

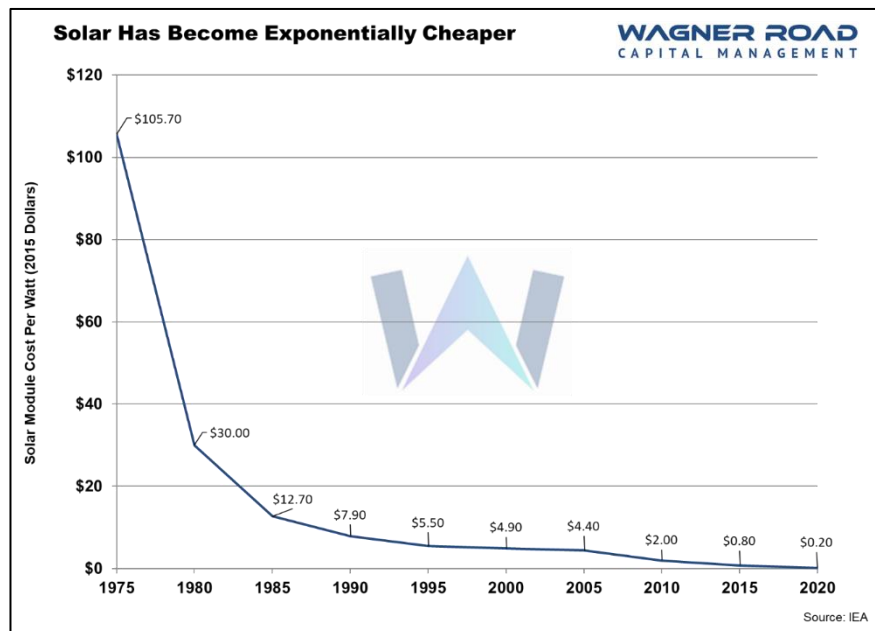
A Survey of Solar Energy

April 3, 2024

It is probably a cliché, but solar energy is the original source of almost all of the world's energy. Food, and even oil, could not happen without the sun's influence. Capturing this power directly from the source and converting it into something useful is a miracle of technology.¹ It is also a business—a historically bad business. It took decades for solar technology to achieve the efficiency necessary to be comparable with oil, gas, or coal.

Inside the industry, the solar business has a long history of financial disasters with poor management. But this can be true for any industry that moves quickly. Solar technology is always getting better and cheaper, and the company with the best solar cells or the cheapest production is not always the best company—there is always a better one coming soon, and the early winners won't last long.

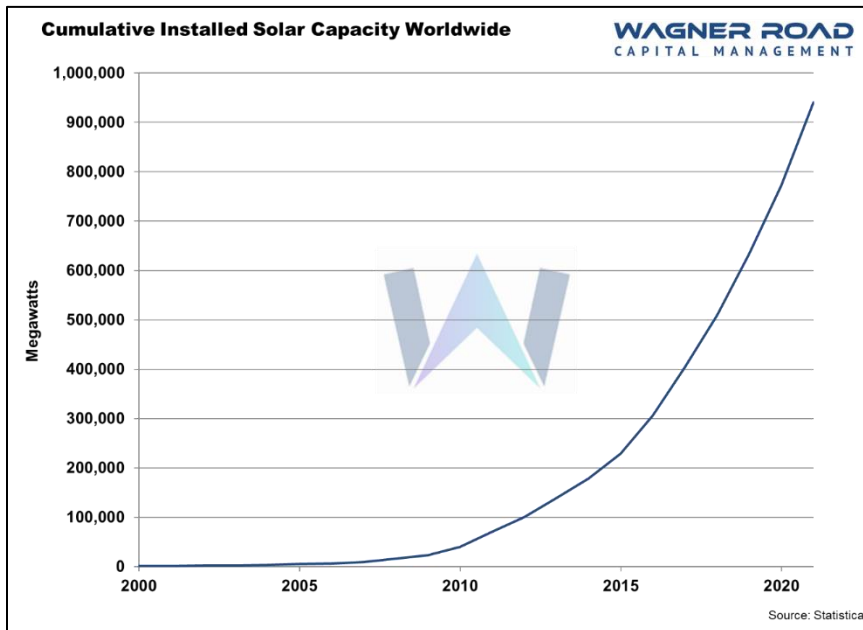
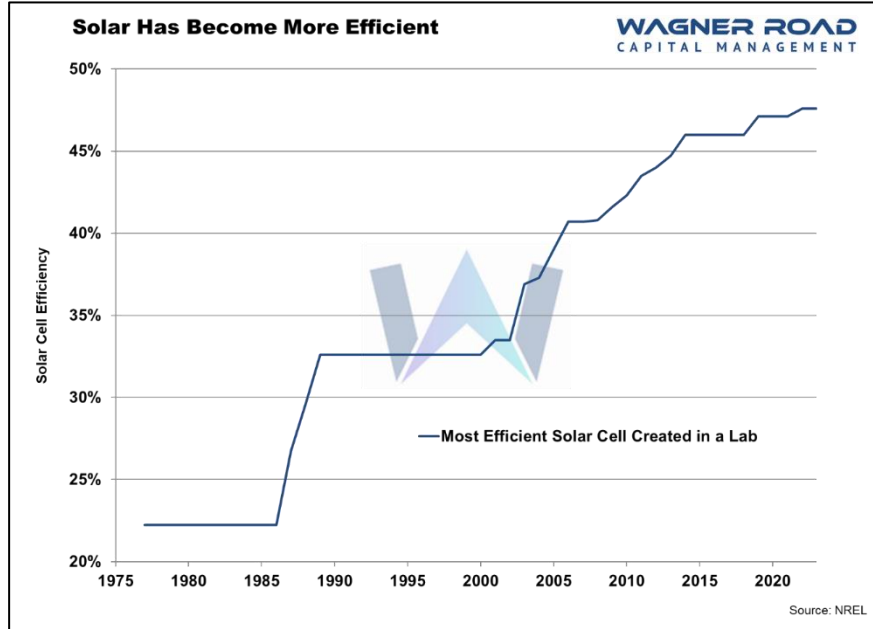
The pace of change for the industry resembles other technologies. Microchips are famous for falling costs, but the cost of solar modules has fallen in a similar way, by a rule known as Swanson's Law (the price of solar modules drops by about 20% every time global solar capacity is doubled). Solar modules are now unbelievably cheap.



¹ A quick technical history of solar cell development is available from [APS](#).

And while costs have gone down, solar efficiency has improved. Solar technology is getting both better *and* cheaper.

The graph to the right represents the best possible technology for the time.² But a new solar installation is unlikely to get more than 22% efficiency, because buyers have to think about durability, quality, and other factors (and the technology has to be commercially viable). But those complications have also improved as the industry matures. Everything about solar is getting better.



It is also becoming more popular. The change in solar capacity over the past 20 years, when put on a graph, looks like a fictional forecast. But *this is what has already been built*. Stated in simple numbers, the global market for solar panels grew by an average of about 30% every year from 2011 to 2021.

² Different sources will give slightly different numbers for solar efficiency, but they all show the same trend. NREL has [much more detailed data](#) on solar efficiency that compares different types of technologies.

These numbers are obviously attractive for investors, but they are the total effect of research coming from many different sources. Not every solar company is getting the benefits of that growth. And while betting on the best new technology is a valid investment strategy, I prefer to wait until the market is more established. And I believe that it's reasonable to call the industry securely established.

But there are still some serious challenges to investing in this industry.

The first one is that solar companies are highly sensitive to economic changes coming from outside the industry. Stock prices for many solar companies received an excessive boost from temporarily high oil prices and the war in Ukraine. Those shocks faded at the same time as the industry got slammed by higher interest rates (and a change in California's net metering rules).³ The global solar energy stock index has fallen by more than 50% over the past 3 years. Residential solar has been repeatedly described as a [state of crisis](#) over the past year. This type of sentiment would make any investor nervous.

The other challenge is deciding which company to invest in. A simple summary of how solar works reveals a few places to look:

1. Solar panels capture sunlight and convert it into DC electricity.
2. Inverters convert DC electricity into AC electricity.
3. Electricity is sent to the grid or stored in batteries.

These three basic steps generate a long list of potential investment opportunities: solar panel manufacturers or solar panel component manufacturers; companies that design and build inverters; utilities that manage the grid; companies that build batteries, or wires, or the infrastructure that supports them... It goes on. The point is that it doesn't have to be all about the technology.

Within those sets of categories, there are different market structures and different ways of competing. Most solar companies are involved with more than one part of the industry. And as the industry matures, larger companies have been expanding their offering from one type of product to a full set of solar energy solutions that can be packaged together. But we'll start with the solar panels.

Solar Panels

Solar panel manufacturing is primarily about having the low-cost operation, and it is dominated by China—[more than 80%](#) of all solar panel production happens in China. This is a major reason for why the cost of solar panels has dropped so dramatically over

³ My preferred way of betting on higher oil prices is by investing in renewable energy or electric vehicles. The long-term effects of higher oil prices generally lead to more investment in alternative energy sources.

the past two decades, but solar panels from China are so much cheaper (in addition to being [subsidized](#) by the Chinese government) that it has pushed almost every other solar manufacturer out of the market.⁴ The most significant American company that produces solar panels is First Solar (FSLR), while Canadian Solar (CSIQ) produces solar panels in Canada.

First Solar, founded in 1999, is one of the few companies that only makes solar panels without other lines of business, and it targets utility-scale solar operations. Canadian Solar, founded in 2001, serves a broader market—it produces solar products for utility, commercial, and residential markets. The company’s products also include inverters and battery storage options.

Industry-wide, the global solar panel market is projected to grow by [16%](#) to [18%](#) annually through the end of the decade. But as a commodity-like business, it’s difficult to see any company focused on solar panels earning spectacular long-term returns.

Inverters

Inverters are more interesting than solar panels—this market is divided by more than just price. There are generally two types of solar inverters:

- String Inverters take the DC electricity from every solar panel in the system and convert it to AC power all at once. These can be modified with the addition of power optimizers that manage each solar panel separately.
- Microinverters convert DC electricity from each solar panel individually.

The basic difference is that microinverters cost more, but allow more flexibility in managing and expanding the overall solar electric system. They are also more efficient. Enphase Energy (ENPH) specializes in microinverters, while SolarEdge Technologies (SEDG) specializes in string inverters with power optimizers.

SolarEdge and Enphase are quite similar in their history and future strategy. The two companies combine for about 90% of the US residential inverter market, with each company sharing about half of that total.⁵ Both were founded in 2006, both were pioneers in creating the inverter market—Enphase introduced the first commercially successful microinverter in 2008, while SolarEdge launched its first successful power optimizer in 2010—and both companies are actively expanding into a full set of energy

⁴ I avoid looking at Chinese companies, but investors may find something they like by looking in this part of the industry.

⁵ Multiple sources cite a 90% combined market share. A report from Wood Mackenzie in 2021 placed both Enphase and SolarEdge at about 45% market share for the US residential inverter market. It has become difficult for either company to gain an edge over the other, and market share should not change dramatically for this market without a major change in technology.

solar products, including batteries that can store extra power generated from solar panels, electric vehicle charging systems, and software that helps to manage the system.

This part of the solar market has been suffering. SolarEdge and Enphase both saw quarterly revenue drop by more than 50%. But the two companies provided diverging outlooks—SolarEdge is projecting to lose money for at least another quarter, while Enphase is calling the bottom. Since both companies have different products and different operations, they can both be right, but the big picture is that the short term has been difficult to forecast.

Going forward, the US residential inverter market is projected to grow by [about 15%](#) each year through the end of the decade. But microinverters have the edge on growth. Worldwide, microinverters still only have [about 12% to 16%](#) of the global market share for all inverters, and the worldwide microinverter market is projected to grow by [almost 20%](#) each year through the end of the decade, roughly twice as fast as the [market for all inverters](#).⁶

Batteries

The percentage of solar projects in the US that include battery storage is expected to explode from 10% in 2022 to almost 30% in 2027.⁷ This will compound with the growth of solar energy that is already expected.

But the solar battery storage business is mostly an add-on for companies that already offer other products. There are solar companies offering battery storage, such as SolarEdge and Enphase, but this market also extends to a wider range of companies, such as Tesla (TSLA) and Generac (GNRC), that are primarily in other businesses.⁸ Any investor looking here will also need to consider the company's other lines of business.

Solar Installers

The solar installer business is highly fragmented and extremely competitive. There are thousands of solar installation companies, but I will only mention the two largest: Sunrun (RUN) and Sunnova (NOVA). Sunrun, founded in 2007, primarily focuses on leasing solar panels to residential customers, lowering the upfront costs. Sunnova, founded in

⁶ There is some disagreement on these forecasts depending on the source, but the microinverter market is generally expected to grow faster.

⁷ [SEIA](#) has a good explanation of the many trends in the US solar market. Changes in net metering rules have made batteries an attractive addition to residential solar systems.

⁸ Tesla and Generac have both made moves to be more involved with solar, but it is not their main business.

2012, has a similar business, leasing or selling residential solar panels. Both companies are expanding their offerings into whole-home energy systems that include extras such as batteries.

This part of the solar industry has generated [criticism](#) for both its sales tactics and its reliance on debt financing for growth (Sunnova in particular has an alarming number of customer service [complaints](#)). It is also low margin and easy for new competitors to enter the market. I expect the solar installation business to match the growth of the solar panel industry without generating any special returns.

And the rest...

There are many other companies involved with the solar industry that have found surprising roles. There is the somewhat obvious business of providing the materials or wires that are needed to build solar systems, and the utilities that might be buying them, but there is one other part of the solar industry that I believe is worth considering: solar tracking systems that help utilities optimize their solar power plants. Companies in this business build systems designed to make sure that solar panels are always facing the sun.

The two largest companies that provide this technology are Nextracker (NXT), founded in 2013 (then acquired by Flex in 2015 and spun off in 2023), and Array Technologies (ARRY), founded in 1989. Of the two, NXT is the industry giant, with about 30% global market share, while ARRY has about 15% market share. NXT's technology also has a slight advantage because it allows solar panels to move individually, rather than moving an entire row at once.

Focused on utility-scale solar projects, this business is not as sensitive to changes in interest rates as the home solar market. The buyers are often major corporations, or even governments, that have more consistent buying power and longer lead times. This should be one of the more stable parts of the industry, and it is projected to grow by [more than 25% annually](#) through the end of the decade, but it's not immune to competition or market sentiment, and it can also be cyclical.

Putting it all together

Each part of the solar industry has different features with similar forecasts, but they are all expected to be much bigger by the end of the decade. The next step is recognizing

which businesses are set up to benefit, and that requires more than just the story. Let's take a quick look at the numbers.⁹

	Solar Panels		Inverters		Installers		Solar Tracking	
Company	First Solar (FSLR)	Canadian Solar (CSIQ)	Enphase Energy (ENPH)	SolarEdge (SEDG)	Sunrun (RUN)	Sunnova (NOVA)	Nextracker (NXT)	Array Technologies (ARRY)
Market Position or Business Description	American solar panel producer	Canadian solar panel producer	Micro-inverter producer	Power optimizer producer	Leases solar panels	Leases or sells solar panels	30% of global solar tracking market	15% of global solar tracking market
Year Founded	1999	2001	2006	2006	2007	2012	2013	1989
Year Public	2006	2006	2012	2015	2015	2019	2023	2020
Market Cap	\$18,400	\$1,300	\$16,700	\$4,000	\$3,000	\$800	\$8,500	\$2,200
Cash	\$1,947	\$1,921	\$289	\$338	\$679	\$213	\$368	\$249
Debt	\$464	\$1,453	\$1,294	\$627	\$10,124	\$7,031	\$145	\$661
Revenue TTM	\$3,319	\$7,883	\$2,291	\$2,977	\$2,260	\$721	\$2,282	\$1,577
Net Income TTM	\$831	\$353	\$439	\$34	(\$1,605)	(\$418)	(\$85)	\$137
Free Cash Flow TTM	(\$785)	(\$422)	\$586	(\$361)	(\$3,429)	(\$2,070)	\$348	\$215
Net Margin	25%	4%	19%	1%	-71%	-58%	-4%	5%
ROIC	11%	6%	18%	0%	-6%	-2%	57%	12%
ROE	13%	17%	49%	2%	-27%	-30%	44%	45%
Debt/Equity	0.08	0.62	1.32	0.30	2.00	4.60	0.19	2.37
3-Yr Avg. Rev. Growth	7%	33%	44%	27%	35%	65%	18%	22%

As expected from the structure of the industry, solar panel producers and solar installation companies have significantly negative free cash flow and relatively poor returns on invested capital. Solar installers also have massive debt loads, despite attractive revenue growth. The inverter producers and solar tracking companies have better positions in the marketplace *and* better numbers. The difference may be a matter of whether an investor prefers residential solar (inverter companies have faster growth and highly variable returns) or utility-scale solar (solar tracking companies should be more consistent).

⁹ Numbers are sourced from Morningstar and Yahoo at the end of the quarter. Dollars are in millions. ROIC for NXT may not be reliable because the company is recently public.

Any nuance in the solar industry has been lost in the bubble and the recent collapse of the bubble. The short-term has been chaotic and uncertain, with most of the recent economic changes being unfavorable for the industry. But the long-term fundamentals of the solar industry are not going to change. The world-wide industry is forecasted to grow by more than 15% each year, with microinverters capturing a larger market share of the inverter part of the market. The US home solar market is forecasted to grow by about 15% each year, with battery storage solutions becoming a much larger percentage of new installations. The Inflation Reduction Act is also expected to give the industry a total boost of [about 50% in the US](#) over the next 10 years.

The changes in solar technology over the past few decades have been truly impressive. The failures of solar businesses have been equally impressive. But parts of the industry are transitioning into a more mature business. The story is no longer all about growth. Now it's also about stability and predictability. The startup phase is over.

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