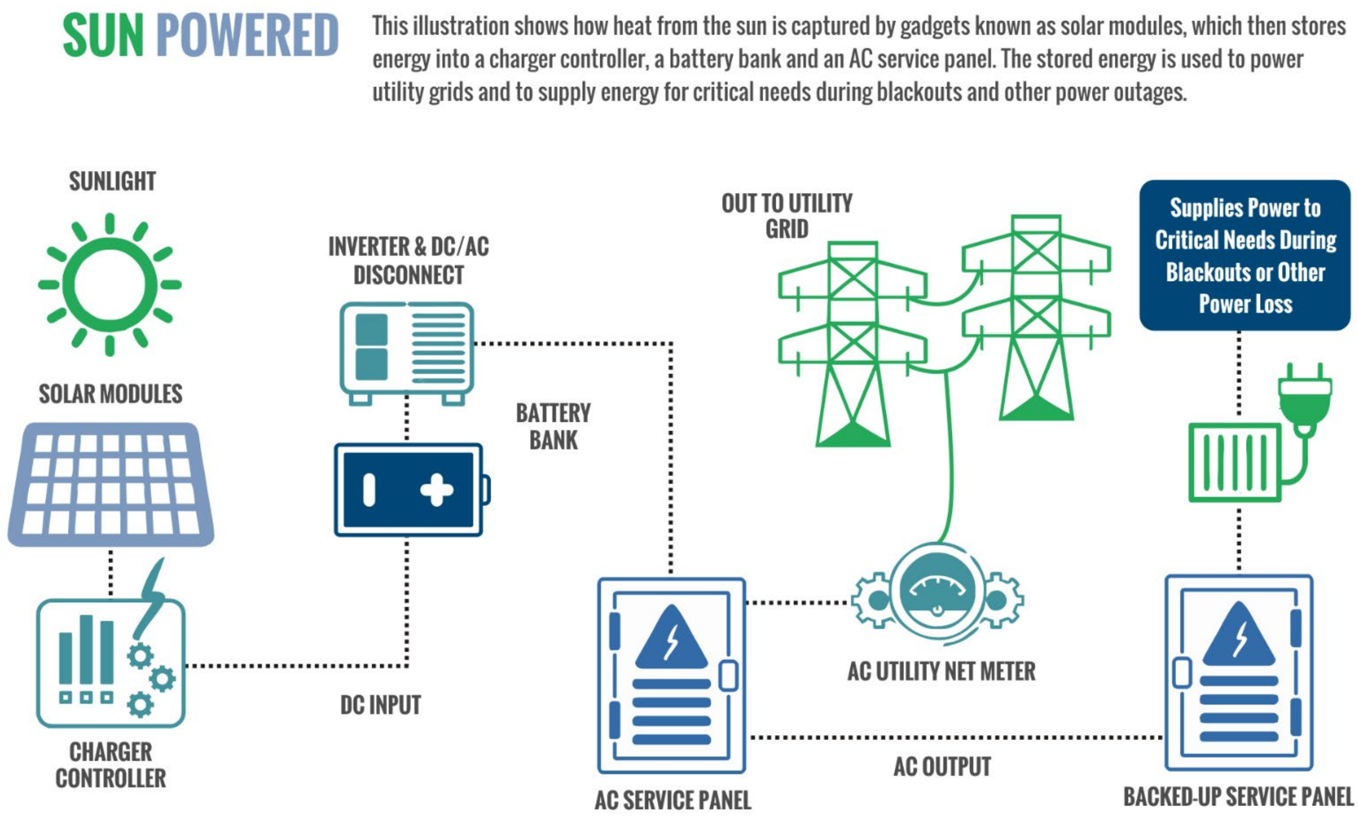
[6] Source: U.S. Energy Information Administration, *Annual Energy Outlook 2021,* Feb. 8, 2021 https://www.eia.gov/todayinenergy/detail.php?id=46676#:~:text=In%20its%20Annual%20Energy%20Outlook,for%20most%20of%20that%20growth
[7] Source: Kleinman Center for Energy Policy, *Have We Reached Peak Carbon Emissions?* Daniel Kammen, Feb. 22, 2021 https://kleinmanenergy.upenn.edu/research/publications/have-we-reached-peak-carbon-emissions/
[8] Sources: https://en.wikipedia.org/wiki/Solar_energy; https://www.energy.gov/eere/solar/how-does-solar-work

Harnessing Solar Power Through Technology[9]

There are two main types of solar energy technologies:

> ***Photovoltaics (PVs),*** which are used 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.
>
> ***Concentrated Solar-Thermal Power (CSP),*** which uses mirrors to reflect and concentrate sunlight onto receivers (such as solar modules, as seen in the chart below) that collect solar energy and convert it to heat. This heat can then be used to produce electricity or stored for later use following the process shown below. CSP is used primarily in large power plants.

Solar Energy Generation Process



Source: EQM Indexes; This illustration shows how heat from the sun is captured by gadgets known as solar modules, which then stores energy into a charger controller, a battery bank, and an AC service panel. The stored energy is used to power utility grids and to supply energy for critical needs during blackouts and other power outages.

[9] Source: https://en.wikipedia.org/wiki/Solar_power

Systems Integration

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.

Why Go Solar?

Solar energy can help 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, as well as operate at similar efficiency for small- to large-scale use.

Solar Energy Users

Solar energy systems come in all shapes and sizes. Residential systems are found on rooftops, such as those across the United States. Businesses are also opting to install solar panels. Furthermore, utilities are building large solar power plants to provide energy to all customers connected to the grid.

The Solar Energy Revolution: A Brief History[10]

Solar energy was used by humans as early as 7th century B.C., as they used sunlight to light fires with magnifying glass materials. In the 3rd century B.C., the Greeks and Romans were said to harness solar power with "burning mirrors" to light torches for religious ceremonies. Historians of Chinese civilization documented the use of mirrors for the same purpose later in 20 A.D.

In the late 1700s and 1800s, researchers and scientists used sunlight to power ovens for long voyages. They also used sunlight to produce solar-powered steamboats.

The technology to develop solar energy as we know today dates back to the 1860s. American inventor Charles Fritts, driven by expectations that coal would soon become scarce, installed the world's first rooftop PV solar array. He used 1%-efficient selenium cells, a photoelectric device used to generate or control an electric current, on a New York City roof in 1884.

The development of solar technologies stagnated in the early 20th century in the face of the increasing availability, economy, and utility of coal and petroleum.

However, the 1973 oil embargo and the 1979 energy crisis caused a reorganization of energy policies around the world, bringing renewed attention to developing solar technologies. Deployment strategies focused on incentive programs, such as the U.S. Federal Photovoltaic Utilization Program in the 1970s and Japan's Sunshine Program in the 1980s.

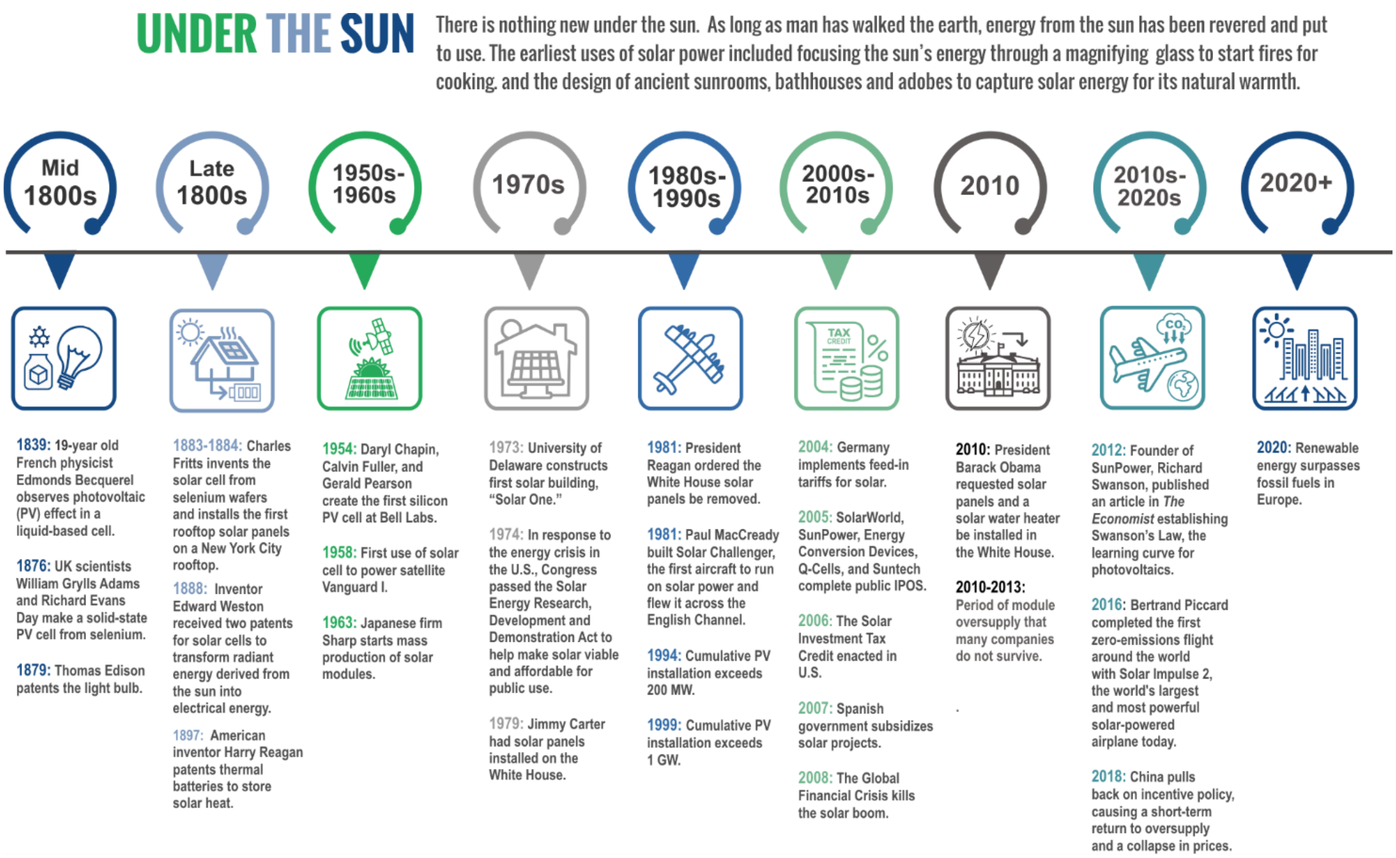
[10] Sources: Energysage.com https://news.energysage.com/the-history-and-invention-of-solar-panel-technology/, Wikipedia.com https://en.wikipedia.org/wiki/Solar_power

Other efforts included the formation of research facilities in the United States, Japan, and Germany. Between 1970 and 1983, installations of PV systems grew rapidly, but falling oil prices in the early 1980s moderated the growth of PVs from 1984 to 1996.

Mid-1990s to early 2010s

In the mid-1990s, development of both residential and commercial rooftop solar, as well as utility-scale PV power stations began to accelerate due to supply issues with oil and natural gas, global warming concerns, and the improving economic position of PV relative to other energy technologies. 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.

Moreover, in 2012, Tokelau (a New Zealand territory) became the first country to be powered entirely by PV cells, with a 1MegaWatt system using batteries for nighttime power.



Source: EQM Indexes

Current Status

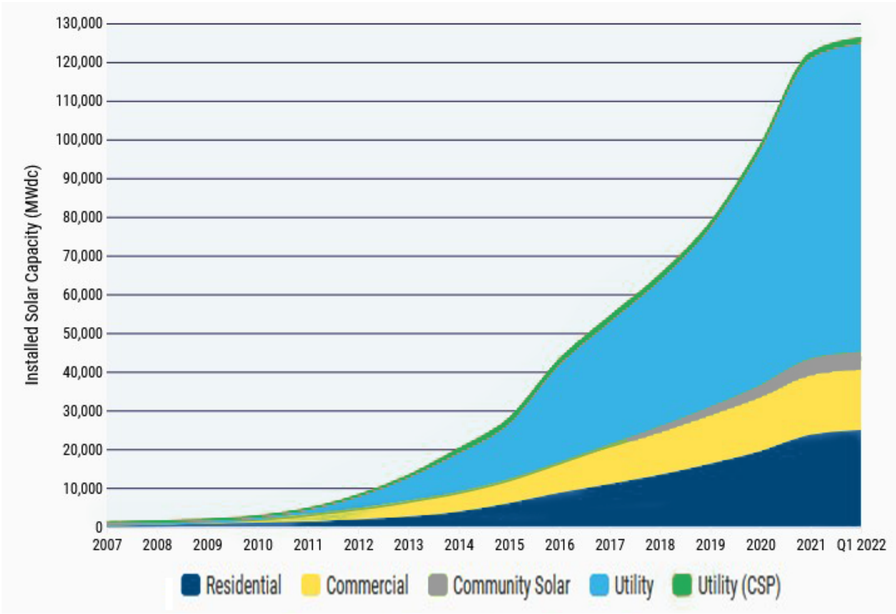
For several years, worldwide growth of solar PV was driven by European deployment, but has since shifted to Asia, especially China and Japan, and to a growing number of countries and regions all over the world, including Australia, Canada, Chile, India, Israel, Mexico, South Africa, South Korea, Thailand, and the United States.

From 2000 to 2013, worldwide PV growth has averaged 40% annually and total installed capacity reached 303 gigawatts (GW) at the end of 2016, with China having the most cumulative installations (78 GW) and Honduras having the highest theoretical percentage of annual electricity usage which could be generated by solar PV (12.5%). The largest PV manufacturers are located in China.

Concentrated solar power (CSP) also started to grow rapidly, increasing its capacity nearly tenfold from 2004 to 2013, albeit from a lower level and involving fewer countries than solar PV. As of the end of 2013, worldwide cumulative CSP capacity reached 3,425 megawatts (MW).

In the United States, solar energy has experienced an average annual growth rate of 33% over the last decade. Thanks to strong federal policies like the Solar Investment Tax Credit, rapidly declining costs, and increasing demand across the private and public sectors for clean electricity, there are now more than 121 GW of solar capacity installed nationwide, enough to power nearly 23 million homes.[11]

Cumulative U.S. Solar Installations

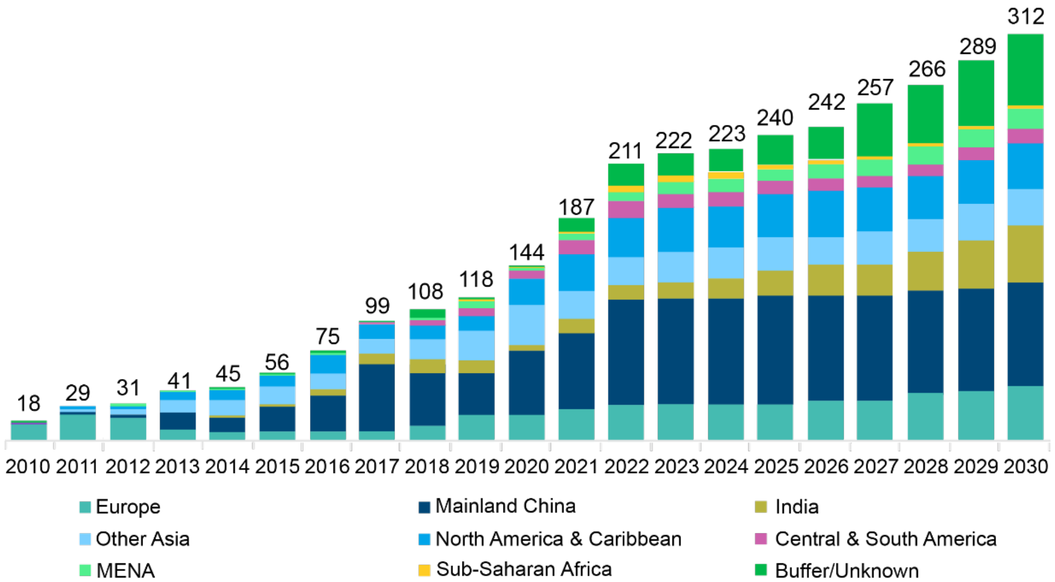


Sources: Solar Energy Industries Association and Wood Mackenzie Power & Renewables 2020; This illustration shows the cumulative solar installations in the United States (measured in Megawatts of direct current) from 2006 to 2020 for residential, non-residential, utility, and utility (CSP).

[11] Sources: Solar Energy Industries Association, Wood Mackenzie U.S. Solar Market Insight Q2 2022 https://www.seia.org/solar-industry-research-data

In 1956, solar panels cost roughly $300 per watt. By 1975, that figure dropped to just over $100 a watt. Today, a solar panel can cost as little as $0.34 a watt.[12]

Photovoltaic Annual Installation Forecast by Region



Source: PV Magazine, US 2021 solar panel shipments total $9.8 billion at $0.34/W, https://pv-magazine-usa.com/2022/08/01/us-2021-solar-panel-shipments-total-9-8-billion-at-0-34-w/

Costs continue to fall for PV, making it increasingly cost-competitive with oil, which has spiked in price following the Russian invasion of Ukraine. The cost of shipments of solar modules has fallen precipitously over 20 years, from $4.88/W in 2000 to $0.34/W in 2021, based on the Energy Information Administration's recent release of its module shipments report.

Investment Case for Solar Energy

Five Key Benefits of Solar Energy[13]

1. ***Sustainable Source of Green Energy*** – Sunlight offers a free, abundant source of zero-carbon producing energy, unlike fossil fuels, nuclear, coal, and natural gas.
2. ***Cost Effective*** – Solar energy costs continue to decline due to technological advances and economies of scale, creating cost-parity in many world regions.
3. ***Diverse Applications*** – Solar energy can be used to generate electricity (photovoltaics) or heat (solar thermal).
4. ***Scalable Solution*** – Installations can be large scale (utility) or small scale (residential and commercial buildings).
5. ***Battery Storage*** – Solar-plus-storage systems facilitate the source of electricity 24 hours a day/seven days a week to solve solar energy's intermittency issues.

[12] Ryan Kennedy, *US 2021 solar panel shipments total $9.8 billion at $0.34/W*, PV Magazine, August 1, 2022.

[13] Sources: Bloomberg NEF, 2020, 2 International Energy Agency, 2020; IEA World Energy Outlook; In the IEA's Stated Policies Scenario, based on policy setting as of March 2021 and a steady recovery of economic activity to pre-Covid levels in 2021, the world's CO_2 emissions rise to 36 Gt in 2030. In contrast, the IEA's Sustainable Development Scenario (SDS) maps a course to meet climate, clean air, and energy access goals in which emissions peak and decline to less than 27Gt by 2030.

Sunlight offers a free, abundant source of zero-carbon producing energy, unlike fossil fuels, nuclear, coal, and natural gas.

Solar Energy Growth[14]

Growing global demand for sustainable green energy solutions has created an investment opportunity for companies in the solar energy supply chain. Of all of technology's utopian visions of the future, a world of clean solar power may be one of the closest to realization. Solar is the fastest-growing source of new primary energy supply, which is expected to increase by 20-fold from 2019 through 2050, as shown in the chart below.

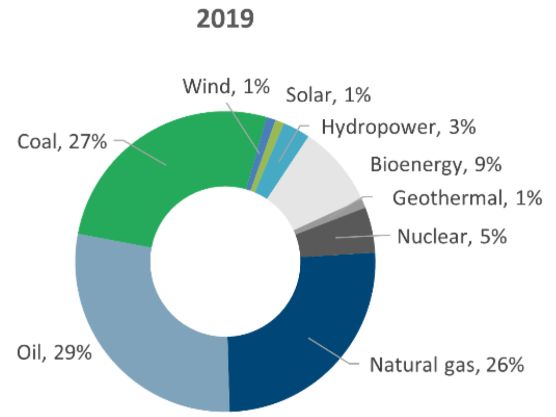
Solar Energy Capacity Forecast to Grow 800% from 2019 to 2050 Worldwide Electric Power Capacity Forecast Through 2050 (in Gigawatts)

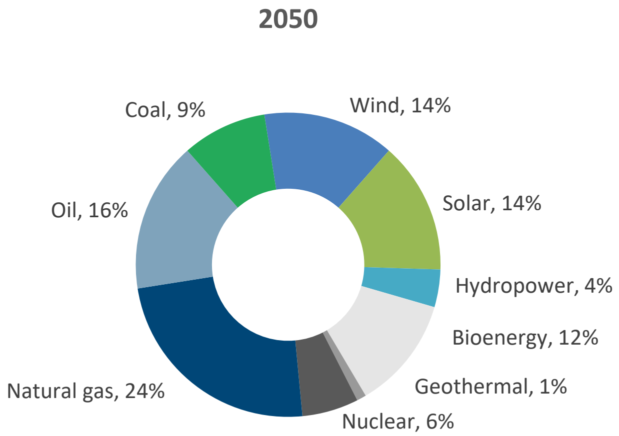
World primary energy supply by source

Units: EJ/yr

Source	2019	2030	2040	2050
Wind	5	20	42	81
Solar	4	25	54	85
Hydropower	15	22	25	26
Bioenergy	54	61	67	73
Geothermal	3	5	4	4
Nuclear	29	30	28	27
Natural gas	155	160	157	139
Oil	173	164	133	94
Coal	158	131	95	61
Total	**596**	**618**	**605**	**590**

Source: BloombergNEF, 2020





This illustration shows the forecast for capacity growth for all conventional and renewable energy sources worldwide, including coal, gas, oil, nuclear, hydroelectric, wind, solar, storage, and others. Clockwise from top of top pie chart shows 2019 worldwide electric power capacity growth forecasts for wind at 1%, solar at 1%, hydropower at 3%, bioenergy at 9%, geothermal at 1%, nuclear at 5%, natural gas at 26%, oil at 29%, and coal at 27%. Clockwise from top of bottom pie chart shows 2050 worldwide electric power capacity growth forecasts for wind at 14%, solar at 14%, hydropower at 4%, bioenergy at 12%, geothermal at 1%, nuclear at 6%, natural gas at 24%, oil at 16%, and coal at 9%.

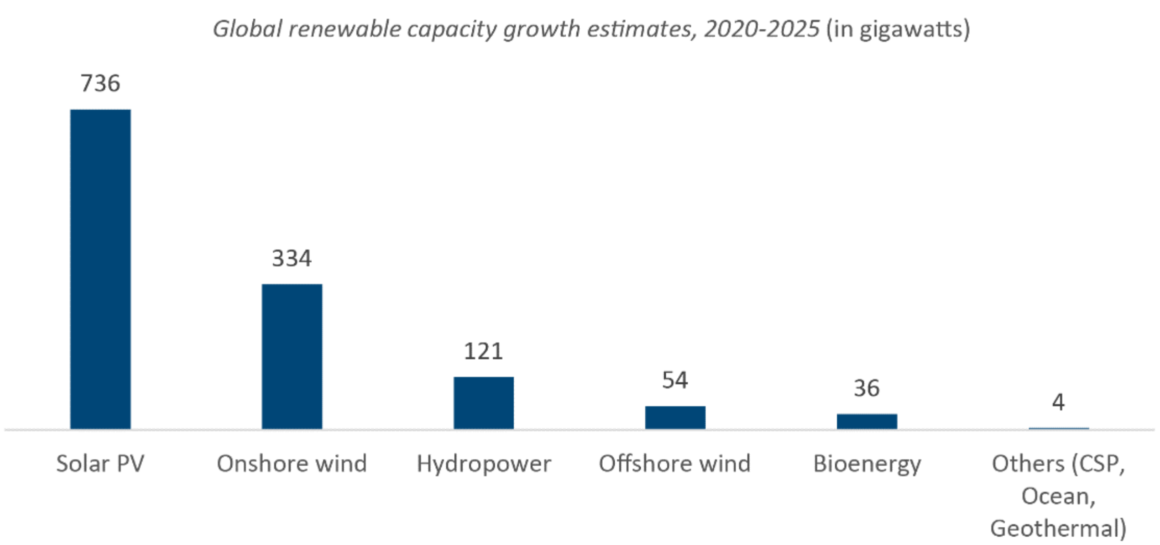
[14] Sources: DNV Energy Transition Outlook 2021. Historical data source: IEA Web (2020).

The International Energy Agency's pathway to Netzero calls for scaling up solar rapidly this decade, reaching annual additions of 630 GW of solar PV, four-times the record levels set in 2020. For solar PV, this is equivalent to installing the world's current largest solar park roughly every day.

Renewables are expected to lead the power generation mix, reaching 80-90% in 2050. Most of the growth in renewables is expected to come from solar and onshore wind, due to declining costs. In 2022, renewables are set to remain the leading power sector category for investment, after a record 2021 when more than $440 billion was spent for the first time ever. Despite numerous recent issues affecting the sector, such as supply chain and inflationary pressures and tighter financing conditions, there is a strong pipeline of projects due to more ambitious climate goals and strong policy support. Renewable capacity is expected to make up nearly 95% of the increase in global power capacity through 2026.

The world is in the middle of a power revolution – and the new governmental consensus that the world needs to transition to a lower-carbon economy will likely continue to fuel the trend. In addition, the technology behind solar continues to advance rapidly, and declining costs over the past decade have made previously unviable technical solutions practical. Even though costs have risen in recent months for the first time in a decade due to supply chain pressures and the higher cost of financing, solar energy remains the cheapest new source of electricity in most major countries, even before accounting for the exceptionally high prices seen in 2002 for coal and gas. As costs are expected to resume declines in the future, solar operations will undercut fossil-fuel-based power generation. Even with relatively lower oil prices over the last five years, solar has become extremely competitive on price, reaching an inflection point of affordability that is resulting in a drastic increase in solar use around the world.

The Sun is Shining Bright on Solar Energy Growth



Source: International Energy Agency, 2020
This illustration shows the estimated amount of renewable power capacity growth between 2020 and 2025 as measured in gigawatts (GW). One GW can power 300,000 homes. Solar PV is forecast to have the largest capacity growth of 736 GW, followed by Onshore Wind with 334 GW, Hydropower with 121 GW, Offshore Wind with 54 GW, Bioenergy with 36 GW and Other (CSP, Ocean, and Geothermal) with 4 GW.

Solar Is an Inexpensive Source of Clean Energy[15]

Solar power has cheapened at a blistering pace. Just 12 years ago, solar was the most expensive option for building a new energy development. Since then, the cost has dropped by 90%, according to data from the Levelized Cost of Energy report by Lazard. Utility-scale solar arrays are now the least costly power option to build and operate.

Source: Lazard 2021."Levelized Cost of Energy Analysis – Version 15.0". This illustration shows the selected historical mean of unsubsidized levelized cost of energy values, in US dollars. From the left axis, the yellow line shows the cost of solar was $359/Megawatt hour (MWh) in 2009, dropping to $36/MWh in 2021; the cost of gas peak was $275/MWh in 2009, dropping to $173 in 2021; the cost of solar thermal tower was $168/MWh in 2009, falling to $141/MWh in 2021; the cost of wind was 135/MWh in 2009, falling to $38/MWh in 2021; the cost of nuclear was $123/MWh in 2009, increasing to $167/MWh in 2021; the cost of coal was $111/MWh in 2009, falling to $108/MWh in 2021; the cost of gas combined cycle was $83/MWh in 2009, falling to $60/MWh in 2021; and the cost of geothermal was $76/MWh in 2009, rising to $75/MWh in 2021.

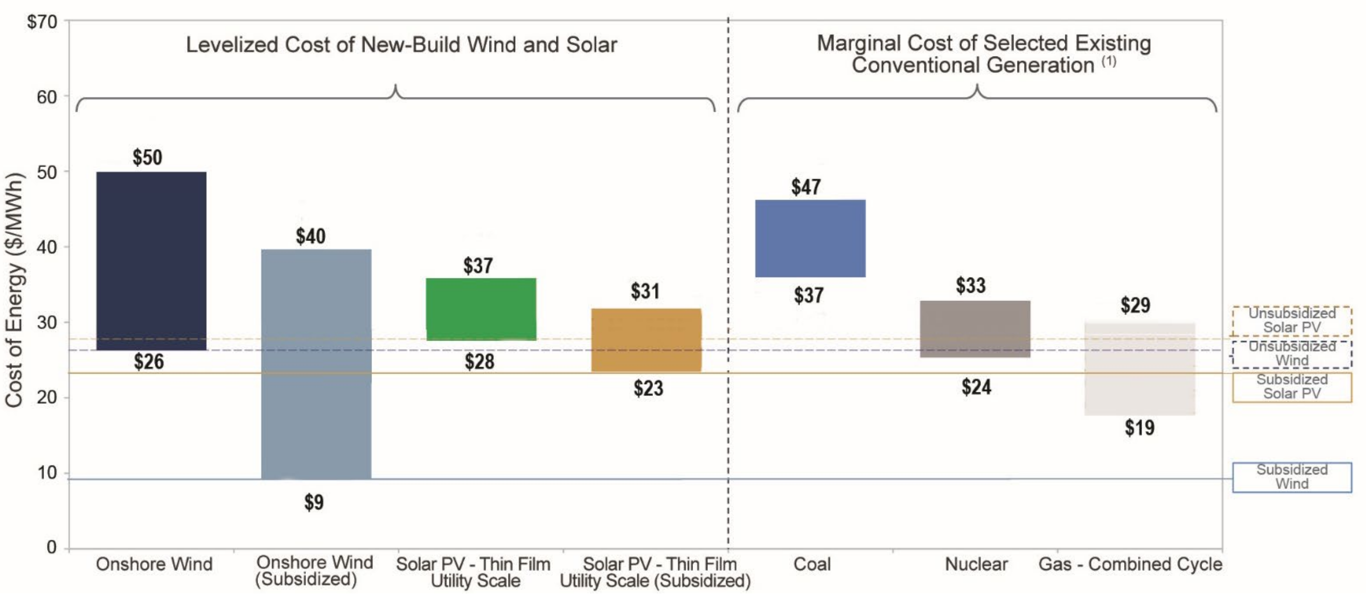
As shown in the chart below, even certain unsubsidized new-build renewable energy generation technologies are approaching a levelized cost of energy (LCOE) that is competitive with the marginal cost of existing conventional generation. LCOE is a measure of a power source that allows comparison of different methods of electricity generation on a consistent basis.

Unsubsidized new-build utility-scale solar ranges from $28-37 per Megawatt hour (MWh). This is competitive with the marginal costs to run existing coal or nuclear power plants at $37-47/MWh and $24-33/MWh, respectively. Declining solar energy prices have been made possible by both research and development, as well as the economic "learning curve" concept, which means that as more of a technology is deployed, it becomes cheaper and more efficient.

[15] Source: Lazard 2021. Represents the marginal cost of operating coal and nuclear facilities, inclusive of decommissioning costs for nuclear facilities. The subsidized analysis includes sensitivities related to the TCJA and U.S. federal tax subsidies.

Clean Energy Is Competitively Priced vs Dirty Energy

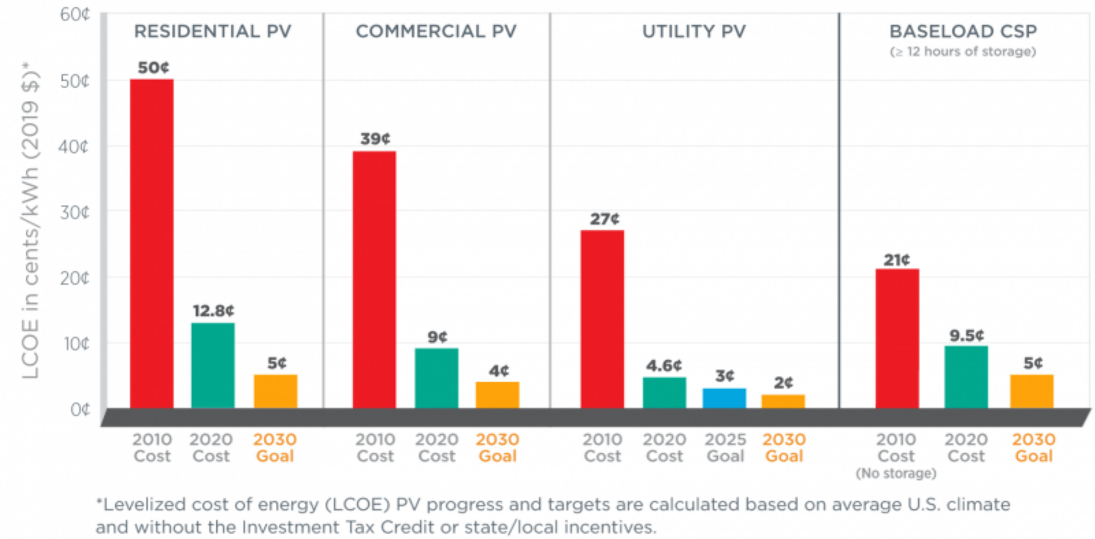
Levelized Cost of Energy Comparison: Renewable Energy vs Marginal Cost of Selected Existing Conventional Energy



Source: Lazard Asset Management, estimates as of October 2021
This illustration shows renewable energy prices are comparable to conventional energy costs, especially the prices for Onshore Wind Subsidized, Solar PV-Thin Film Utility Scale, and Solar PV-Thin Film Utility Scale Subsidized.

The Falling Cost of Solar Energy: A Potential Catalyst for Increased Adoption

Solar Energy Technologies Office and Goals
Photovoltaics (PV) and Concentrating Solar Thermal Power (CSP)



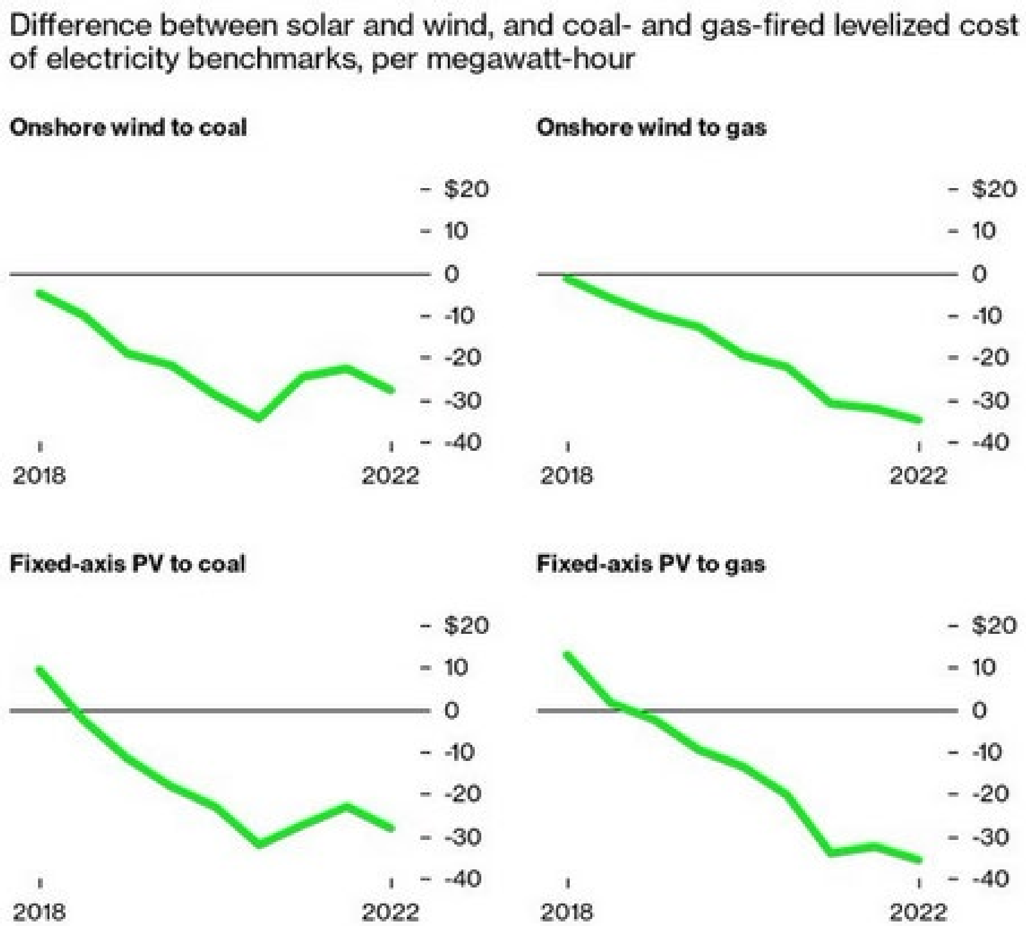
Source: U.S. Department of Energy. This illustration shows the drop in U.S. utility-scale solar power cost per kilowatt-hour (kWh) since 2010 and cost forecasts through 2030. The cost of utility PV solar power in 2010 was $0.27/kWh, falling to 0.046/kWh in 2020. The U.S. Department of Energy forecasts solar energy costs will further drop to $0.03/kWh in 2025 and to $0.02/kWh in 2030.

The U.S. Department of Energy has set a goal of reducing the cost of utility-scale solar power to 2 cents per kilowatt hour by 2030. This follows the 2011 SunShot Initiative, which set a goal for 2020 and reached it three years early. Figures in the chart above show the LCOE, which takes into account costs of construction and operation.

This reduction in cost, together with solar policy incentives, has led to rapid growth in solar PV generation capacity, from providing less than 0.1% of the U.S. electricity supply in 2011 to over 3% in 2020. This upward trend is expected to continue. To fully decarbonize power generation by 2035, solar power may need to supply more than 40% of U.S. electricity.[16]

As seen in the charts below, while renewable costs have risen over the past year, coal and gas prices have risen significantly more. This has caused the renewable discount to gas/coal power to widen, not shrink based on a levelized cost of energy comparison. Renewables' discount to gas is now the biggest ever.

Renewables Price Below Fossils



Source: BloombergNEF
Note: Levelized cost is the average net present cost of electricity for a solar power projected over its entire lifetime.

[16] Source: Solar Energy Technologies Office, Solar Futures Study (2021).

Furthermore, the results of competitive procurement of renewables through auctions or power purchase agreements (PPA) confirm the competitiveness of renewables. Data from the IRENA Renewable Auction and PPA Database indicate that utility-scale solar PV projects that have won recent competitive procurement processes in 2021 – and that will be commissioned in 2022 – could have an average price of USD 0.04/kWh (Figure S.3). This is a 30% reduction compared to the global weighted-average LCOE of solar PV in 2020 and is around 27% less (USD 0.015/kWh) than the cheapest fossil-fuel competitor, namely coal-fired plants.[17]

Declining Solar-Module Prices[18]

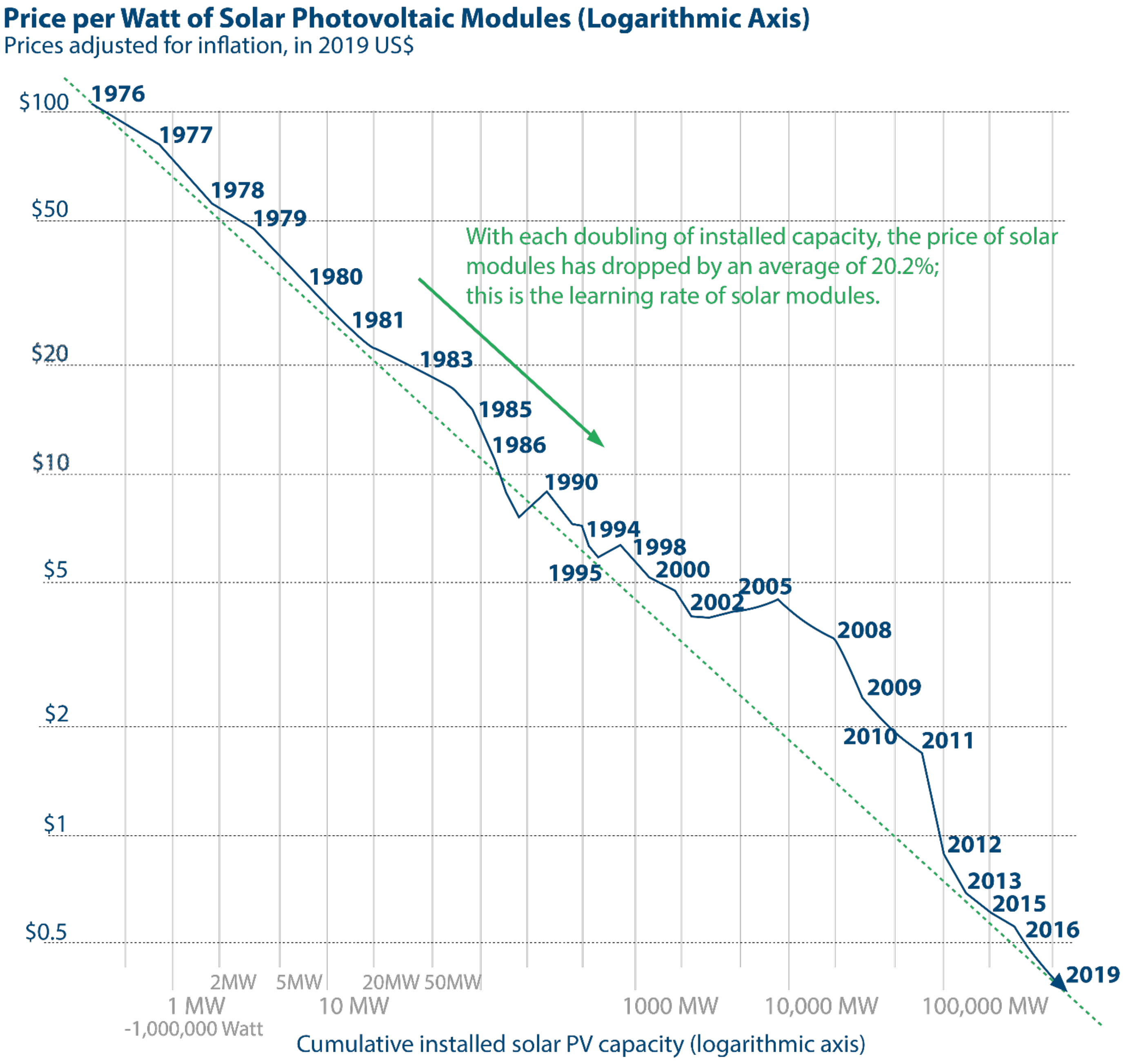
The technological cost of solar modules, a key material used to generate solar power, has rapidly declined, as shown in the chart below. This is an important reason for lower solar energy prices.

Solar module prices typically decline as more of them are produced. For more than four decades, each doubling of global cumulative solar capacity has been associated with a 20.2% decline in solar module prices, as shown in the chart below. The price of solar modules declined from $106 in 1976 to $0.38 per watt in 2019, a decline of 99.6%.

Unlike fossil fuels, there is no raw "input" fuel cost associated with solar energy. A solar plant's cost is determined by the cost of the technology alone.

[17] IRENA. "Renewable Power Generation Costs in 2020", 2021.
[18] Source: https://ourworldindata.org/cheap-renewables-growth

Solar Modules: 99% Price Decline

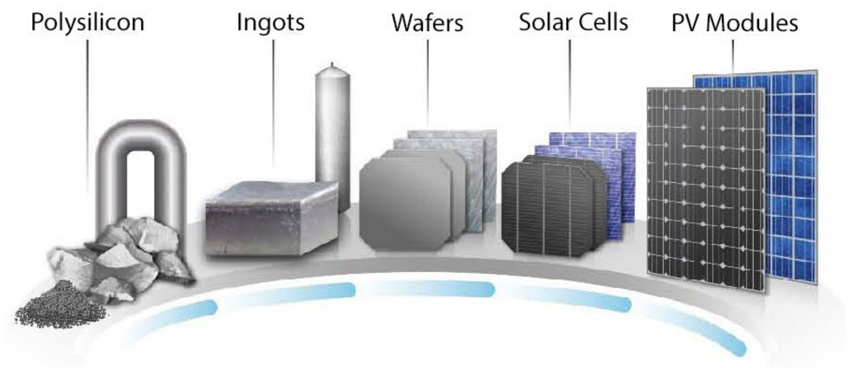


Sources: OurWorldinData.org; Lafond et al. (2017) and IRENA Database; the reported learning rate is an average over several studies reported by de La tour et al. (2013) in Energy. The rate has remained very similar since then.

This chart shows the price of solar modules declined from $106/Watt in 1976 to $0.38/Watt in 2019, a decline of 99.6%. With each doubling of global cumulative solar capacity has been associated with a 20.2% decline in solar module prices.

Solar Energy Supply Chain[19]

There are several components involved with solar energy development, starting from the manufacturing of equipment and module production, all the way to installation and operation. The chart below shows these components and their definitions.[20]



Source: National Renewable Energy Laboratory and Wikipedia.com. This illustration shows the components of solar energy generation.

1. Polysilicon

Polycrystalline silicon, or multicrystalline silicon, also called polysilicon or poly-Si, is a high purity, polycrystalline form of silicon, used as a raw material by the solar photovoltaic and electronics industry. Polysilicon is produced from metallurgical grade silicon by a chemical purification process, which is called the Siemens process, involving the distillation of volatile silicon compounds and their decomposition into silicon at high temperatures. An emerging, alternative process of refinement uses a fluidized bed reactor.

2. Ingots

An ingot is a piece of relatively pure material, usually metal, which is cast into a shape suitable for further processing. In steelmaking, it is the first step among semi-finished casting products. Ingots usually require a second procedure of shaping, such as cold/hot working, cutting, or milling to produce a useful final product.

3. Wafers

In electronics, a wafer is a thin slice of semiconductor, such as a crystalline silicon used for the fabrication of integrated circuits. In photovoltaics, it is used to manufacture solar cells. The wafer serves as the substrate for microelectronic devices built in and upon the wafer. It undergoes many microfabrication processes, such as doping, ion implantation, etching, thin-film deposition of various materials and photolithographic patterning. Finally, the individual microcircuits are separated by wafer dicing and packaged as an integrated circuit.

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[19] Source: Wikipedia.com
[20] Sources: Green Rhino Energy, "The Solar Value Chain: Value Chain Segments & Activities" http://www.greenrhinoenergy.com/solar/industry/ind_valuechain.php; For definitions: Wikipedia.com

4. *Solar Cells*

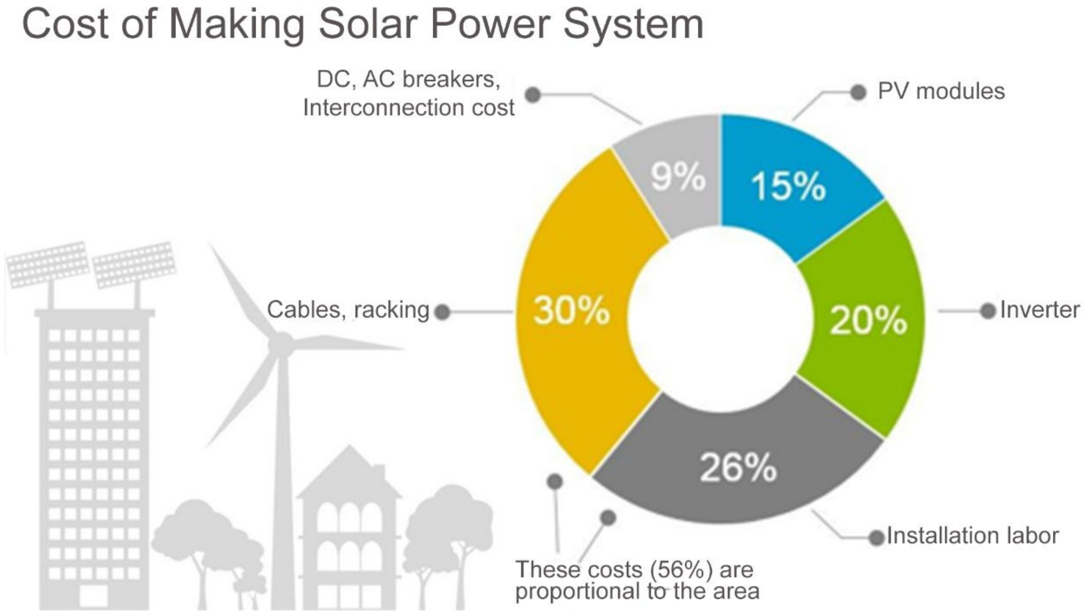
A solar cell or photovoltaic cell is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect, which is a physical and chemical phenomenon. It is a form of photoelectric cell, defined as a device whose electrical characteristics, such as current, voltage or resistance, vary when exposed to light. Individual solar cell devices are often the electrical building blocks of PV modules or solar panels. The common single junction silicon solar cell can produce a maximum open-circuit voltage of approximately 0.5 to 0.6 volts.

5. *PV Modules/Solar Panels*

A PV module or solar panel is an assembly of photovoltaic cells mounted in a framework for installation. Solar panels use sunlight as a source of energy and generate direct current electricity.

Components of Building a Solar Power System

More than half of the cost of building a solar power system goes into installing cables, racking, and labor. Other cost components include building an inverter, PV modules, DC and AC breakers, as well as interconnection.



Source: National Renewable Energy Laboratory. The illustration shows the cost of building a solar power system. Cables and racking make up 30% of the cost, 26% goes into installation labor, 20% goes into building an inverter, 15% into PV modules, and 9% goes into installing DC and AC breakers/interconnection.

- ***Direct Current (DC) and Alternating Current (AC) Circuit Breakers*** – The function of a breaker is to detect when too much current (amps) is flowing through the circuit, then disconnect the circuit from the main power source to protect the wiring from overheating. During the act of disconnecting, the internal contacts separate. As they pull apart from each other, an arc will form as the current jumps across the air gap. (You may have experienced this on a smaller scale with a static electric shock.) If this arc continues to jump the air gap, the current will continue to flow through the circuit, defeating the purpose of the breaker. This arc must be extinguished. The AC and DC breakers extinguish this arc differently. This design difference is why AC and DC breakers are not interchangeable.[21]

- ***Cables*** – Aluminum and copper cables are the two common conductor materials used in residential and commercial solar installations. Copper has a greater conductivity than aluminum, thus it carries more current than aluminum at the same size.[22]

- ***Racking*** – Racking is used to safely fix solar panels to various surfaces such as roofs, building facades, or the ground. The system is designed to be easily retrofitted to existing rooftops and structures.[23]

- ***PV Modules*** – PV Modules are an assembly of photovoltaic cells mounted in a framework for installation.

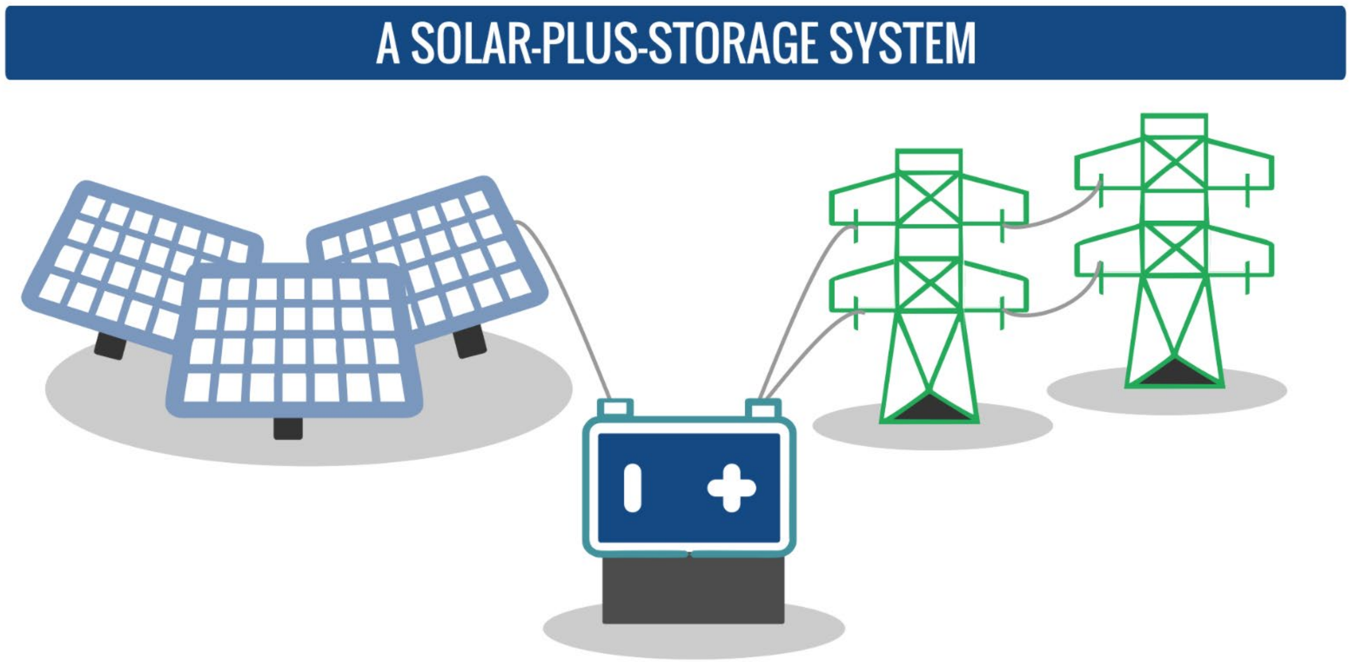
- ***Inverter*** – An inverter is one of the most important pieces of equipment in a solar energy system. It's a device that converts DC electricity, which is what a solar panel generates, to AC electricity, which the electrical grid uses.[24]

[21] Source: blog.GoGreenSolar.com https://blog.gogreensolar.com/2015/02/ac-vs-dc-breakers.html
[22] Source: CED Greentech https://www.cedgreentech.com/article/solar-wire-types-solar-pv-installations#:~:text=Aluminum%20or%20Copper%3A%20The%20two,aluminum%20at%20the%20same%20size.&text=Aluminum%20or%20Copper%3A%20The%20two,aluminum%20at%20the%20same%20size.
[23] Source: https://www.sunrun.com/go-solar-center/solar-terms/definition/solar-racking-system#:~:text=Also%20called%20photovoltaic%20mounting%20systems,to%20existing%20rooftops%20and%20structures.
[24] Source: Office of Energy Efficiency & Renewable Energy https://www.energy.gov/eere/solar/solar-integration-inverters-and-grid-services-basics#:~:text=What%20are%20Inverters%3F,which%20the%20electrical%20grid%20uses

Solar Battery Storage[25]

Solar panels collect sunlight and transform it into electricity. But they can make that energy only when the sun is shining. That's why the ability to store solar energy for later use is important. It helps to keep the balance between electricity generation and demand. Lithium-ion batteries are one way to store this energy.

A lithium-ion battery is a type of rechargeable battery commonly used for portable electronics and electric vehicles. In the batteries, lithium ions move from the negative electrode through an electrolyte to the positive electrode during discharge, and back when charging.



Source: Office of Energy Efficiency & Renewable Energy https://www.energy.gov/eere/solar/articles/solar-plus-storage-101. This illustration shows the solar-plus-storage system, which is charged by a connected solar system, such as a photovoltaic system.

Many solar-energy system owners are looking at ways to connect their system to a battery so they can use that energy at night or during a power outage. Simply put, a solar-plus-storage system is a battery system that is charged by a connected solar system, such as photovoltaic.

[25] Sources: Office of Energy Efficiency & Renewable Energy https://www.energy.gov/eere/solar/articles/solar-plus-storage-101; Wikipedia.com https://en.wikipedia.org/wiki/Lithium-ion_battery

Clean Energy Goes Global[26]

Many countries are expected to invest in clean energy in the coming decades to help meet their net-zero carbon emission goals.[27]

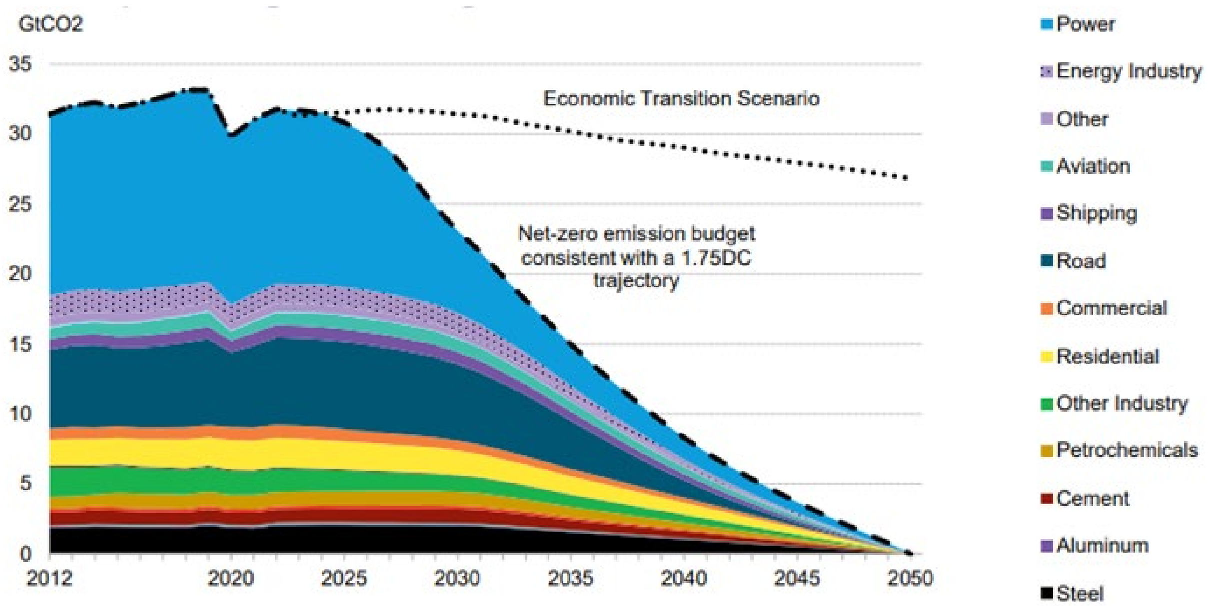
- Globally, over $15 trillion is expected to be invested in new power capacity (an average of $486 billion per year) between 2020-2050.
- Solar is expected to account for 28% of all renewable energy investment globally. Over $4 trillion ($135 billion per year on average) will be invested in solar.

As over 100 countries strive to meet their net-zero carbon emission targets by 2050, many will prioritize converting or substituting dirty-energy powered utilities for clean-energy alternatives.

For example, U.S. President Joseph Biden has set a goal of zero emissions from electric utilities by 2035 and a broader goal of net-zero greenhouse gas emissions by 2050.

Nearly 50% of all global carbon emissions come from utilities (see chart below), while the rest come from sectors like transportation and industries where technologies may be slower to evolve from dirty energy to clean energy (i.e., airlines still need to fly on jet fuel, not electric vehicle technology).

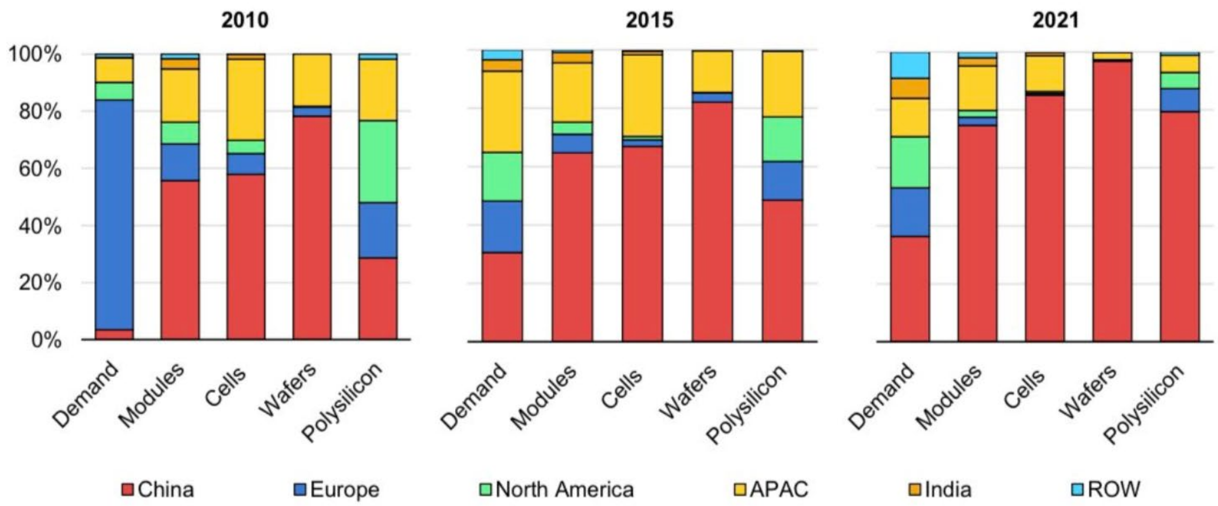
Global Carbon Budget by Sector to Meet Zero Emissions in 2050 and Keep Warming to ~1.75 Degrees C



Source: BNEF: New Energy Outook 2021, "Roads to Carbon Neutrality"

26 Sources: BloombergNEF and Morgan Stanley Research
27 Sources: BloombergNEF and Morgan Stanley Research; Includes investments in generation and storage capacity.

Solar PV manufacturing capacity by country and region, 2010-2021



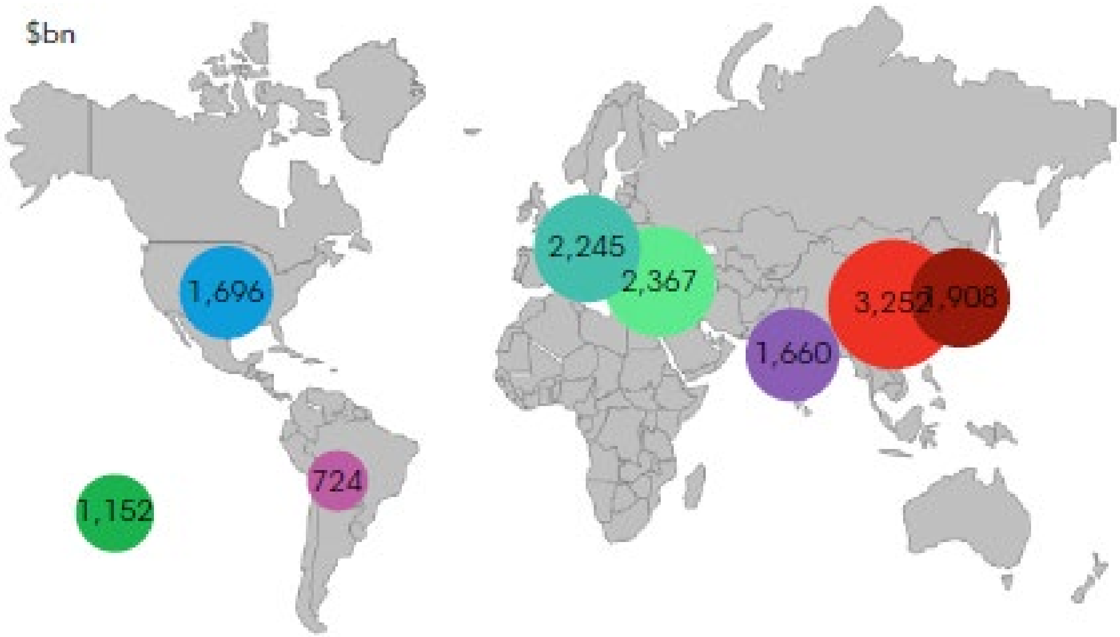
Notes: APAC = Asia-Pacific region excluding India. ROW = rest of world

Source: IEA, All right reserved

As over 100 countries strive to meet their net-zero carbon emission targets by 2050, many will prioritize converting or substituting dirty-energy powered utilities for clean-energy alternatives.

However, there are expectations that worldwide electric utility power capacity will almost triple between 2019-2050 as more and more technologies adopt clean electric energy solutions and technologies.

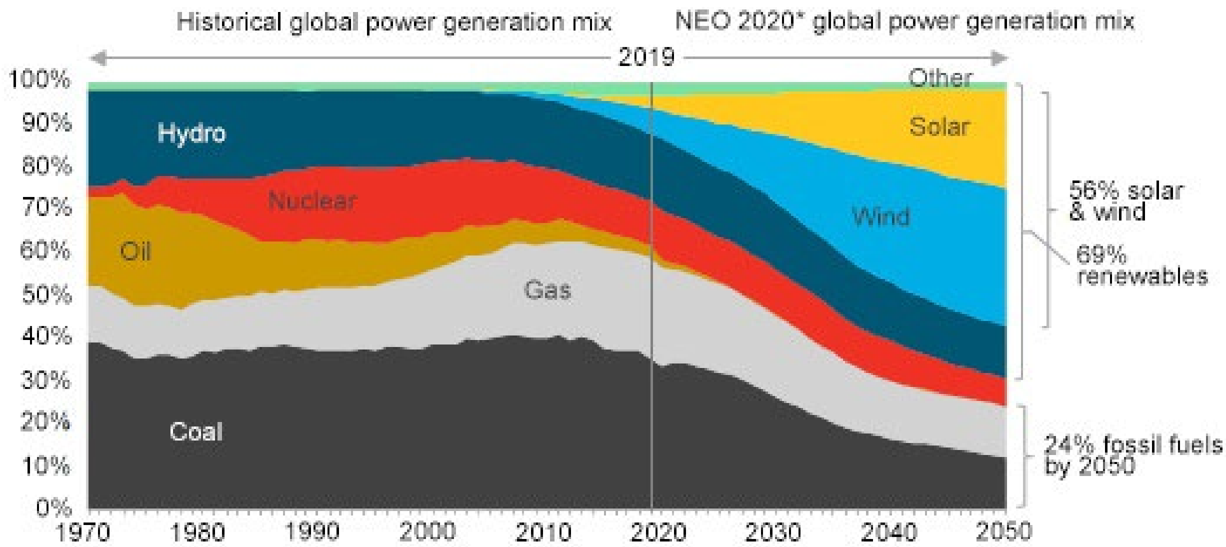
Investment in New Power Capacity in Billions by Region, 2020-2050



Sources: BloombergNEF; OurWorldinData.com https://ourworldindata.org/world-region-map-definitions; Includes investments in generation and storage capacity, 2020. This illustration shows the forecast for investments in power capacity by global regions in U.S. dollars ($ billions).

As the total installed capacity of electric power rapidly grows, solar and other renewable energy sources will also increase their share of the global electricity generation mix from now through 2050, as shown in the chart below.

Global Electricity Generation Mix



*Source: Bloomberg NEF and International Energy Agency, *New Energy Outlook 2020. This illustration shows that the global share of renewable energy is expected to increase to 69% by 2050, with solar and wind energy accounting for 56% of that figure. The share of fossil fuels is expected to decrease by 24% by 2050.*

Investing in the HAN Solar Energy UCITS ETF

The HAN Solar Energy UCITS ETF is Europe's first Solar Energy ETF. It offers pure-play exposure to the global megatrend away from fossil fuels ("dirty energy") to solar ("clean energy"). The UCITS ETF is designed to provide investors with diversified, rule-based exposure to the global solar industry in a single investment vehicle.

In order to be eligible for inclusion in the index underlying the UCITS ETF, companies must derive at least 5% of their revenue from solar-related business operations. Some of the business segments included in the index are:

- Manufacturing of photovoltaic, solar cells and systems
- Producers of solar power generation, equipment, and components
- Providers of solar power system installation, development and/or financing
- Manufacturing of solar-powered charging and energy storage systems

Eligibility also requires that a company be listed on a regulated stock exchange, excluding U.S. over-the-counter listed companies. Companies must have a minimum market capitalization of $250 million USD and an average daily traded value of $2 million USD over the last six-month period.

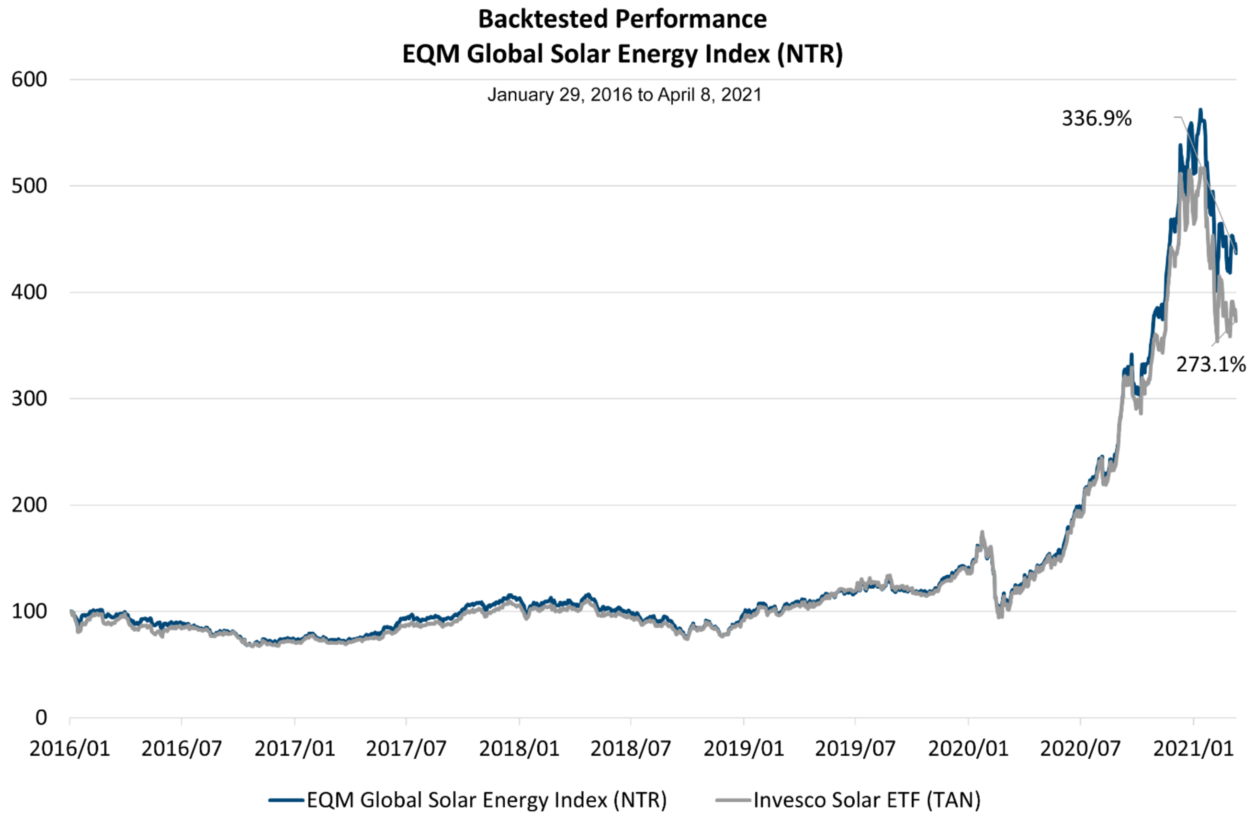
China-headquartered companies will be included only if exchange traded ADR versions or Hong Kong exchange traded versions are available.

Companies with more than 60% of their revenues from solar-related business are categorized as CORE constituents and receive a weight multiplier of 1.0. Companies deriving between 5% and 60% of their revenue from solar operations are considered NON-CORE and receive a multiplier of 0.5. The index components are then equally weighted within the two component groups.

Consistent with the green energy exposure goals of the fund, holdings are also screened for compliance with the United Nations Global Compact principles and for business involvement in the fields of oil sands, fossil fuel, and/or controversial weapons.

The index is rebalanced quarterly in January, April, July, and October.

The investment approach was backtested from January 29, 2016 to April 8, 2021 with the cumulative results for the EQM Global Solar Energy Index (SOLARNTR) on a net total return basis appearing in the chart below relative to the Invesco Solar ETF (TAN). Returns are quoted in USD.



Values between January 29, 2016 and April 8, 2021 have been calculated pursuant to a backtested methodology. The inception date for the EQM Global Solar Energy Index (SOLARNTR) was April 14, 2021. Backtested performance is hypothetical and is provided only for informational purposes to indicate historical performance had the index been available over the relevant time period. Investors have requested this information from the index provider as a means to follow the index's hypothetical performance on a year-to-date basis. The Invesco Solar ETF ("TAN") is a passive ETF that tracks the MAC Global Solar Energy Stock Index. Index returns reflect the reinvestment of income dividends and capital gains, if any, but do not reflect fees, brokerage commissions, or other expenses of investing. Investors may not make direct investments into any index.

Key Takeaways

Several catalysts are expected to drive demand for solar energy in the foreseeable future. Now may be a good time for investors to invest in companies within the solar-energy supply chain through ETFs.

- ***Global solar energy growth is at an important inflection point –*** The two key drivers of growth are: 1) The commitment from many countries to promote a clean-energy future; and 2) the falling cost of renewable energy. Solar capacity is forecasted to grow faster than any other energy source from 2020 to 2050 as clean energy increasingly replaces dirty energy.

- ***Solar is now the cheapest new source of global electricity in most major countries*** – Solar is less expensive than fossil fuels, and solar energy's lower cost may pave the way for wide-scale rapid adoption.

- ***There have been global policy pledges by more than 100 countries to get to net-zero carbon emissions by 2050.***

- ***Global solar energy provides a sustainable, carbon-neutral, and cost-effective source of power.***

- ***Growing global demand for sustainable green energy solutions has created investment opportunities for companies throughout the solar energy supply chain*** – The transition to clean energy is seen as net-jobs positive.

- ***The pivotal shift toward renewable energy and the continued development of the technology to support it may present an appealing opportunity*** – Investors may consider investing in companies within the solar energy supply chain, particularly those providing solutions and enabling the transition to clean energy from dirty energy."[28]

[28] Source: Kleinman Center for Energy Policy, "Have We Reached Peak Carbon Emissions?" Daniel Kammen, Feb. 22, 2021 https://kleinmanenergy.upenn.edu/research/publications/have-we-reached-peak-carbon-emissions/

EQM INDEXES

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Definitions[29]

Fossil Fuel – Formed by natural processes, such as decomposition of buried dead organisms containing organic molecules that release energy in combustion. Fossil fuels contain high percentages of carbon and include petroleum, coal and natural gas.

Gigawatt – A unit of electric power equal to one billion watts.

Levelized Cost of Energy (LCOE) – A measure of a power source that allows comparison of different methods of electricity generation on a consistent basis.

Megawatt-hour (MWh) – The unit used to describe the amount of energy a battery can store.

Renewable Energy – Collected from renewable resources, which are naturally replenished on a human timescale, including carbon-neutral sources such as sunlight, wind, rain, tides, waves, and geothermal heat.

Watt – A unit of power used to quantify the rate of energy transfer.