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Changing Paradigms in Technology, Trade and Development

Changing paradigms in the solar industry, a case study

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Abstract

At the moment, there are few industries in the world as fast changing as the solar energy industry.

The interest and use of solar energy is as old as mankind. However, the modern solar industry truly started in the fifties, with the discovery of a practical way to make electricity from light, with silicon that could make a photovoltaic material. Photovoltaics is now clearly to become the number one of renewable electrical energy sources in the world.

The most striking trend from 2000 to now has been the rise of China, at present the world's largest.

Now, the shift is back to the US, Europe and "sunny countries", in the developing world. More and more companies are getting into solar, all over the world.

Solar energy is the key issue for the 1.5 billion people still living without any electricity at all.

Hence the major trends are:

New technologies, cheaper and more efficient, new formats
Many more players worldwide
China dominance changing

Solar energy is clearly the future. There is a huge amount of effort to improve it, as it has still barely scratched the surface.

The games are constantly changing, with fast growing demand, continuous innovations, new players getting in, big business increasingly interested, China holding on, etc.

Keywords: solar industry, photovoltaics, world development of solar, geopolitics of solar, China solar

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The fast emerging solar industry

Solar is the largest energy resource available on earth. The Earth receives over 173 000 terawatts of energy every year, which is more than 10 000 times what mankind needs. Total electricity consumption worldwide was 25 000 TRh in 2016. Total world energy consumption, from all sources, fossil and renewables, was 150 000 TRh. The actual direct photovoltaic electricity world consumption is less than 2% of this total, still infant…

The challenge is to master this energy. The photovoltaic panels industry is growing over 40% a year worldwide, with the cost of solar panels fast falling, by 80% since 2000. Although solar is not yet 2% of the total world energy now, it should grow to 20% before 2030.

The past and future development of solar energy is a very illustrative example of world competition, geopolitics and massive changes of paradigms.

By the fifth century BC, the Greeks were struggling with an energy crisis. Their predominant fuel, charcoal from trees, was scarce since they had stripped their forests in order to cook and heat their houses. Wood and charcoal were rationed. One solution was to plan the architecture, so that each house could take advantage of the sunshine in the way Socrates described. This worked and a crisis was avoided.

There were a few attempts at solar cells the 19^{th} century (Alexandre Becquerel in 1839, Willoughby Smith in 1873, Charles Fritts in 1883), observing that sunlight striking certain materials generates some detectable electric current.

The first practical silicon solar cell was created at Bell Labs. By 1954, Bell Labs demonstrated a photovoltaic, PV, panel to the public by hooking it up to a toy Ferris wheel and a radio transmitter. This device was 6% efficient, which was quite an advance over previous solar cells. It was also a true “panel,” with several individual cells connected together to form a solar “battery.”

During the ’50s and ’60s, research on silicon solar cells continued. Small cells began to appear during this period in some toys and consumer devices. Then, PV cells started being used as a power source for early satellites. In 1962, the Telstar communications satellite was powered by solar cells.

These high-grade solar cells used in satellites and spacecraft, although expensive, were small in the cost of these systems, so there was no pressure to reduce costs. Yet, by the early ’70s, solar cells using cheaper materials had been developed to reduce the cost to $20 per watt. This, combined with the energy crisis starting in 1973, created a new interest for solar power.

The technology was still not ready for mass adoption, however. Efficiency was still only about 10 %, and it remained too expensive.

Efficiency, that is photovoltaic conversion efficiency, is the ratio of the electric power produced by a solar cell to the power of the sunlight striking its surface.

Now, there is a true acceleration of interest in solar energy, both at the residential level and on larger utility scales. This is due to several factors:

A significant decrease in cost
Increases in the efficiency of solar cells
An encouraging regulatory and taxation environment
Widespread concern over climate change
Significant innovations

Now, prospects look good for continuing growth, a compound annual growth rate in cumulative installed capacity of 43% since 2000.

New technical developments

The most common type of solar cell is a semiconductor device made from silicon, like a solid-state diode. Well-known solar panels are made from a number of solar cells wired together to create the desired output voltage and current. The cells are protected by some encapsulating materials in a protective package and topped with a glass window.

There are several types of solar panels, mostly silicon-based.

Polycrystalline panels, generally blue, are the simplest to manufacture and therefore the cheapest, but they can suffer in high-temperature climates.

Monocrystalline panels, black, are longer-lasting, more efficient, and performing better in low-light conditions, which makes them a little more expensive.

Thin-film panels, growing, are the least efficient of all. However, light and flexible, they can be integrated into roof shingles or put on to window panes.

Among the materials of choice:

Crystalline silicon (c-Si) is still dominant today, with about 90% of the global PV market, and it will continue to dominate for at least the next decade. Silicon PV is abundant, efficient, reliable, and proven, but it absorbs light poorly. This results in thick, heavy, inflexible solar cells and modules with relatively high manufacturing costs. For silicon, there is not much room to grow in terms of cell efficiency (25% is the current lab record), although production modules continue to improve. Typical modules are 16-21% efficient, with multicrystalline (mc-Si) technologies at the low end and single-crystalline (sc-Si) technologies at the high end.

Commercial thin-film (TF) PV technologies, can use

Cadmium telluride CdTe

Hydrogenated amorphous silicon (a-Si:H)
Copper indium gallium selenide CIGS

They are all better than c-Si, using less material, at relatively low cost with high efficiency.

CdTe dominates the thin-film market with simple manufacturing and high efficiency (21% cell record, production modules up to 15%) but has major intrinsic scaling issues.

Tellurium is scarce and hard to extract from copper ores.

Amorphous silicon is abundant, cheap, and flexible, but its maximum efficiency, 13.4% current cell record, is too low to compete with crystalline silicon.

CIGS is efficient, 21.7% cell record, modules up to about 15%, but tough to make reliably, and it also runs into materials scaling issues with indium, gallium, and selenium.

Emerging thin-film technologies, include perovskites, organic materials, dye-sensitized solar cells, and quantum dots, all complex, but much simpler, versatile, and cheaper in future developments. Printed solar cells are paper-thin, lightweight and extremely inexpensive to produce.

There are new emerging techniques, such as perovskites and quantum dots. These new materials are of great interest for thin films, because they may reach a lower cost per watt than silicon and current thin films, for simpler manufacturing and reduced materials use. These new approaches also offer new performances, like transparency, flexibility, very light weight, thus opening new applications for PV.

Some of the most promising recent research for silicon alternatives has involved materials called **perovskites**, named after Count Lev Aleksevich Perovski (1792-1856), a Russian mineralogist. Perovskite solar cells might attain a theoretical maximum of 31% efficiency, instead of the 16 to 20% efficiency of the silicon cells, while cheaper to manufacture than silicon cells.

In 2009, researchers started trying to make solar cells using perovskite materials. The major interest of perovskite solar cells is that they are cheap, cheaper than silicon. High-quality silicon crystals must be made at high temperatures using very precise processes. Perovskite cells can be made at nearly room temperature using simpler methods. Perovskite solar cells are not ready for commercial use yet, maybe ten years away. There could be new techniques featuring layers of perovskite solar cells on top of silicon cells in order to maximize total efficiency.

Unlike silicon cells, perovskite solar cells can be transparent or even made into different colors. However there still are hurdles. Perovskites are sensitive to dampness, so the cells need to be sealed inside a kind of polymer case that protects them from exposure to air and water.

There are a few companies investing in perovskite research, including Oxford PV, which was founded to commercialize technology produced by the University of Oxford, and the Institute for Silicon Photovoltaics in Berlin.

Groups at Notre Dame University, Indiana, at the University of Toronto, have developed a **photovoltaic paint made from semiconducting nanoparticles**. The material is not yet efficient enough to replace conventional PV panels, but the manufacturing process is simpler. The advantage of semiconducting nanoparticles is that they can be applied by painting over a variety of surfaces. This makes installation potentially far easier than rigid panels.

Global PV market by technology in 2016

Polycrystalline silicon multi-Si (54.9%)
Monocrystalline silicon mono-Si (36.0%)
Cadmium telluride for thin films CdTe (5.1%)
Amorphous silicon for thin films a-Si (2.0%)
Copper Indium Gallium Selenide CIGS (2.0%)

Other research directions

Research in photovoltaics is very active, some approaches still in very early stages.

Solar thermal fuels appear quite promising.

A team at MIT works on developing a **practical solar thermal fuel**. This is to store solar energy internally and stably over a long time and to release it as heat on demand when exposed to a catalyst or some triggering heat. Solar thermal fuel accomplishes this through non-reactive transformations of its molecules.

Since the work at MIT, which used fulvalene diruthenium, several laboratories are trying to solve problems with manufacturing and material costs in order to develop a system where the fuel is sufficiently stable in its energized state and can be recharged, used many times without deterioration. The innovation is to attach the fuel, in this case, azobenzene to carbon nanotubes. This caused its molecules to line up in an orderly array. The result is a solar thermal fuel with 14% efficiency and an energy density similar to a lead-acid battery.

Carbon nanotubes and fullerenes to replace silicon

A team at Stanford has created such a prototype PV cell. Its efficiency is far below that of even ordinary available silicon solar cells, but it uses nothing but carbon as a raw material. The Stanford prototype contains none of the toxic materials that form part of the electrodes in conventional solar cells. It is a more environmentally friendly alternative to silicon, but it still needs to see its efficiency rise before becoming economical.

At Oregon State University, a solar thermal fuel has been made into a transparent film that can be applied to car windshields.

Artificial photosynthesis

Another way to create fuel directly from sunlight has been developed by researchers at the University of Illinois at Chicago. Their “artificial leaves” use sunlight to convert atmospheric carbon dioxide into “syngas,” a mixture of hydrogen gas and carbon monoxide. Syngas can be burned directly or converted into more conventional fuels. The process has the added advantage of removing CO2 from the atmosphere.

A team of researchers in Finland is trying create a tree that stores solar energy in its leaves. These leaves could then be used to power small appliances and mobile phones. The trees are likely to be 3D printed, using biomaterials that mimic organic wood. Each leaf generates power from sunlight, but can also use kinetic energy from the wind. The trees are designed to survive indoors as well as outdoors.

Monolayers

One promising area involves monolayers, layers of materials one molecule thick, like graphene. These result in PV materials that, while only a few percent efficient in absolute terms, are thousands of times more efficient than conventional solar cells per unit mass.

Cyanobacteria

There are experiments with biological material in solar cells. Bacteria, specifically cyanobacteria, can eventually make it easier to power wireless devices. The efficiency of these bio-solar cells is far less than conventional PV cells, but there is hope this will work. One of the researchers at the Binghamton University Thomas J. Watson School of Engineering and Applied Science, Seokheun ‘Sean’ Choi, believes bio cells would be useful for remote areas where it is difficult to replace batteries.

Solar cells in space

In Japan, the JAXA, Japanese Space Agency, believes that getting closer to the sun is the best way for efficiency. The Space Solar Power Systems, SSPS, project is trying to send solar panels to near-Earth orbit. The power collected will be wirelessly transmitted back to base station via microwaves. If successful, this technology could be quite a breakthrough.

Infrared light

Right now, infrared rays pass right through the panels and are wasted. But if this spectrum of invisible light can be captured, it could boost energy efficiency by 30%.

PERC

PERC stands for “Passivated Emitter Rear Contact.” With PERC solar cells, mono crystalline solar modules generate higher power, up to 10% more power than older technology. PERC technique was developed by Martin Green at the University of New South Wales, in 1983. It is only recently that innovations in cell materials permitted PERC to be developed into panels. PERC permits higher power outputs by allowing more light to penetrate the cell. With PERC, a “passivation layer” is added to the rear of the cell so light can be better captured throughout the cell.

Other

IBM is trying to make individual PV cells smaller so that more of them could be squeezed into tighter spaces. The company believes it could eventually pack ten times more PV cells into the same space.

Limitations of solar energy

Efficiency is, at the moment, the biggest hurdle to better solar power. More than 80% of all existing solar panels have an energy efficiency of less than 15%. Most of these solar panels are stationary, which means they miss out on direct sunlight. A majority of the sunlight that hits the panels is wasted.

PV solar does not produce at night. It also produces much less in the early morning and late afternoon, when there are high loads for cooking, heating, and other activities.

At higher latitudes, in winter, the total time of solar exposure drops, with the lower sun angle. Tilting the panels requires more expensive mounting that can deal with wind loads.

Densely cloudy days can cut power levels. Snow needs to be removed for the panels to work.

So the big limitation is that solar will not work well at higher latitudes and in winter, or at night.

As compared to other forms of renewable energy, there are quite a lot of drawbacks of Solar Energy:

Modules are low efficiency
Solar energy can be obtained only during the day, a battery will be required to use at night.
The output is quite variable, from 0 to peak in about 8 hours.

However, there are a lot of positive points mainly that it is very easy to install for a small scale plant, like a house roof.

From its start, solar energy was plagued by an original sin which never affected any other industry. Major individual expenses such as cars, computers, were never boosted by any State subsidies. This is different for solar energy as since the beginning, there was a partnership with the utility companies. Most people share their solar energy with their utility companies.

Net-metering is considered everywhere as the most popular and cost-effective way to store electricity. It hooks solar panels back into the power grid, so if there is need for more energy than the solar installation can provide, it will take on the grid. When the solar system produces more than needed use, the excess flows back out in the grid, reducing the billing meter somehow.

A much saner approach, one that has hardly been explored yet, is off-grid, where the electricity is all stored in a large battery bank.

In the US typical household power consumption is about 11 700 kWh each year, in France 6 400 kWh, in the UK 4 600 kWh, in China 1 300 kWh, and in India 1 000 kWh.

In the US, the average of 900 kWh per month, about 40 batteries worth, can add up to $16,000 for batteries. Yet, storing energy off-grid means electricity in even the remotest areas, or being free from grid failures.

Everywhere in the US as well in Europe, there have been subsidies, supposedly to help transition communities into energy independence. This had major drawbacks though. For instance, in France the main public owned utility started buying the excess current much more than the going electricity price, so there was a huge rush to solar. When the utility decided it was too much to cope with, the subsidies were ended and the domestic solar industry was practically killed, and still is.

The solar farms

There has been an interest in so-called “solar farms”, where more of less large areas, hopefully not fit for agriculture, are covered with panels.

This may seem like a very obsolete move in the long term, considering that the true virtue of the solar energy is to get away from the grid. Yet, to a number of people it may seem like to last forever, with links to the grid, whereas it should be only a temporary solution before total independence from the grid become the ideal in the long run. True, batteries and electricity storage are not yet performant but they should be in the medium run, just a few years, and this is really the major issue, the true sea change in the electrical industry. Access to electricity is needed 24 hours per day. Solar power can give that only by storing excess energy generated when sunny and draw from the grid otherwise. This will not be true forever.

But politicians all over are short-termists and do not yet see the true final issue.

In the meantime, there is a development of intermediate-scale PV installations. These are bigger than residential but still far smaller than utility-sized solar generating stations. For instance, in the US, there are some lots of land planted with rows of solar panels rather than used for crops or pastures. In this case some solar farms may be a way for communities to gain some of the benefits of solar power without requiring each individual to invest in a separate rooftop system.

Of course, at the present time, utility-scale solar installations are cheaper, per kilowatt-hour, than residential ones. In fact, the cost to supply electricity generated by large-scale solar plants has reached parity in some places with the cost from fossil powered plants.

Large solar farms operated by governments or utility companies have many energy storage strategies. They can store excess solar energy as gravitational potential energy by pumping water into elevated tanks or reservoirs and reclaim it by allowing the water to fall through turbines. They can compress tanks of gas or springs, or they can use chemical energy, either in the familiar form of batteries or using a more sophisticated process, like splitting water to produce hydrogen that is burned when the Sun goes down.

A solution to possible lack of space for photovoltaics could be floating solar farms. Ciel et Terre International, a French energy company, has been working on a large scale, floating solar panels since 2011. They have already installed a trial farm off the coast of the UK and are now looking at attempting similar projects in India, France, and Japan.

The only practical solution for the homeowner, outside linking to the grid, is the electrical storage battery. However, the capital cost and extra maintenance of a battery system is at the moment, significant. So it is still more advantageous, to install a grid-attached system and not rely only on home installation. The home owner can sell excess generating capacity to the electrical utility during the day, while drawing upon grid power at night or when panels are not producing. Using the grid as energy storage not only makes PV panel installation cheaper and simpler, but it lets the system pay for itself faster, as many states require the utility to pay the homeowner for power fed into the grid. One drawback is that the electricity supply is exposed to blackouts.

Recently, Tesla Motors has adapted the lithium-ion battery technology developed for its electric vehicles to serve as also as a packaged power backup system for the home. This device, the Power Wall, is designed to work both as energy storage for a rooftop solar installation and as backup power in case of grid blackouts.

Improvement in battery efficiency and the drop in battery cost is just as important as improvement in solar panel efficiency for off-grid residential solar power.

If recent improvements continue, these installations will become more popular. And if the market share of electric cars continues to increase, their batteries may become a dominant energy storage and demand-leveling system.

Main world actors in solar energy

Production and supply through the value-chain in the solar industry involves several steps of production, with still many companies competing.

Production starts at silicon metal, to make high purity silicon. High purity silicon in different grades of purity is used for making silicon ingots, which are sliced to wafers in a process called wafering. Pure polycrystalline silicon wafers are used for photovoltaics. Dislocation-free and extremely flat single crystal silicon wafers are used in the manufacture of computer chips.

The main world actors present in each processing step maybe specialized at one or two steps, or integrated at two or more steps. In all cases, Chinese companies are dominant, as the following short reminder lists indicate.

It is quite difficult to rank and assess the relative strengths and impact of upstream PV manufacturers, from polysilicon production to module supply, and the thin-film companies within the dominant c-Si supply mix.

In fact, the whole Tier issue has become almost completely irrelevant in the past few years, since focus has been limited to end-market shipments, regardless of whether any upstream manufacturing took place.

PV Tech organization and magazine is a leading source endeavoring to understand the constantly changing structure of the solar industry and its many Tiers.

Silicon producers

Most of them rare down integrated into wafers, PV cells etc.

Renewable Energy Corporation REC, Norway, with plants worldwide, fully integrated down.
Elkem, China, bought in 2011 to Norway by China National Bluestar
JFE Steel, Japan, merger of NKK and Kawasaki Steel Corporation
Nitol Solar, Russia
SunEdison, USA, bankrupt in summer 2017
Mississippi Silicon, USA

High-purity silicon

Renewable Energy Corporation REC, Norway
Silfex Inc., USA
SunEdison, USA, bankrupt in Summer 2017
Tokuyama Corporation, Japan
Wacker Chemie AG, Germany
Silicio Ferro Solar, Spain

Polysilicon manufacturers

Wacker Chemie, Germany
Jiangsu Zhongneng GCL, China, subsidiary of GCL
OCI, Korea
Hemlock Semiconductor, USA, dropped from first rank in 2011
Xinte Energy TBEA, China

Silicon wafer manufacturers

A partial list of major producers of wafers (made of high purity silicon, mono- or polycrystalline) includes:

Applied Materials, USA
Hemlock Semiconductor Corporation, USA
LDK Solar, China
NexWafe, Germany
Okmetic, Finland
ReneSola, China
Renewable Energy Corporation REC, Singapore
Shin-Etsu Handotai, Japan
Sil'Tronix Silicon Technologies, France
SUMCO, Japan
SunEdison, bankrupt in Summer 2017
Wacker Chemie AG, Germany

Top 10 solar cell producers in 2016

Nine of the top-10 cell producers for 2016 have capacity based in China, with most now also having overseas plants located in Southeast Asia.

Hanwha Q-Cells, Korea
JA Solar, China
Trina Solar, China
First Solar, USA

JinkoSolar, China
Motech, Taiwan
Tongwei Solar, China
Yingli Green, China
Canadian Solar, Canada
Shunfeng, China

Yet cell production is still highly fragmented, and the level of integration is not well-known.

Of all the stages of the value-chain, the cell step is the most fragmented. Adding up the cell production from the top-10 in 2016, the total capacity produced is still less than 40% of the whole industry. In fact, there are 50 cell producers to account for about 90% of the industry output. However, all is still hazy, as many of the companies are increasingly reporting less information on in-house cell production, capacity and technologies, focusing instead on reporting finished module shipments.

At least one-third of the cells used in the shipped modules from the top-10 were made by outside companies. This is mainly because of the fast growth of demand for solar panels in China. Module makers need cell supply on short notice, and whatever integrated facilities they may have often are not ready and cells must be purchased to independent suppliers.

Globally, around 50% of the total solar panel/module production is handled by only top 20 companies.

Top module suppliers in 2016

The list below of over 30 companies roughly ranked by importance, shows the dominance of the Chinese module manufacturers. But every year, there is a change in the list of top 20 solar manufacturers in the world as they shift places, drop off the list, merge, or emerge as new market leader.

JinkoSolar will continue being the leading module supplier in 2017. The top 30+ are:

Jinko Solar, China, also Portugal, Malaysia, South Africa. Integrating silicon ingots, wafers, solar cells
Trina Solar, China, number 1 or 2 for crystalline silicon solar panel in the world
Canadian Solar, Canada, but all activity in China
Hanwha Q-Cells, Korea, also producing ingots, solar wafers, solar cells and solar modules
JA Solar, China
GCL, China Hong Kong
First Solar, USA, rigid modules and Cd-Te based thin film panels
Yingli Green, China
Talesun, part of Zongli, China
Risen Energy, China
Sun Power Corp, USA, subsidiary of French Total, with plants in Spain and Korea
Mitsubishi Solar Electric, Japan, high efficiency solar panels and new Diamond Premium
Hareon Solar, China, making solar cells and solar panels
Neo Solar Power, NSP, Taiwan
Axitec, Germany and USA, mainly solar modules, for Asia
ShunfengInternation Clean Energy (SFCE), China, solar cells and solar modules
Motech Solar, Taiwan
Longi Silicon (including LERRI Solar), China, p-type mono silicon wafers and cells
CentroSolar, Germany, US with PERC technology
DelSolar, Taiwan
Vikram Solar, India
Grape Solar, USA
Daqo, China, polysilicon, wafers, modules
Heavy Engineering Corporation Limited (HEC), India, to integrate a large module production
Sharp Solar, Japan
Kyocera Solar, Japan
Solar Frontier, Japan
Solarworld, last survivor in Germany, bankrupt in May 2017

ReneSola, China
Chint Group, China, getting into solar
Hareon Solar, China, wafers, cells and modules
EGing PV, China
CSUN, China, cells and modules
BYD, China, batteries, electrical cars, cells, modules
HT-SAAE Shanghai Aero Auto Electromechanical, China

The Silicon Module Super League, SMSL, companies are a group of six crystalline silicon, c-Si, module suppliers in the solar PV industry. The Big Six industry group members are Canadian Solar, Hanwha Q-Cells, JA Solar, Jinko Solar, and Trina Solar. Longi, the world's largest solar monocrystalline silicon manufacturer and GCL, the world's largest solar poly crystalline silicon manufacturer, have both joined the SMSL.

These SMSL module suppliers are expected to ship about half of the world supply in 2017.

A serious new comer, worldwide, is Tesla, in the US. Tesla purchased the energy company SolarCity to become a vertically integrated firm that supplies solar power, a system for storing it, and vehicles that consume it, with the vehicles potentially becoming an integral part of the storage system. Industry analysts forecast that by the year 2020, there will be 70 GWh of electrical storage available in the form of the batteries inside Tesla automobiles, not including cars of other manufacturers.

Tesla is very invested in the SolarCity project. They have installed, in 2016, more battery storage than the entire United States installed in 2015. The company intends to produce a *“smoothly integrated and beautiful solar-roof-with-battery product that just works, empowering the individual as their own utility, and then scale that throughout the world.”* Since the Solar City purchase, Elon Musk and his company have announced plans and technical achievements, including advanced inverters and solar roofs.

Tesla and Panasonic are planning a solar panel manufacturing factory in Buffalo, New York. Tesla Power Wall is already one of the most popular domestic energy storage devices in the world.

The structure of the industry is just at its beginnings like the car industry was in the 1920s, with hundreds of manufacturers, the “dot com” boom in the 1990s, many startups, most of which will fail, though some do succeed, but there already are very large players present all over the world .

The games are constantly changing, with fast growing demand, continuous innovations, new players getting in, big business increasingly interested, China holding on, etc.

China and geopolitics of solar energy

The global solar market in 2016 was even more dominated by China than it was the year before.

China produced over 80% of the world capacity for crystalline-silicon solar panels which is the most popular type. That year, the United States accounted for 1%. But rankings move every year.

All the largest Chinese manufacturers are moving out from the domestic market and getting increasingly present all over Asia, Europe and the US.

So at the moment, end 2017, the trend since 2000 has been the rise of China, by far the largest in the world. But now, there is a shift back to the US, Europe and “sunny countries”, in the developing world. More and more companies are getting into solar, all over the world.

Solar energy is the key issue for the 1.5 billion people still living without any electricity at all.

Solar in India

With determined policy of the government on renewable energy sources, especially solar, India will certainly be the **next Solar Super Power**. The solar revolution is gradually picking pace. The solar energy will make India energy independent. The plan of India in the short term is to increase solar power production from 20GW to 100GW by 2022, and potentially 40% of energy needs by 2030.

Solar power will help accelerate the growth of the Indian economy in many ways. India in general has more than 300 days of sunlight every year. Estimates say that if all of this energy is captured it can generate 5 000 trillion kWh of solar energy. This is 4 times the current peak demand for power, about 250GW. This energy generation will be key to improve the overall quality of life in India.

With rising costs of electricity, reduction in prices of solar PV panels and government policy support, buying a solar PV system has become of interest in many parts of India. The drive to buy solar PV is increasing. Yet, there is still some lack of awareness about technology, brands, and prices amongst the consumers in the country. All this will shortly be overcome.

Solar Panels in India:

Rank	Brand/Manufacturer	Installed Capacity (in MW)
1	Vikram Solar	500
1	Waaree Solar	500
2	Goldi Green Technologies Pvt. Ltd.	450
3	Tata Power Solar Systems Ltd.	300
4	Moser Baer Solar Limited	230
5	XL Energy Limited	210
6	Solar Semiconductor	195
7	Emmvee Photovoltaics Private Limited	150
8	Navitas Green Solutions Pvt. Ltd	135
9	Satvik	125
9	Panchwakra Solar	125
10	Surana Solar	100

The leaders are Vikram and Waaree.

The future of solar energy

Short-term issues that may change solar demand outlook

Uncertainty about the US market
Continuing growth of the Chinese domestic market, and fast supply expansion in Asia
Still little growth in the European solar demand
Hopeful demand in India and many other sunny countries

Solar energy seems to be the most elegant solution to energy needs. The challenge has always been collecting that energy. Even though most people are aware of photovoltaic cells, solar panels have been expensive enough to keep them marginal. Their low efficiency and the high costs per cm2 made them difficult to break through.

That has changed. In the last ten years, the cost of solar panels fell by 80%, and it is now growing fast. Within the next 30 years, the International Energy Agency forecasts that solar energy could count for up to 16% of the world entire energy, plus 11 % for solar thermal energy, from less than 2 % now.

From the beginning, the development of solar energy has been the result of subsidies. It was believed that the industry could not survive without government help. However, this point of view is quickly becoming obsolete. In geographical locations where the sun is strongest, solar power actually beats fossil fuel electricity in terms of price, even without subsidies.

Even in countries where the solar energy industry needs subsidies to operate, such as in Europe and the United States, costs are getting cheaper. American utility companies have made 20 year agreements to purchase solar power at prices roughly 5 cents per kilowatt-hour, sometimes even lower. These prices are sometimes low enough to compete with electricity from natural gas. If gas prices rise in the future, which is probable, solar will be even more competitive.

So while wind, hydropower, and geothermal extraction may work well on a local or regional scale in certain areas, the potential of solar greatly exceeds any other renewable energy source. It is the only contender, besides nuclear power, for a global solution to supply the world with the massive amount of energy it demands.

It is believable that over 40 years, solar PV could account for more than half the world power, with wind, hydro, geo, natural gas and nuclear accounting for the rest.

Already many places in the world, Brazil, Canada, France, Iceland, Sweden, have had electricity grids with minority amounts of fossil fuels. This happened sort of naturally, replacing non-intermittent energy sources, fossil fuel, with another non-intermittent energy source such as hydro, geothermal, biomass or nuclear.

Solar today is about where electricity was in the late 19th century.

Solar products of all sorts will hit the market in applications hardly imagined today, like solar roadways. Solar technology will be integrated into more and more products, cars, boats, trucks, hvac, refrigeration, mobile phones, windows, roofing, siding, solar trees, etc.

The future is solar bright.

Rooftop photovoltaics, combined with smart grid techniques and energy storage, will continue to grow, at least 20-40 % annually. Utility solar will also continue to grow, to provide grid stability.

Emerging markets will see a much larger rise of PV for both rooftops and utility-scale projects.

Thin film solar techniques will increase their mark with a leveled cost of energy, LCOE, greater scalability and more general uses. The application of thin film in emerging markets is one of the most promising. With few investments in thermal plants, neither grid, many countries could leapfrog with decentralized production and storage. This may be done with crystalline PV but thin film seems like a better bet.

Solar panels will become ubiquitous in developing tropical countries where power grids are poor and there is much sun. There are many plans to make solar power a reality in Africa.

Solar panels will continue to gain popularity in developed countries for homes. Non-home installations will become a viable business when panels get cheap enough, and this is soon.

Panel costs will continue to drop, but manufacturing will continue to use silicon and not easily jump to new technologies. Conversion efficiency will progress slowly and not be a major economic driver, as in many situations just having a larger area of solar cells will be simpler than raising conversion efficiency.

Solar will well reduce the daytime peak for electric demand, but once the peak has been flattened, further use of solar will depend on storage, which is a whole different set of technologies to develop.

Solar thermal power will be slower to develop and not be anywhere as popular as photovoltaics for a long time.

Solar energy is clearly the future. Up to now, the sun true potential has just been scratched.

There is a tremendous amount of research everywhere to improve the way sunrays are collected and converted into energy. This drive will help solar energy contribute an ever increasing part of energy demand.

The coming sun energy boom is set to change civilization.

There still are major problems in the foreseeable future

Even if the PV panel is perfectly manufactured and conditions are ideal, the theoretical maximum efficiency is about 33 %. Commercially available solar panels still only achieve about 20%.

Another major problem is electricity storage, still unsolved, but not as bad as in the wind power, at least in sunny areas.

Another politic misconception is that of the “solar farms”, the true future is to get away from the grid.

And then there is a major hope for a world energy changing breakthrough, as Tewari and his team are working in India.

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