SOLAR POWER INDUSTRY

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B. Prakash & Associates

Disclaimer

The conclusions reached, and views expressed in the study are matters of opinion. Our study is based on the general understanding and the dynamics of the solar power industry prevailing as on the date of the study and our experience. However, since solar power industry just like any other industry is impacted with changes in the political, economic, environmental and regulatory factors, there can be no assurance that the market may not take a contrary position to our views.

This study covers solar energy industry, its background, dynamics of the industry, sectorial performance and future growth and potential of India and some other countries. This study is based on the information gained from various industry reports, news articles and journals. We have no responsibility to carry out any review of our comments for changes in the industry dynamics occurring after the date of issue of this study.

Further, this study shall not be used or quoted in whole or in part or otherwise referred to in any document or delivered to any other person or entity without our prior written consent.

This study contains observations and comments based on our review and neither B Prakash & Associates nor its employees and associates are responsible for any loss or damage occurring on implementation of views expressed in this report.

Aim and Objective of the Study

The aim and objective of this study is to understand the background, current fundamentals and the future growth aspects of the India's solar power industry and study solar market of other countries contributing to the growing solar industry. Further, the study aims to understand current position of India as compared to the other leading countries.

Basis for the Study

The basis for the entire study is continuous accumulation of knowledge and data through various reports, news articles and journals.

Scope of Work

The scope of our work specifically includes the following:

(i) Historical Background
(ii) Regulating and Administrating Institutions
(iii) Factors impacting the solar market
(iv) Industry Performance
(v) Future growth aspects with reference to some countries

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1 Introduction

India's energy sector is one of the most critical components of infrastructure that affects the economic growth and therefore is also one of the largest industries in India. Globalization has positively influenced almost every sector in the country including the power sector. India being one of the fastest growing economies of the world is spurring a rapid increase in energy consumption.

Electricity demand of India is expected to double over the coming decade with the key question still hovering after 70 years of Independence is whether India can manage rapid expansion of its economy with the current state of electricity in the country? Demand supply imbalance, transmission & distribution losses, low plant load factor etc have been key areas and needs to be aptly addressed to devise a sustainable model to strike the balance between economics & environment.

The trends indicate that primarily the power sector was entirely dependent on fossil fuels for power generation posing a consequential damage to the nature. However, this seems to have been realised by the country evidenced by a steady replacement of traditional sources of electricity by renewable resources.

Given the higher dependency on non-renewable resources, the steps for steady, rapid transformation shall be instrumental for achieving the desired sustainable model for the Electricity Sector of India. India has seen an evolution in energy usage with a shift from non-renewable to renewable energy sources. However, a lot remains yet to be achieved.

Indian leaders from the top down have embraced the need to transform the country's energy industry, by setting ambitious goals to make India a world leader in the adoption and deployment of low emissions energy efficiency and renewable energy infrastructure by concentrating on wind and solar energy. To say that, 'clean energy transition is vital' is an understatement. India can meet its growing electricity needs by introducing competitive renewable energy-based solutions while keeping its use of fossil fuels in check and unleash the potential of solar energy in the country.

Solar energy is one of the most abundant and cleanest form of renewable energy resource on the Earth. India is endowed with abundant solar energy, which can produce about 5000 trillion KW of clean energy. If this energy is harnessed efficiently, it can easily reduce our energy deficit scenario and that too with no carbon emission. Many States in India have already recognized and identified solar energy potential and other are lined up to meet their growing energy needs with clean and everlasting solar energy. In near future, Solar energy will have a huge role to play in meeting India's energy demand.

Accordingly, this report focuses on Solar energy industry, its background, factors impacting the industry, sectorial performance, future traction with reference to some countries and project related information to understand its viability.

2 Historical Background

From the beginning, the sun has been personified and worshipped for the light and heat that it provides to the Earth. Eventually, the worship of the sun was replaced with a more practical approach.

Where it all began

The first recorded use of utilising the sun's power was in the 7th century BC, when magnifying glasses or crystals were used to light fires.

400 hundred years later in Egypt, mirrors were used to reflect the light from the sun to illuminate the entrances and corridors to their tombs. The sun-dried mummies and houses were specifically built to trap the sun's heat for lower daytime and higher evening temperatures. The design was simple, yet effective. Much can be learned from the ancient period in harnessing passive energy in order to make it more efficient.

The Romans and Greeks also used solar energy for domestic and ceremonial purposes. The sun's energy was used to light torches for these various ceremonies. The Chinese also used mirrors and reflective objects to light fires in the religious events.

In 212 BC, Archimedes reportedly came to the aid of Greek empire by destroying the Roman Navy at Syracuse. They used highly polished shields to magnify and focus the sun's rays on a specific point, many of the ships were set alight. The Greek navy set fire to a wooden ship in 1973 using the methods Archimedes described in this ancient account.

The Romans also built bathhouses with the windows facing the sun, which were later popularly known as "Sun-Rooms". These sun-rooms got so popular in the Roman empire, that a law mandated that every building should have access to Sun. This was recorded in the Justinian code in 600 AD.

Before Columbus reached the shores of North America, the Native America built their houses in much the same way as the Egyptians. The houses trapped heat for the night and regulated heat during warmer periods.

Meanwhile in the 19th Century

The Swiss inventor Horace de Soussare made the first solar collector in 1767. The design constitutes an insulated rectangle box covered with two smaller boxes inside. When left in the sun, the bottom small box reached temperatures well over 100 degrees Celsius.

Sir John Herschel, the noted astronomer, made a hot box (similar to the one of de Soussare) while on the expedition in the 1830s to the Cape of Good Hope in South Africa. It was a small mahogany container blackened on the inside and covered with glass, set into a wooden frame protected by another sheet of glass and by sand that was heaped up along its sides. Also known as solar oven, or solar cooker, uses sunlight to heat meals and drinks. Today's solar ovens are cheap and popular solutions to prepare meals in parts of world where access to electricity is limited. These devices are only reliant on sunlight to work – there is no fuel required.

1839 marks a big year in the history because Edmund Becquerel, a French physicist, only 19 years old at the time, discovered that there is a creation of voltage when a material is exposed to light. Little did he know, that his discovery would lay the foundation of solar power.

Aubrey Eneas opened the first solar company in Boston, US, in 1900 and called it The Solar Motor Co. William J Bailley invented a solar collector in 1908, which comprised of copper coils feeding an insulated box. This is very similar to the ones we use today.

Although John Ericsson invented the parabolic trough in the mid-1870s, the first quantifiable use was in 1912. Frank Schuman built these troughs for a community in Meadi, Egypt. The power generated was used to power a steam generator, which gave power to a water pump, providing the communities in surrounding area with roughly 20,000 litres per minute. Following the success, Schuman planned to build 20,250 square miles of parabolic trough, enough to provide 270 million horsepower. Unfortunately, World War 1 broke out and his dream was never realised.

Photovoltaic and 21st Century

The history of photovoltaic energy (aka solar cells) started back in 1873. In 1873, Willoughby Smith, an English engineer, discovered photoconductivity in solid selenium. Building on Smith's discovery, in 1876 William Adams along with a student of his, Richard Day discovered that when selenium was exposed to light, It produced electricity. An electricity expert, Werner von Siemens, stated that the discovery was "scientifically of the most far-reaching importance". The selenium cells were not efficient, but it was proved that light, without heat or moving parts, could be converted into electricity.

A process used to make very pure crystalline silicon, known as the Czochralski meter, was developed in the early 1950s. A small US satellite was powered by a cell producing less than one watt in 1958. In 1970, Elliot Burman developed solar cells that were significantly less costly, reducing the price from $100 to $20 per watt. Exxon spearheaded this research.

Then in 1973-74, the oil embargo allowed the solar industry to grow. In 1976, David Carlson and Christopher Wronski manufactured the first amorphous solar panel. Approximately 1.2 billion homes were using Solar Geysers in 1990s; it was becoming more and more popular. In 2005, Professor Vivian Alberts of South Africa invented thin film solar modules.

Today, solar cells are almost everywhere. Solar powered aircraft that can fly higher than most aircraft, solar powered cars, etc. Solar cells are quickly becoming a cost-effective alternative that will allow for serious consideration as alternative source of electricity.

3 Technological Development

Solar energy systems come in all shapes and sizes. Residential systems are found on rooftops, and businesses are also opting to install solar panels to offset their energy costs. Utilities too are building large solar power plants to provide cleaner energy to all customers connected to the grid.

There are two main types of solar energy technologies – photovoltaic (PV) and Concentrating Solar Power (CSP).

3.1 Photovoltaic (PV)

PV is more familiar solar technology, which is utilized in panels. When the sun shines onto a solar panel, photons from the sunlight are absorbed by the cells in the panels, which creates an electric field across the layers and causes electricity to flow. A single PV device is known as a cell. It is made of different semiconductor materials. An individual PV cell is usually small, typically producing about 1 or 2 watts of power. To boost the power output of PV cells, they are connected together in chains to form larger units known as modules or panels. Modules can be used individually, or several can be connected to form arrays. One or more arrays is then connected to the electrical grid as part of a complete PV system. Because of this modular structure, PV systems can be built to meet almost any electric power need, small or large. Solar panel technology has advanced considerably in the last decade. Solar panels are divided into three main technologies: monocrystalline, polycrystalline, and thin-film. Each type of panel utilizes different technology to harness the sun's rays and has a different range of applications.

1) Monocrystalline

Monocrystalline (mono) panels are the most efficient solar panels in terms of solar output relative to panel size. Solar cells made of monocrystalline silicon (Mono-Si), also called single – crystalline silicon (Single Crystal - Si), are quite recognizable by an even colouring and uniform look, indicating high - purity silicon. Monocrystalline solar cells are made out of silicon ingots, which are cylindrical in shape. These panels have the highest efficiency rating in the market at 15% - 22%, and therefore, require the least amount of space. Mono panels also have the longest lifespan of 25 years or more, due to high -purity silicon used during manufacturing. Mono panels have the highest upfront costs of all solar technologies. Monocrystalline solar panels produce up to four times the amount of electricity than thin film solar panels produce.

2) Polycrystalline

The first solar panels based on polycrystalline silicon, which is also known as polysilicon (p-Si) and multi-crystalline silicon (mc-Si), were introduced to the market in 1981. Raw silicon is melted and poured into a square mould, which is cooled and cut into perfectly square wafers. Polycrystalline (poly) solar panels are manufactured using several silicon crystals, and typically carry an efficiency rating of 13% – 17%. Poly panels require more space to match the power output of mono panels due to lower silicon purity. However, poly panels is a much simpler process, making the technology less expensive. Poly panels also have a lifespan of about 25 years. And over time it may prove to be the most cost-effective.

3) Thin Film

Thin Film (TF) is a newer technology made possible by depositing a photovoltaic material onto a surface. The photovoltaic materials used are not as energy – efficient as crystalline silicon, but still get an energy efficiency rating of 7% - 13%. Thin Film panels require much more space to produce a commercially significant wattage, limiting the potential for residential installations. Thin Film panels are much cheaper to produce than mono or poly panels, and can even be made flexible, offering solar options in situations previously thought impractical.

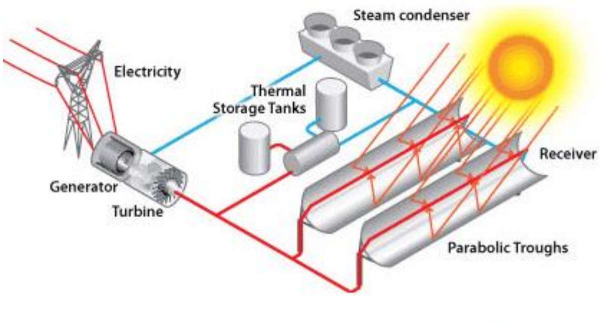
3.2 Concentrating Solar Power (CSP)

Concentrating Solar Power (CSP) technologies use mirrors to reflect and concentrate sunlight into a single point where it is collected and converted into heat. This thermal energy can be used to produce electricity. Concentrating solar power systems are generally used for utility - scale projects. The mirrors in CSP plants focus sunlight onto a receiver that heats a high-temperature fluid, which is used to spin a turbine or power an engine that drives a generator. The final product is electricity. There are several varieties of CSP systems like, Linear Concentrator System, Dish/Engine System, Power Tower System, and Thermal Storage System.

1) Linear Concentrator System

Linear concentrating solar power (CSP) collectors capture the sun's energy with large mirrors that reflect and focus the sunlight onto a linear receiver tube. The receiver contains a fluid that is heated by the sunlight and then used to heat a traditional power cycle that spins a turbine that drives a generator to produce electricity. Alternatively, steam can be generated directly in the solar field, which eliminates the need for costly heat exchangers. Linear concentrating collector fields consist of a large number of collectors in parallel rows that are typically aligned in a north-south orientation to maximize annual and summer energy collection. With a single-axis sun-tracking system, this configuration enables the mirrors to track the sun from east to west during the day, which ensures that the sun reflects continuously onto the receiver tubes.

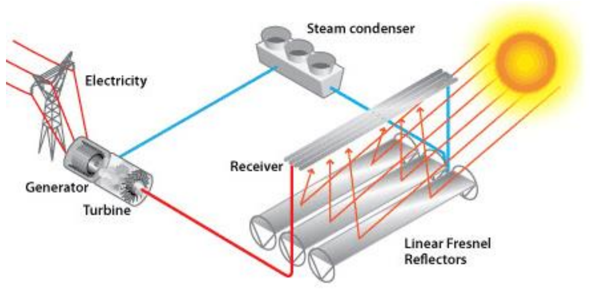
a) Parabolic Trough System



A linear concentrator power plant using parabolic trough collectors.

The most common CSP system is a linear concentrator that uses parabolic trough collectors. The most common CSP system in the United States is a linear concentrator that uses parabolic trough collectors. In such a system, the receiver tube is positioned along the focal line of each parabola-shaped reflector. The tube is fixed to the mirror structure and the heat transfer fluid flows through and out of the field of solar mirrors to where it is used to create steam (or, in the case of a water/steam receiver, it is sent directly to the turbine).

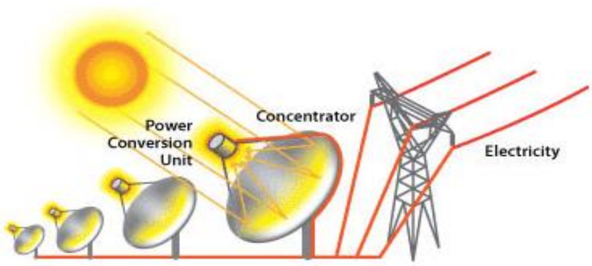
b) Linear Fresnel Reflectors Systems



A linear Fresnel reflector power plant.

The second most common linear concentrator technology is the linear Fresnel reflector system. Flat or slightly curved mirrors mounted on trackers on the ground are configured to reflect sunlight onto a receiver tube fixed in space above the mirrors. A small parabolic mirror is sometimes added atop the receiver to further focus the sunlight.

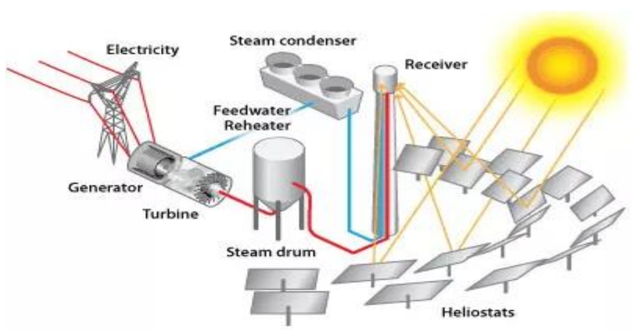
2) Dish/Engine System



A dish/engine power plant.

Dish/engine systems use a parabolic dish of mirrors to direct and concentrate sunlight onto a central engine that produces electricity. The dish/engine system is a concentrating solar power (CSP) technology that produces smaller amounts of electricity than other CSP technologies—typically in the range of 3 to 25[1] kilowatts—but is beneficial for modular use. The two major parts of the system are the solar concentrator and the power conversion unit.

3) Power Tower System



A power tower power plant.

In power tower concentrating solar power systems, a large number of flat, sun-tracking mirrors, known as heliostats, focus sunlight onto a receiver at the top of a tall tower. A heat-transfer fluid heated in the receiver is used to heat a working fluid, which, in turn, is used in a conventional turbine generator to produce electricity. Some power towers use water/steam as the heat-transfer fluid. Other advanced designs are experimenting with high temperature molten salts or sand-like particles to maximize the power cycle temperature.

[1] https://www.energy.gov/eere/solar/articles/concentrating-solar-power-basics

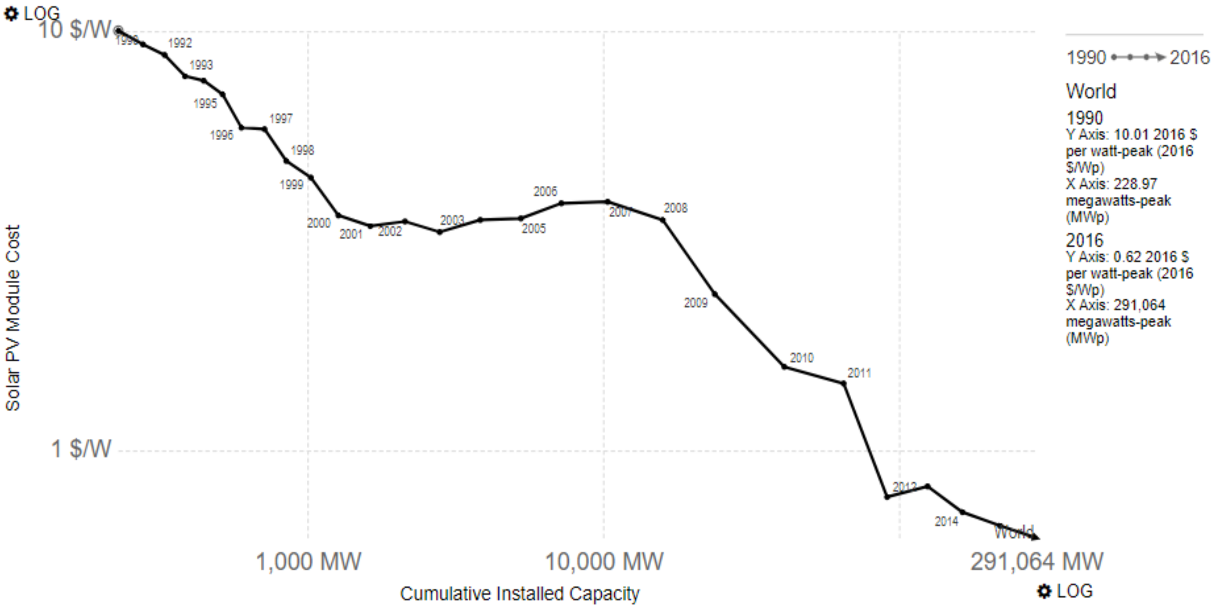
4 World Solar Power

Global installed power capacity reached 6,473 gigawatts (GW)[2] in 2016 from over 5,047 GW in 2010 at a compound annual growth rate (CAGR) of 4.1%. The global power industry is characterized by heavy dependence on thermal fuel sources for power generation, as major power-generating countries such as China, the US, India, Japan and Russia have abundant coal reserves. In recent years, significant economic development in China and India and the increased use of coal resources have driven the rapid growth of thermal generation. With the insecurity surrounding supply of conventional fuels and volatile prices, renewable energy is emerging as a feasible alternative.

However, thermal power is still the largest power-generating source, with a 61.1% share of the global installed capacity in 2016. Cumulative installed capacity for thermal power was 3,954 GW in 2016 and is expected to reach 5,318 GW by 2030 at a CAGR of 2.1%. Hydropower is the second-largest power-generating source with a cumulative installed capacity of 1,200 GW in 2016, accounting for 18.6% of the global power. Renewable energy sources constituted 928 GW (excluding hydropower) in 2016 and had an installed capacity share of 14.3%. Wind power was the largest non-hydro renewable source with a share of over 7.6% of the global power capacity in 2016 followed by solar photovoltaic (4.6%) and biopower (1.8%).

4.1 Global Solar Prices v/s Global Cumulative Capacity

The chart below represents Solar Photovoltaic (PV) module prices (measured in 2016 US$ per watt-peak) versus cumulative installed capacity (measured in megawatts-peak, MWp). This represents the 'learning curve' for solar PV and approximates a 22% reduction in price for every doubling of cumulative capacity. The solar prices have plunged down drastically from USD 10/Watt in 1990s to less than USD 1/Watt in 2016. This reduction was led by reduction in the installation and set up costs of solar and increase in the cumulative capacity. The solar power industry saw an exponential growth from 1990s, where the global installed capacity was less than 1000 MW to the current installed capacity of more than 300 GW.[3]

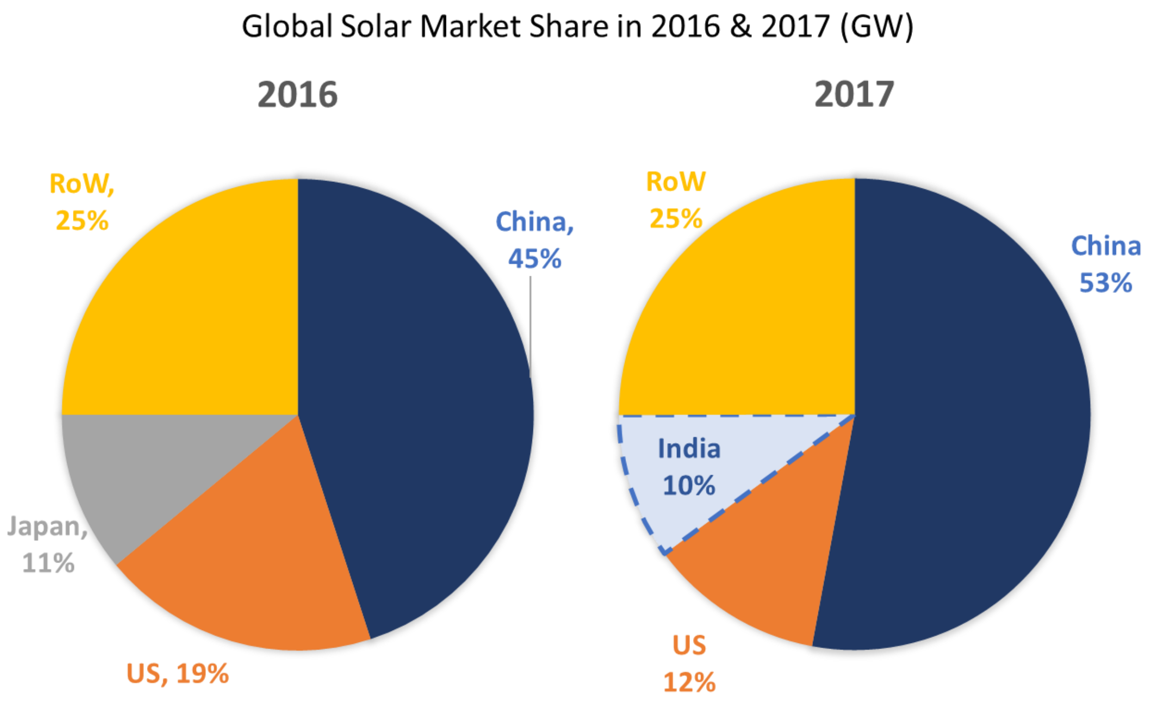


Source: Lafond et al. (2017); IRENA; SolarServer OurWorldInData.org/energy-production-and-changing-energy-sources/ • CC BY-SA

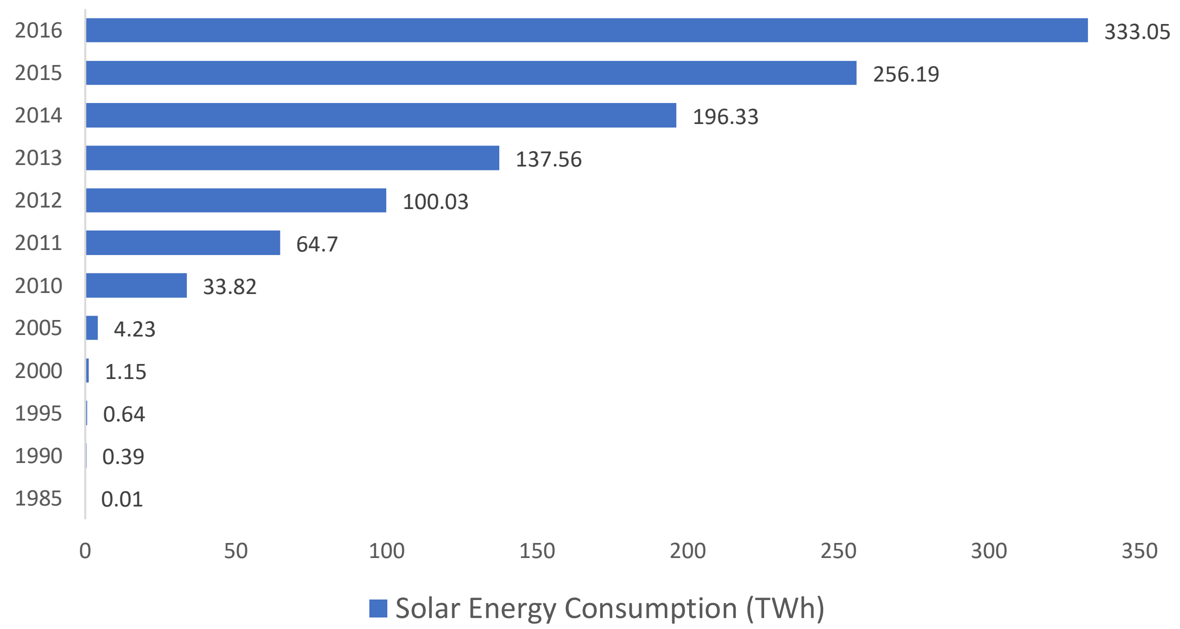
[2] https://www.power-technology.com/comment/q3-2017-global-power-markets-glance/

[3] https://ourworldindata.org/grapher/solar-pv-prices-vs-cumulative-capacity?stackMode=absolute&time=1990..2016&country=OWID_WRL

Total global solar PV installed capacity surpassed 300 GW by the end of 2016. 77 GW was added in 2016, a year-on-year growth rate of 34%. China led with 34.5 GW, followed by the USA (14.5 GW), Japan (10.2 GW) and India (5 GW) in fourth place. However, the global markets installed 98.9 GW of solar PV in 2017. China and India together accounted for 63% of total solar additional installations. China installed 52.83 GW in 2017 well ahead of its closest competitor, US, which installed 10.6 GW followed by India with 9.6 GW.



4.2 Increase in Solar Energy Consumption



The above chart depicts the increase in the solar energy consumption from 1985 to 2016. There has been a significant increase in the global solar energy consumption. The rising electricity demands shift from fossil fuels-based energy to renewable based energy, reduction in the set-up costs of solar power plans, and plunging solar prices are the growth drivers of this exponential growth in the solar energy consumption.[4]

4.3 China (World Leader)

China is the undisputed renewable growth leader. China alone is responsible for over 40% of global renewable capacity growth, which is largely driven by concerns about air pollution and capacity targets which were outlined in the country's 13th Five-Year Plan to 2020. In fact, China already surpassed it 2020 solar PV target, and the IEA expects it to exceed its wind energy by 2019. China is also the world market leader in hydropower, bioenergy for electricity and heat, and electric vehicles.

Today, China represents half of the global solar PV demand, while Chinese companies account for around 60% of total annual solar cell manufacturing capacity globally. As such, market and policy developments in China will have global implications on solar PV demand, supply and prices.

While it still consumes a lot of oil, coal and natural gas, China is experiencing and unprecedented solar boom. As of November 2017, solar PV accounted for 126 GW, a spike of 67% compared to the same time in 2016. Crucially, the country is trying to move away from highly polluting sources of energy, which are estimated to have contributed to 366,000 deaths in 2013 alone. In its yearly overview of the world's energy markets, the International Energy Agency (IEA) finds that China is entering a new phase of its economic development, moving away from heavy manufacturing and other carbon intensive industries. Ambitious investments in clean energy projects such as floating solar farm, located in the coal-rich Anhui province, are part of the same overarching effort to clean up the Chinese economy.

China connected 34.5 GW to the grid, a 128% increase over the 15.1 GW it added the year before. This strong growth rate came as a surprise and was triggered by a feed-in tariff cut in the middle of the year that led Chinese developers to install over 20 GW alone in the first six months of 2016. After demand almost paused in Q3, strongly falling module prices enabled a year-end run that led to an annual installation volume in China representing nearly half of the entire world's new solar capacity in 2016. The year 2017 proved to be an outstanding one for China's solar industry. The country added an astounding 52.8 GW in solar installations, a 53% Year-over-Year (YoY) increase in terms of solar photovoltaic (PV) power capacity by end of 2017 compared to 34.54 GW installed in 2016. China added a total of 133 GW[5] of power generation capacity in 2017 with solar dominating the energy mix. The 53.06 GW of solar added was more than the most conventional form of electricity – thermal power, which could add power capacity to 45.78 GW of the energy mix. For China, this was the first time when solar capacity addition exceeded thermal power in a year.

4.4 United States

The United States was the world's second largest solar power market in 2016. The country's annual installed solar capacity was up 97% year-on-year, achieving 14.8 GW, compared to 7.5 GW in 2015. The solar power industry of the US comprises of utility-scale solar plants as well as rooftop photovoltaics. While the 2016 solar growth was carried on many shoulders – with 22 states each adding more than 100 MW, California remained the largest market with over 5 GW, much ahead of Utah with 1.2 GW. Most of the US solar growth come from utility scale solar, which was even bigger

[4] https://ourworldindata.org/renewables#solar-pv-energy
[5] https://mercomindia.com/china-2017-solar-report/

than the years before – reaching around 10 GW or over two thirds of newly added capacity. This was due to an expected expiration of the 30% solar investment tax credit at the end of 2016, which finally did not take place, but resulted in a huge pipeline that was contracted to be online by the end of that year. As of the end of 2017, the US had over 50 GW of installed capacity of solar PV.

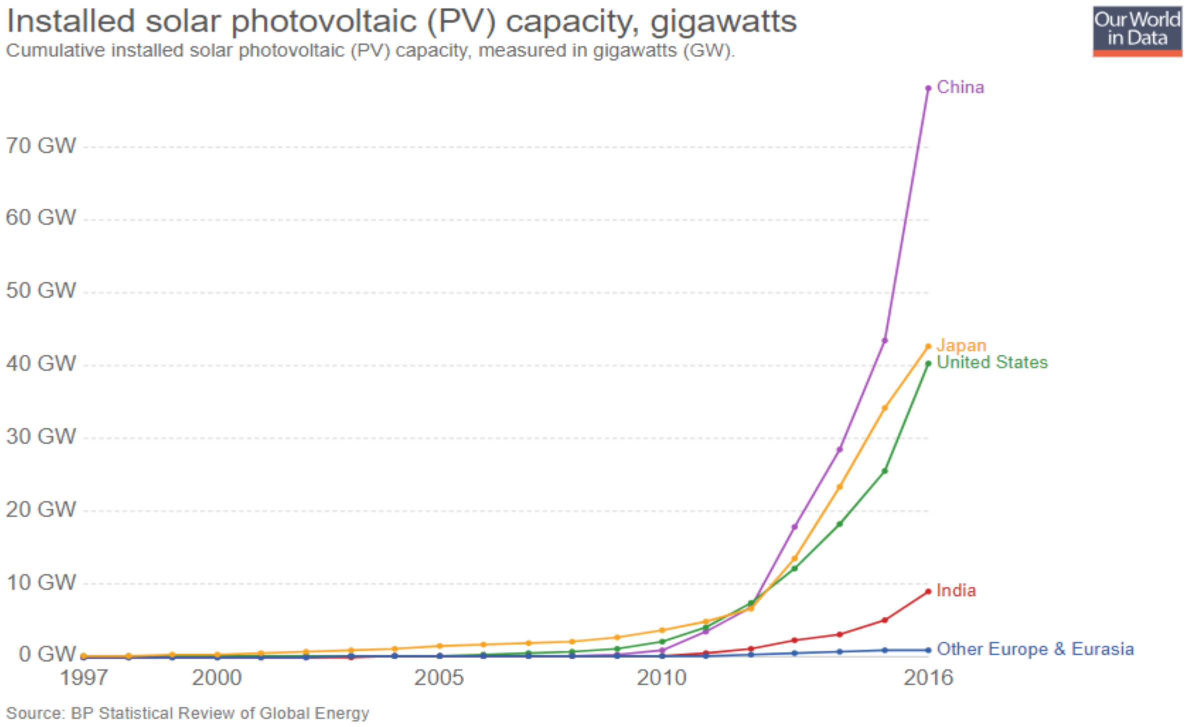
4.5 Japan

Following its demand climax in 2015, the solar market in Japan decreased as anticipated in 2016, despite its nearly 50 GW solar capacity is in pipeline but is yet not built utility-scale solar plants. At 8.6 GW newly added capacity, Japan was still the world's third largest solar market in 2016. But in the coming years, new PV capacity additions are expected to shrink further. The reasons for Japan's solar market consolidation are manifold – from declining government support for solar, which prefers the comeback of nuclear and heavily invests in coal, to PV development and grid connection difficulties and an energy market reform that is unbundling the oligopoly of Japanese power generation companies. As Japan will move from a feed-in tariff to a tender scheme for large-scale solar this year, the PV rooftop segment will soon play an increasing role in the country's solar market.

4.6 Europe

After a slight market uptick in 2015, solar power in Europe continued its several-year long downward trend in 2016, adding 6.7 GW, a 21% decrease compared to the 8.6 GW installed in 2015. The European market decline in 2016 is primarily a result of the UK terminating its attractive solar incentive program. Two European countries belonged to the top 10 global solar markets in 2016 – the UK ranked 4th and Germany ranked 5th.

Developed countries are slowly shifting towards utility scale projects, whereas in emerging markets, governments are trying to encourage more rooftop solar growth. Asia continues to dominate the solar industry while Europe continues to fall in rankings. In 2016, Asia-Pacific has become the largest solar-powered region in the world – with 147.2 GW of total installed capacity, equal to 48% global market share. The European solar pioneers, which still owned the major global portion in 2015, are now ranked second – with a cumulative PV capacity of 104 GW and a 34% share. America (including north, Central and South America) remains third at 45.9 GW and a 15% stake. The Middle East and Africa lost market share – the total solar capacity of 4.7 GW results in a world market share of 1.5%



China is the undisputed leader in solar power industry. However, by the end of 2016, India for the first time surpassed the installed capacity of European Union, making India rank fourth in the world.

In summary, the low cost of solar has sparked huge interest for this clean and flexible technology in many countries around the world. China dominated in solar power in 2016 and a few other solar markets were driven by 'traditional' subsidy schemes.

5 Indian Solar Industry

5.1 Historical Background of Indian Solar Power

Solar power is an attractive source of power as it is abundant, freely available and offers solution to fossil fuels emissions and global climate change. Earth receives solar energy at a rate of approximately 1,73.000 TW, which is more than enough to fulfil the global energy requirement.

India has 300 clear sunny days in a year and has high solar insolation, making India a potential country for solar power generation. The Rural Electrification Program of 2006 was the first step by the Indian Government in recognising the importance of solar power. It gave guidelines for the implementation of off-grid solar applications. This primarily included solar lanterns, solar pumps, home lighting systems, street lighting systems and solar home systems. In 2007, as a next step, India introduced the Semiconductor Policy to encourage the electronic and IT industries. This included the silicon and PV manufacturing industries as well. Market players like Titan Energy System, Indo Solar Limited and KSK Surya Photovoltaic Venture Private Limited have installed plants for PV modules. This move helped the manufacturing industry to grow.

There was also a need for a policy to incorporate solar power into the grid. The Generation Based Incentive (GBI) scheme, announced in January 2008 was the first step by the government to promote grid connected solar power plants. The scheme for the first time defined a feed-in tariff (FIT) for solar power (a maximum of Rs. 15/kWh). Since the generation cost of solar power was then still around Rs. 18/kWh, the tariff offered was unviable. Also, under the GBI scheme, a developer could not install more than 5MW of solar power in India, which limited the returns from scale. One of the main drawbacks of the GBI scheme was that it failed to incorporate the state utilities and the government in the project development, leaving problems like land acquisitions and grid availability unaddressed. As a result, despite the GBI scheme, installed capacity in India grew only marginally to 6MW by 2009. In June 2008, the Indian government announced the National Action Plan for Climate Change (NAPCC). A part of that plan was the National Solar Mission (NSM).

The NSM guidelines indicated that the government had improved on the shortcomings of the GBI scheme. It aimed to develop a solar industry, which was commercially driven and based on a strong domestic industry. The extra cost of generation of solar power was being borne by the federal government under the GBI scheme. Even before the NSM, Gujarat was the first state to come up with its own solar policy in January 2009. The Gujarat solar policy initiated a process of the states formulating their own policy frameworks independent of the federal guidelines. The renewable purchase obligations for state distribution companies, a demand-driven scheme, further accelerated the formulation of solar policies at the state level. These policies exist independent of each other as well as the NSM. One of the key novelties of the Gujarat policy was that it introduced the concept of solar parks. These parks offered a comprehensive solution to concerns over land acquisition, grid connectivity, and water availability, hence offering developers a project allocation packaged with the necessary infrastructure. Other states like Karnataka, Andhra Pradesh and Rajasthan have followed suit in developing solar power development programs. Rajasthan has implemented land banks as well to make land acquisition easier. As more states plan to meet their solar power obligations, new policies are expected to be offered, creating as very vibrant set of markets across the subcontinent.

5.2 Indian Regulatory Evolution

The importance of electricity was recognised by the Indian Government since the Electricity Supply Act 1948. It established Central Electricity Authority (CEA) as an advisory body for power planning, policy making and monitoring progress of State Electricity Boards (SEBs) which were state level, vertically integrated utilities responsible for power generation, transmission and distribution.

Amendments to the Electricity Supply Act in 1991, allowed private players, including foreign investors, to come in as independent power producers and enter into long-term supply contracts (power purchase agreements) with utilities.

In 1996, the vertically integrated SEBs were restructured and privatised. Orissa was the first state to unbundle its SEB into private companies each responsible for one of generation, transmission, or distribution—and created an independent body for regulating and determining tariffs for the electricity sector. As India's economy continued to face crippling power shortages, states started restructuring their SEBs and establishing state electricity regulatory commissions (SERCs) under their own state reform legislative initiatives. The Electricity Regulatory Commission Act of 1998 set up the Central Electricity Regulatory Commission (CERC) and brought regulatory consistency to the states.

In 2003, the Electricity Act was established to consolidate the laws relating to generation, transmission, distribution, trading and use of electricity. Notable initiatives were the delicensing of thermal generation, the introduction of power trading as a licensed activity, the strong emphasis on competition, the adoption of multiyear tariff frameworks, and the promotion of rural electrification and renewable energy. The EA mandated unbundling and corporatizing utilities and establishing independent regulators as steps that would increase utility accountability for performance to external stakeholders, limit state government control, and create internal accountability for results.

After the establishment of the Electricity Act 2003, sustainability and energy security have been spotlighted through India's National Action Plan on Climate Change, which were released in 2008. The action plan comprises eight national missions to enable progress on various fronts, with several goals relevant to the electricity sector, such as increasing the share of solar energy in the generation mix and raising energy efficiency through industrial energy savings, greater adoption of efficient appliances, and demand-side management.

With the steady shift of power sector from non-renewables to renewables led to some regulatory modifications for renewable energy resources which mainly focused on bringing competition in different segments, setting up an independent regulatory commission (Ministry of New and Renewable Energy - MNRE), and establishing a proper funding mechanism (Indian Renewable Energy Development Agency - IREDA).

At the central level, the Ministry of New & Renewable Energy (MNRE) is the nodal ministry dealing with renewable energy. MNRE's objective is to develop and deploy renewable energy to augment the energy needs of the country. MNRE has set up three specialised technical institutions - National Institute of Solar Energy (NISE), National Institute of Wind Energy (NIWE) and Sardar Swaran Singh National Institute of Renewable Energy. Whereas, IREDA is a non-banking financial company operating under the MNRE, which provides loans and also directs funds and other initiatives to promote renewable energy. Additionally, Solar Energy Corporation of India (SECI) is involved in all segments of renewable energy and among other things, owning solar power plants, generating and selling power and in other segments of renewable energy sector activities, including manufacturing of solar products and materials. The Ministry of Power (MoP) formulates the broader electricity law framework which has a direct impact on renewable power procurement and the overall institutional structure for such procurement. Therefore, at the Central level, MNRE leads the charge on renewable energy development and deployment but relies on the MoP for large-scale policy changes to achieve its objectives.

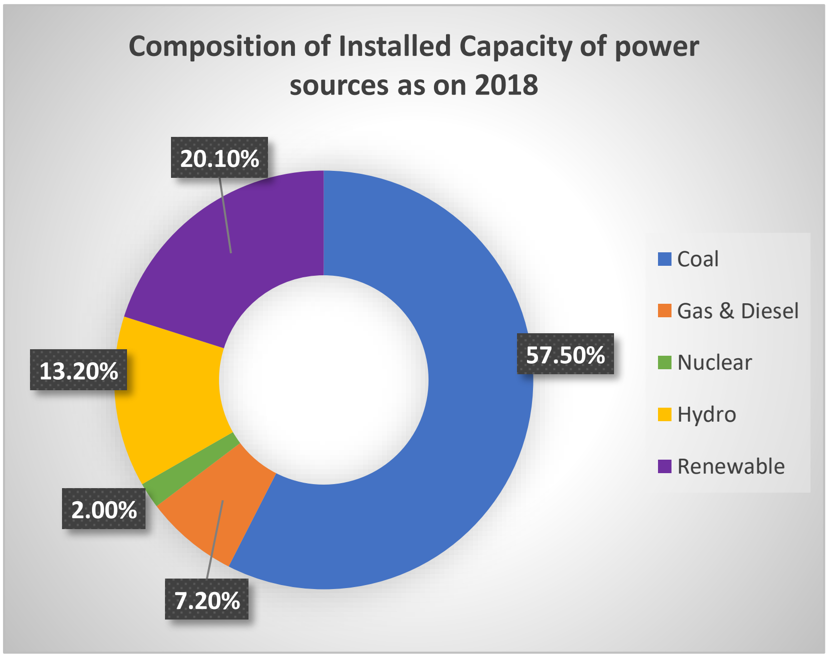
5.3 Indian Solar's Growing Capacities

The Indian power sector is one of the most diversified power sectors in the world. Sources for power generation range from non-renewable sources like coal, lignite, natural gas, oil, hydro and nuclear power to other renewable sources like wind, solar and agriculture and domestic waste. The total installed capacity of power generation in India has increased more than three times from 100.35 GW[6] as on 1st January 2010 to 340.53 GW as on 31st March 2018 out of which 32.2% of total installed capacity is constituted by renewable power plants.

One of the renewable energy source that is available in abundant in India is solar energy which is why it is one of the fastest developing industry in India. The Indian Government took its first step in recognising the importance of solar power by establishing The Rural Electrification Program 2006. It gave guidelines for the implementation of off-grid solar applications. India's solar installed capacity reached 20 GW (20000 MW) in March 2018 from 0.16 GW (161 MW) in March 2010. The 20 GW was initially targeted for 2022 but India achieved the target 4 years ahead of the schedule.

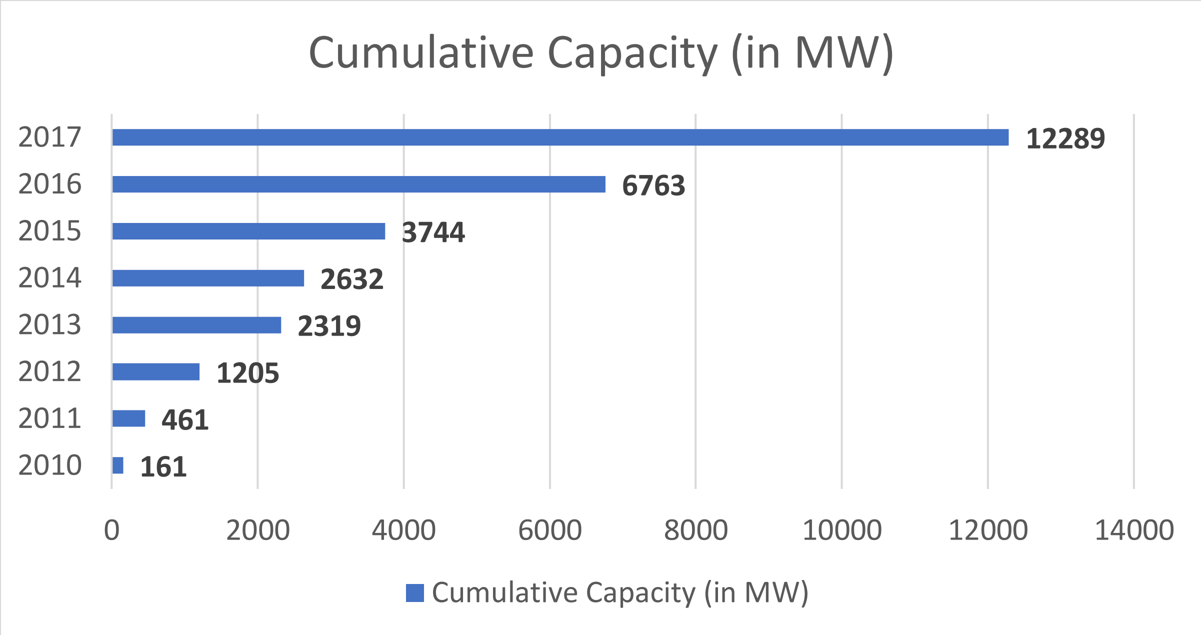
With the growing economy and power production of 1433.4 TWH (Terawatts Hours) in 2017, India was the 3rd largest producer and consumer of electricity in world, having a steady increase in installed capacity of 340.53 GW as on 31st March 2018 from installed capacity of 132.3 GW as on 2007.

However, according to Central Electricity Authority (CEA), India's apex power planning body, the per capita electricity consumption of India reached 1075 KWH (Kilowatt Hours) in 2015-16 from 631.4 KWH in 2005-06. India's per capita electricity consumption crossing 1000 KWH is certainly a milestone but without much significance. One-fourth of the households in the country still have no access to electricity, with some states in East and North East having less than even 30% households with electricity access. India's per capita consumption is among the lowest in the world. In comparison, China has a per capita consumption of 4000 KWH, with developed countries averaging around 15000 KWH per capita. India's robust economy needs a way to sustain its exponentially increasing appetite for energy. India's electricity sector is dominated by fossil fuels, particularly coal, which in 2016 produced about three fourths of all electricity. However, government is pushing for an increased investment in renewable energy, to balance sustainable development along with energy security. Making choices for the future, India has placed its bet on both coal and solar. Coal shall provide base load power and solar peak load power.



To encourage investments in renewable energy, the Government of India has targeted to increase the capacity of 88.9 GW under the 12th Five Year Plan (2012-17) and around 100 GW under the 13th Five Year Plan (2017-22). The target for renewable energy has been increased to 175 GW by 2022. Investments of around USD 250 billion are planned to meet the estimated contribution of 60 GW of wind energy followed by 100 GW of solar energy by 2022.

[6] https://powermin.nic.in/sites/default/files/uploads/Annual_Report_2009-10_English.pdf



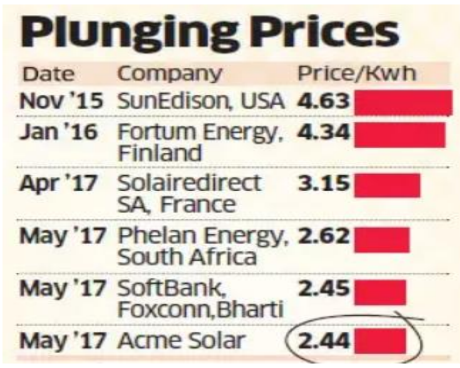
In India, the installed capacity of solar energy increased from 0.16 GW (161 MW) as on 2010 to 20 GW (20000 MW) as on March 2018. Over the last few years, the solar power's installed capacity in the country has increased tremendously owing to favourable government initiatives coupled with development in manufacturing technology of solar panels.

According to the International Renewable Energy Agency (IRENA), India overtook the continents of North America and Europe, as well as Japan, in terms of solar power capacity added during 2017. India added 9.6 GW[7] of solar capacity in 2017, up from 4.25 GW in the previous year. At the end of the year, India's cumulative solar installations reached 20 GW. Telangana became the first Indian state to achieve more than 3 GW of cumulative installed solar capacity in 2017 after it added approximately 695 MW of solar installations during the fourth quarter of 2017 alone. Karnataka grabbed the number two spot in cumulative solar installations with 2.8 GW after adding approximately 950 MW during the fourth quarter of 2017. But in the first quarter of 2018, Karnataka became India's top solar PV state. So far, in 2018, Karnataka has maintained its brisk pace of solar project commissioning.

Indian Solar Power Industry is anticipated to have double digit growth in the next few years, due to government's policy to increase the share of solar energy in the power generation mix and falling equipment (PV Modules) prices globally.

5.4 Plunging Solar Prices

Solar power tariff in India has witnessed a drastic fall over the last few years. Low solar tariffs are hurting the solar developers and obviously gaining the buyers. It began when Government of India started awarding projects to developers through reverse auction basis. Even though India holds an enormous opportunity for the developers to grow their portfolios aggressive bidding have diminished their returns.



Plunging Prices

Date	Company	Price/Kwh
Nov '15	SunEdison, USA	4.63
Jan '16	Fortum Energy, Finland	4.34
Apr '17	Solairedirect SA, France	3.15
May '17	Phelan Energy, South Africa	2.62
May '17	SoftBank, Foxconn,Bharti	2.45
May '17	Acme Solar	2.44

[7] https://cleantechnica.com/2018/04/24/india-beats-north-america-europe-japan-in-2017-solar-additions/

Solar power tariffs in India dropped to a historic low of 2.44 per unit (1 unit = 1 KWH)[8] in May 2017, after Acme Solar Holdings SGB Cleantech, the joint venture of SoftBank, Foxconn and Bharti Enterprises, won the auction of 500 MW of projects in Rajasthan. Acme won 200 MW with the record low tariff. Before that, the lowest tariff had been INR 3.15/KWH, arrived at during an NTPC auction of 250 MW at the Kadapa Solar Park in Andhra Pradesh on April 2017. Fall in the cost of solar panels globally has brought the solar tariffs down.

While the solar market has become a buyer's market, developers have been working on a very thin margin due to low solar tariffs. DISCOMs either manage to get the solar developers reduce their prices or refuse to purchase the power. A case in point being Andhra Pradesh which has refused to sign a Power Purchase Agreement (PPA) with state owned NTPC Ltd.'s 250 MW[9] project at Kadapa in South-Central Andhra Pradesh, which was awarded to French clean energy firm Engie's subsidiary Solairedirect SA for INR 3.15 per unit. There is a unique situation developing in the Indian solar industry where the tariff procurers believe that the next tender will further bring down the tariffs and that there is no urgency to sign PPAs to buy the electricity at higher tariffs.

However, solar tariffs perked up in the latest Karnataka auction. The solar tariffs rose sharply from their lowest level in the latest solar auction of 860 MW conducted by Karnataka's Renewable Energy Development ltd. (KREDL)[10]. The lowest price was Rs. 2.94 per unit above the winning tariffs of Rs. 2.44 per unit at the last two auctions in Rajasthan in May last year. Though Karnataka gets lower solar radiation than Rajasthan and the winning tariff was expected to be consequently higher, the 50 paise per unit rise is striking.

The developers for long had been quoting low solar tariffs relying on the information of consistent fall in the cost of the solar panels. This indeed happened but recently the developments have seen a slight uptick in the prices of the solar panels. India is overly dependent on China for the solar panels. Around 90% of solar equipment used in India is imported, mostly from China, since it is substantially cheaper than the locally manufactured variety. Supplies to oversees were disrupted as the demand for panels shot up in the Chinese market itself, this led to the increase in the solar tariffs. This uptick in tariffs confirms the view of many developers and lenders that bidding in the last few solar auctions had been too aggressive, and some correction was likely, more so because the cost of solar panels and modules has been rising in China.

5.5 India's Coal Dependency and Solar Challenges

India, a major importer of coal from Indonesia, has doubled its production targets, aiming to produce 1.5 billion tons of coal by 2020. The intent is to reduce its import dependence and provide coal to the underutilized thermal power plants in the country. India is also rapidly expanding its coal-fired electricity generation capacity, with around 113 GW of new capacity already under construction in addition to the 205 GW of existing capacity. In 2012, electricity generated from sub-critical coal-fired thermal plants accounted for 71 percent of India's electricity generation and this scenario is expected to change only slightly in the next two to three years. Given the investments underway and the abundance of the resource in the country, coal will undoubtedly continue to play a dominant part in India's energy mix.

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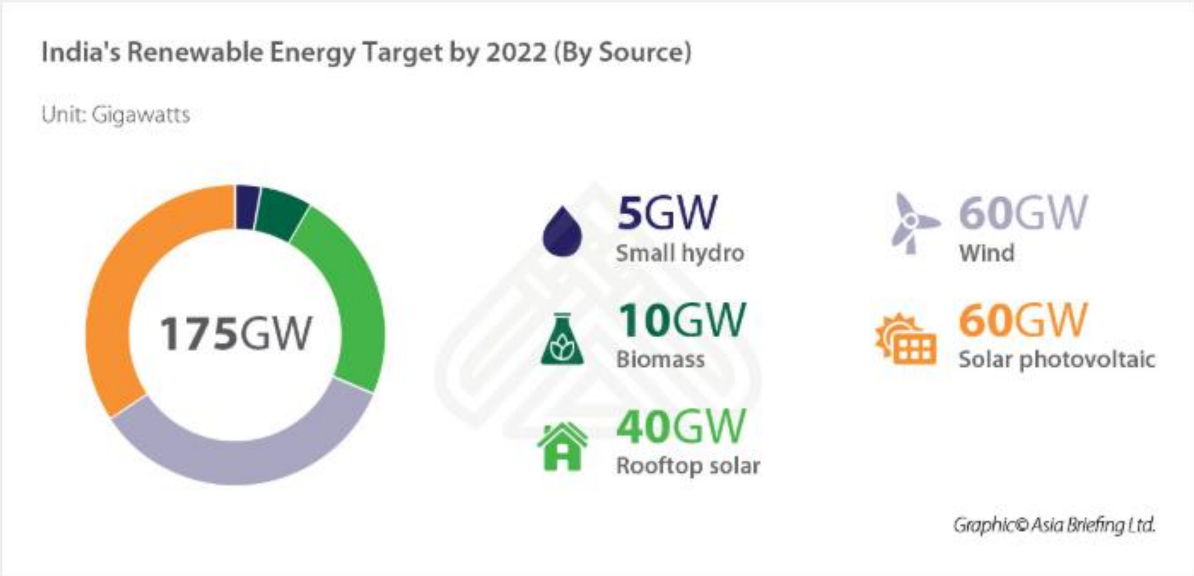
[8] https://economictimes.indiatimes.com/industry/energy/power/solar-power-tariff-drops-to-historic-low-at-rs-2-44-per-unit/articleshow/58649942.cms

[9] https://www.livemint.com/Industry/YP4O4FOY598j9CqmRaRfOM/Will-low-tariffs-eclipse-Indias-solar-run.html

[10] https://economictimes.indiatimes.com/industry/energy/power/solar-tariffs-perk-up-in-latest-karnataka-auction/articleshow/62765631.cms

However, India is also moving to increase the share of renewable energy. India has set a goal to achieve 175 GW of renewable energy capacity by installing 100 GW of solar, 60 GW of wind, 10 GW of biomass, and 5 GW of small hydroelectric projects by 2022. Of the 100 GW target of solar, 40 GW is expected to be achieved through the deployment of rooftop projects, 40 GW through utility-scale plants, and 20 GW through ultra-mega solar parks. This is an ambitious goal considering that world's installed solar power capacity in 2014 was only 181 GW. India wants to grow its solar capacity to not only provide electricity to remote areas but also to reduce the carbon emissions. India, in its INDC (Intended Nationally Determined Commitment), committed to reducing its emissions intensity by 33 percent to 35 percent below 2005 levels by 2030.[11]



While the impetus has been provided by the centre, almost every state in the country now has a renewable or solar energy policy. Incentives like GBI (Generation Based Incentive), AD (Accelerated Depreciation), Viability Gap Funding, capital subsidy, and feed-in-tariffs, both at the federal and state level have helped increase India's total installed solar capacity by over 80% in September 2016 to reach 8.1 GW. Initiatives for the development of 25 solar parks, Ultra Mega Solar Power Projects, canal top solar projects, and 100,000 solar pumps for farmers are at different stages of implementation. However, the political economy of a weak power sector and the continuous power struggle between the state and centre has undermined this progress to an extent.

Internationally, India has pledged USD 30 million over five years to establish International Solar Alliance (ISA) with 121 nations across the globe as members, to facilitate easier finance from multilateral banks for solar projects. Domestically, India is working on incentives to promote renewable energy deployment over coal through fiscal instruments like an increased coal access, cuts in fossil fuel subsidies, increase in taxes on petrol and diesel, and market mechanisms like Renewable Energy Certificates (REC) and a regulatory regime of Renewable Generation Obligation (RGO) and Renewable Purchase Obligation (RPO). However, ramping up India's solar capacity from 8.1 GW to over 100 GW in the next six years would entail adding over 15 GW in solar capacity every year, which necessitates finding solutions to a number of structural problems.

[11] https://thediplomat.com/2016/09/indias-power-struggle-and-solar-epiphany/

5.6 Grid Evacuation Infrastructure Concerns

States like Rajasthan, Gujarat, Madhya Pradesh, Tamil Nadu, Andhra Pradesh, and Telangana account for around 80% of India's total installed solar capacity against only 38% of India's overall power consumption. Most of the other power consuming states are lagging behind in setting up new solar capacities. On the other hand, states with high capacity for renewable energy are facing significant grid curtailment, upsetting project cash flows and the expectations of investors.

The Green Energy Corridor Project, spearheaded by the state-owned Power Grid Corporation and financed by the Asian Development Bank (ADB) and Germany's development bank KFW, is expected to enhance the electric grid's transmission capacity. It is designed to transmit 55 GW of solar and wind power being generated in eight renewable energy-rich states to load centres in the country's north. However, if grid evacuation infrastructure doesn't match the pace at which India wants to scale up solar energy, the stability of the grid might be compromised.

Apart from this, India also needs to invest in R&D to augment grid level storage in order to balance the variability in the grid due to renewable penetration, reduce its exorbitant Aggregate Technical and Commercial (AT&C) losses, strengthen its wholesale market, and design its DSM (Demand - Side Management) architecture. The government's recent Integrated Power Development Scheme (IPDS) policy intends to reduce AT&C losses, strengthen Sub-transmission and distribution network, and fix administrative losses in accounting, billing, and collections through IT integration. Rapid implementation at the state level, however, will be the key to success.

5.7 High Cost of Financing

India will need $250 billion in the next six years and $1 trillion by 2030 to provide 24/7 electricity to all its citizens. The World Bank sees this solar impetus as an investment opportunity and is providing $1 billion to support India's ambitious solar initiatives. However, the harsh on-the-ground reality is that the high cost of capital, foreign currency risk, and unfavourable terms of debt are the biggest deterrents for renewable energy projects in India. Inferior terms of debt such as high costs, short tenor, and a variable interest rate add approximately 30% to the total cost of renewable energy in India compared to developed countries. The increased cost is a major barrier for solar producers.

5.8 Powerless Regulators and Fledgling State Power Distribution Utilities (DISCOMs)

Enforcement of the Renewable Purchase Obligation (RPOs) target (17% by 2022, with an 8% minimum provision for solar energy) has so far been slack due to misalignment of incentives and lack of enforcement mechanisms. India's Supreme Court has signalled a strong stance against those who are non-compliant with the RPO. However, the Central Electricity Regulatory Commission (CERC) and State Electricity Regulatory Commissions (SERCs) need to ensure stricter compliance, yet both are handicapped by staffing crunches and have backlogs of pending cases.

State DISCOMs, on the other hand, are in distress due to political pressures as well as poor financial and operational practices such as billing irregularities, pricing failures, a legacy grid infrastructure, network unreliability, transmission and distribution losses, and electricity theft (averaging 22.7 percent). Government policies like Ujwal DISCOM Assurance Yojana (UDAY) and the Power Sector Development Fund (PSDF) are intended to turn around these DISCOMs, which have accumulated losses of approximately $54 billion (as of March 2015), in the next 2-3 years. Under these policies, the central government mandates states to take up to 75 percent the DISCOMs' debt and ensure their financial viability. However, the problems of repressed tariffs, power subsidies, political interference, poor infrastructure, lack of stringent compliance and enforcement mechanisms, and poor management practices at DISCOMs are going to remain the biggest impediments to the success of the envisioned turnaround.

5.9 Land Acquisition Woes

60 percent of India's ambitious 100 GW goal focuses utility-scale ground-mounted grid-connected solar energy. Most state governments have promised single window clearances for environmental impact assessment and easy land acquisition procedures in their solar energy policies. However, the truth is that land acquisition in India continues to be one of the biggest hurdles to investment opportunities in solar projects. The 2013 land acquisition law calls for consent from 70 percent of families in case of public-private partnership projects and 80 percent If the land is being acquired for a private company. A social impact assessment is also mandated by law for any land acquisition. Unfortunately, in 2015 government failed to get the amendment to the Land Acquisition Bill 2013 necessary to simplify norms of consent and social impact assessment.

5.10 Rooftop Solar

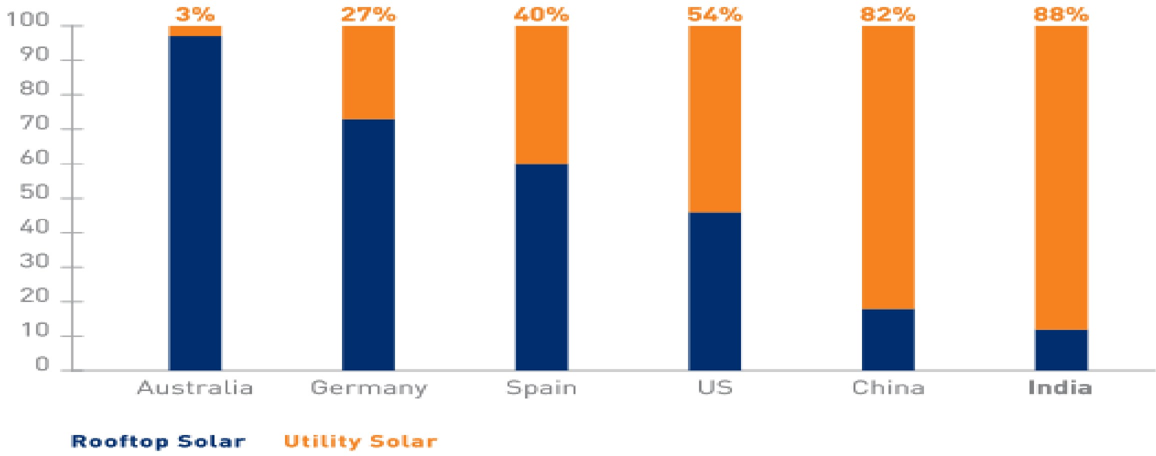
Currently Solar Energy fulfils about 0.5%[12] of earth's energy needs, however, as per several reports, Solar Energy is on the way to become one of the largest sources of energy. It is expected to supply 16% of energy requirements by 2050. India alone has set up a target of 100 GW solar by 2022. Out of which, 40 GW is to come from rooftop solar. Nonetheless, this journey doesn't seem easy. There are obstacles at every step.

One of the biggest markets for solar energy is the distributed rooftop segment. This is a game-changer segment. Advantages of rooftop solar PV plant are multi-fold. It aids DISCOMs by reducing the peak demand during daytime and leads to decreased transmission and distribution losses as the power is consumed at the point of generation, it reduces land and interconnection costs, it has minimum government intervention as there is less involvement of government infrastructure, it can also be set up in remote places, and it also produces considerable savings for the consumer over its lifetime because of the increasing costs of grid electricity. All the other energy solutions, wind energy, thermal energy, utility scale solar, nuclear, hydro and many others, require huge setups and investments. Then, these also require deeper and troubling government intervention. Hence, solar rooftop segment presents a huge opportunity for countries like India.

[12] https://amplussolar.com/blogs/narendra-modis-india-facing-unique-solar-challenges

Despite the obvious advantages, rooftop Solar has not really taken off. In India, rooftop solar has maintained a 10% - 12%[13] share of overall solar capacity. This is much lower than other key markets such as US, Germany, China, Spain and Australia.

Figure 2: Share of utility scale solar vis-à-vis rooftop solar



Source: BRIDGE TO INDIA research

But there has been a significant slowdown in the pace of tenders announced mainly due to weak power demand growth in the country. By many accounts, the Indian solar market is on a roll. About 12.4 GW of projects have completed auctions and are in execution stages right now. 7 developers have built up project portfolios exceeding 1 GW mark. But all is not as it seems. The pace of new tender announcements and that of completed auctions have slowed down significantly in 2016 (-68% and -59% respectively) Southern states have frontloaded capacity buildout – Karnataka (Installed plus tendered capacity of 69% as against March 2022 target); Andhra Pradesh (74%) and Telangana (70%) – and are bound to slowdown. Amongst other large states, Maharashtra and Gujarat, like many others have surplus power availability and remain unenthusiastic to new solar power.

5.11 Anti-Dumping Petition

With an increase in the volume of imports of cells and modules by 33% to 45%[14] between July and December 2016, the Indian Solar Manufacturers Association (ISMA), the representative body of the domestic manufacturers of solar cells, modules and panels, approached the Directorate General of Anti-Dumping and Allied Duties (*DGAD*), requesting an imposition of a duty on importers of cheap solar inputs.

In March 2018, however, it withdrew the petition it had filed in July 2017 for anti-dumping investigation on solar cells and modules imported from China, Taiwan and Malaysia, and said it would file a fresh plea, seeking to extend the period of investigation after a considerable increase in solar imports was noticed in the second half of 2017.

Currently, solar power plants using domestic solar cells have been subsidised through Viability Gap Funding (VGF) to enable domestic manufacturers to remain competitive in the local solar power market. Most of the big projects, however, have been using Chinese modules, which are way cheaper than subsidised Indian ones.

[13] https://amplussolar.com/blogs/narendra-modis-india-facing-unique-solar-challenges

[14] https://www.thequint.com/news/environment/indian-solar-sector-funding-fell-65-last-quarter

Indian solar manufacturing industry has been under significant stress due to dumping of cells and modules by China since 2011.

Anti-Dumping, if implemented will enable solar manufacturing ecosystem, which in turn will create 250000 jobs, enable self – sufficiency in renewable power, provide a platform for R&D and make India an alternate supplier of solar products to the global markets. However, it will also make the costs of the solar projects to go up. With rising costs and dropping tariffs will impact the already thin margins of the solar developers in India.

In January 2018, the Director General of Safeguards proposed a 70% safeguard duty on imported solar cells and modules after a petition was filed by ISMA again. Following the move, there was unrest in the sector, with some developers voicing that it would have a negative impact.

The Anti-Dumping petition was filed asking for the duty, stating that damaged and cheap solar cells were impacting indigenous manufacturing units. Moreover, Chinese dumping of products in India was accentuated owing to duties enforced by European Union and the US on Chinese imports, causing them to divert all the stock to India at a cheaper price than the cost. While the outcry has been that the duty be imposed retrospectively, the existing cost and viability of plant will be impacted.

6 Project Cost of Solar Power Plants

Solar Power industry in India is gaining more and more prominence with each passing day. According to the Benchmark Capital Cost Order of CERC for the FY 2016-17, the capital cost of setting up a 1 MW solar PV projects in India would be around INR 501.32 lakhs/MW. The cost of setting up a solar power plant has reduced by 34.2% over the past 5 years. The capital cost of solar PV plant experience declines over the years mainly due to steep decline in price of solar PV modules, which constitute 60% - 70% of capital cost.

6.1 Modules

Figure 1: Monthly average Chinese module spot prices (Source: Mercom)

Module prices for the first 10 months show a drop of 8.5% in the first 10 months of 2015. However, in the last few months it showed a steady trend. According to the data collected by CERC, since November 2014, the regional module prices have dropped 11% - 15%, though they recovered a bit by the end of the year due to heavy demand from China and US. Assuming the similar 11% drop over the next 12 months, the module prices by the end of 2017 is expected to fall to $0.48/W from the 2016 year-end module prices of $0.54. It should be noted that the estimated prices of modules are typically higher than the bulk prices that are negotiated by companies for large MW scale plants. Thus, it was observed that the prices for modules being deployed in the Indian market currently are in the range of $0.43/MW - $0.50/W. The exchange rate considered is the average exchange rate for INR to USD for the past 6 months (May 2015 – October 2015). The commission has also considered module degradation of about 0.6%, which gives a module degradation cost of INR 9.89 lakhs/MW. Accordingly, the total module cost is proposed at **INR 310.19 lakhs/MW**[15]

Summarising the cost components[16]

S. No.	Particulars	Capital Cost norm proposed for FY 2016-17 (INR lakhs/MW), for Solar PV Projects	% of Total Cost
1	PV Modules	310.19	62%
2	Land Cost	25	5%
3	Civil and General Works	35	7%

[15] http://www.cercind.gov.in/2015/orders/SO17N.pdf
[16] http://www.cercind.gov.in/2015/orders/SO17N.pdf

4	Mounting Structures	35	7%
5	Power Conditioning Unit	30	6%
6	Evacuation Cost (Cables and Transformers)	40	8%
7	Preliminary and Pre-Operative Expenses	26.13	5%
	TOTAL CAPITAL COST	501.32	100%

Considering the above facts and data, the Commission proposes to consider total cost of Solar PV power projects for the FY 2016-17 as **INR 501.32 lakhs/MW** as Benchmark Project Capital Cost of Solar PV Projects.

6.2 Operations and Maintenance (O&M) Cost

The Operations and Maintenance (O&M) Costs comprise of the expenses which are manpower related as well as administrative in nature and thus, inflationary in trend. O&M of the plant is extremely essential and any compromise in O&M expenses will make it difficult for plant to run for 25 years. Most of O&M cost comprises manpower cost which is independent of capital cost. O&M contracts are either outsourced or taken care by the EPC developer itself. Therefore, commission proposed the O&M cost for the FY 2016-17 as **INR 7 lakhs/MW**[17] with an escalation rate (inflationary) of 5%.

[17] http://www.cercind.gov.in/2016/regulation/SOR_119.pdf

7 Economics of Solar Power Plant

Lying between Tropic of Cancer and Tropic of Capricorn, most of India's land mass fall squarely in the tropical region giving it peak solar radiation, particularly in summer months. The National Institute of Solar Energy's study indicated that the country has the potential to generate 748.89 GW[18] of solar power.

Along with the various government initiatives for solar power projects, equally important was a well-timed drop in the cost of solar panels and components for creating solar power, which saw the tariffs reduce from INR 7.8 per unit to INR 2.44 per unit (1 unit of electricity = 1 KWH). However, there continue to be some dark clouds on the horizon in spite of such sunny figures. A combination of economic and policy factors has slowed down the growth in the sector, particularly in the last few months.

In past few months, almost all the major Chinese module manufacturers had increased their module prices and were renegotiating supply contracts signed earlier, putting in jeopardy already strained margins of the projects that have been secured at very low tariff bids in recent months across India. The development is expected to impact project implementation plans of several leading solar project developers which have already been stung by the rapidly increasing competition in the sector.

The Indian government is expected to impose an Anti-Dumping Duty (ADD) on imported solar panels in order to boost sales of locally made panels manufacturers. This is bound to increase the costs of setting up power plants as 89%[19] of the solar panels used in India are imported, mostly from China, Taiwan, and Malaysia whose products are around 10% cheaper than the locally manufactured products.

The ADD is likely to make projects even less viable. Developers are already forced to quote low tariffs to win the few available projects, risking low returns, and an increase in cost due to the duties would add even more pressure. In the last few months, activity in India's solar energy has stalled. The industry is struggling with the rising solar panel prices and flat power demand, while, on the other side, the government hasn't held auctions for solar projects.

Hence, the viability of solar project bids at below INR 3 per unit may be adversely affected if the increase in the solar panel prices by 6-7 cents/watt sustains over coming quarters. The level of solar tariffs witnessed a sharp reduction in the last six months, with the lowest tariff falling to INR 2.44 per unit in May 2017 at Bhadla solar park auction in Rajasthan. ICRA, a ratings agency, estimates, a 6 cent/watt increase in the PV module price would result in an increase of about 11% in the total capital cost, which in turn is estimated to result in a decline in cumulative average Debt Service Coverage Ratio (DSCR) by 0.12 times and a decline in project IRR by 180 basis points for a solar power project with a tariff of INR 2.50 per unit. Also, the bidding activity for award of solar projects had slowed down in 2017 (till October) as reflected in awarded project capacity of 3.75 GW against 7.20 GW a year ago. The GST roll out from July 2017, an upward pressure on PV module price level in recent months as well as the finalisation of the new bidding guidelines for award of solar projects in August 2017.[20]

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[18] https://yourstory.com/2018/03/indias-sunny-energy-future-rooftop-solar-power/

[19] https://qz.com/1130039/indias-solar-power-sector-stares-at-another-crisis-as-modi-government-prepares-to-help-local-manufacturers/

[20] https://www.financialexpress.com/economy/solar-projects-in-india-eyeing-a-crisis-viability-under-question-now/942662/

8 Advantages and Challenges involved

India has tremendous scope of generating solar energy. The geographical location of the country stands to its benefit for generating solar energy. The reason being India is a tropical country and it receives solar radiation almost throughout the year, which accounts for 3000 hours of sunshine. This is equal to more than 5000 trillion KWH. Almost all parts of India receive 4-7 KWH of solar radiation per sq. metres. This is equivalent to 2300 – 3200 sunshine hours per year. States like Andhra Pradesh, Bihar, Gujarat, Haryana, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan and West Bengal have great potential of tapping solar energy due to their location. Since majority of the population lives in rural areas there is much scope for energy being promoted in these areas.

Advantages of Solar Energy in India

1) **Renewable and Clean Energy Source**
   Among all the benefits of solar energy, the most important one is that solar energy is renewable and clean energy source. It can be harnessed in all areas of the world and is available every day. It is an inexhaustible source of energy and environment friendly. When in use, it does not release CO2 and other gases which pollute the air.
2) **Reduces Electricity Bills**
   On consumption of electricity generated by the solar system in order to meet some of the energy needs, energy bills will drop. The savings on the electricity bill is dependent on the size of the solar power and electricity usage. Moreover, if more electricity is generated than usage, the surplus electricity is exported back to the grids and bonus payments are received for that amount.
3) **Diverse Applications**
   Solar Energy can be used for diverse purposes. Solar energy can be used for variety of purposes like heating, drying, cooking, or electricity, which is suitable for the rural areas in India. It can also be used in cars, planes, large power boats, satellites, calculators and many more such items, which is suitable for the urban population.
4) **Technology Development**
   Technology in solar industry is constantly advancing and improvements will intensify in the future. Development in the technology can potentially increase the effectiveness of solar panels. There was a recent breakthrough in solar cell technology that could boost the efficiency of existing PV by 70% or more. The amount of sunlight solar cells can convert into usable energy is typically limited to around 30%[21], with many existing solar panels falling short of that due to less than optimal conditions.

Disadvantages of Solar Energy in India

1) **High Upfront Cost**
   The Initial cost of purchasing a solar system is fairly high. It includes paying for solar panels, inverters, batteries, wiring and installation. Nevertheless, solar technologies are constantly developing, so it is safe to assume that the prices will go down in the future.
2) **Requirement of High Surface Area**
   The more electricity you want to produce, the more solar panels you will need, because you want to collect as much sunlight as possible. The land space required to install a solar plant is quite large and that land space remains occupied for many years altogether and cannot be

[21] https://inhabitat.com/new-photovoltaic-solar-technology-boosts-efficiency-to-50/

used for other purposes. This is a huge challenge for a densely populated country like India where there already is scarcity of land.

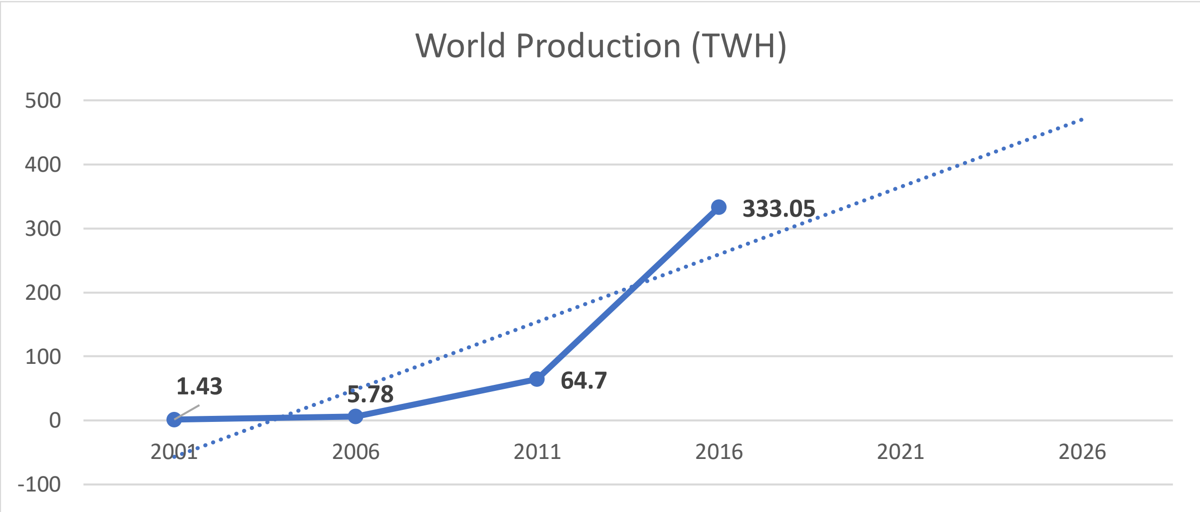
3) **Weather Dependent**
Although solar energy can still be collected during cloudy and rainy days, the efficiency of the solar system drops. Solar panels are dependent on sunlight to effectively gather solar energy. Therefore, a few cloudy/rainy days can have a noticeable effect of the energy system. It should also be taken into account that solar energy cannot be connected at night.

4) **Maintenance Cost**
Solar panels require considerable maintenance as they are fragile and can be easily damaged. The solar panels are to be kept relatively clean, so cleaning them up on regular basis is necessary. Although, there are no moving parts, there is no wear and tear, inverter needs to be changed after 5-10 years because it is continuously working to convert solar energy into electricity. Apart from the inverter, the cables also need maintenance to ensure that the solar power system runs at maximum efficiency.

9 Future Growth

9.1 World

With the increasing carbon emissions from fossil fuels generated power, drastic climate changes and depleting reserves of fossil fuels raised questions about how the world will cope up with the increasing power demand. Therefore, many countries have now started to shift their dependency of power generation from non-renewable sources to renewable sources. The potential of solar power, which is available abundantly, as a clean power was recognised by many countries.

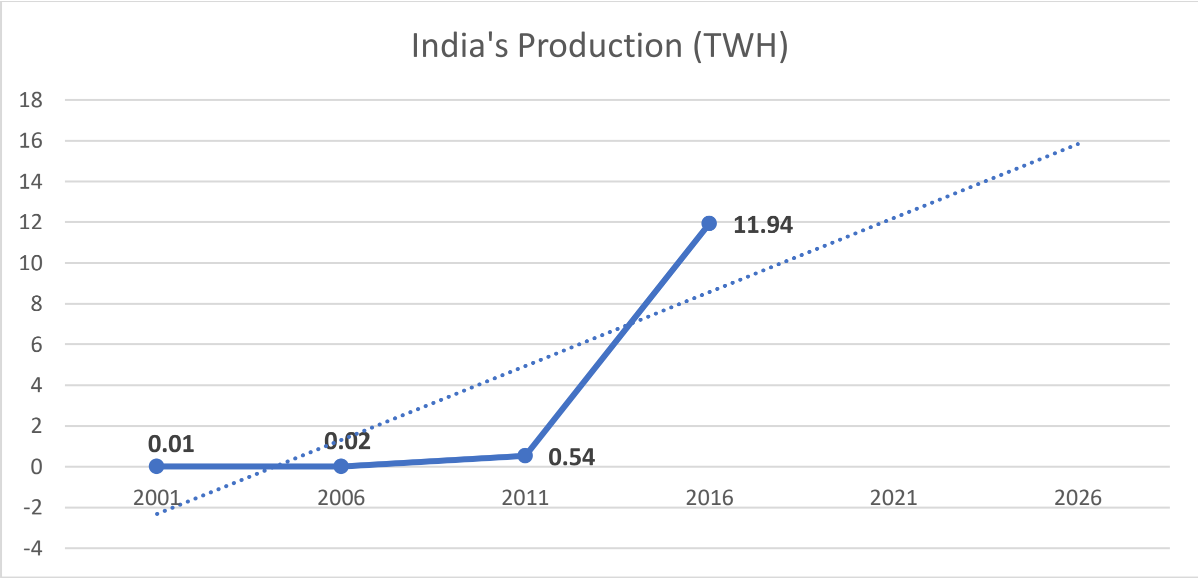


Many countries are now investing heavily in solar power plants and also constructing policies supporting and encouraging private investment. As shown in the chart above, the solar power production as on 2001 was as low as 1.43 TWH which increased to 333.05 TWH as on 2016 and it is expected to reach around 470 TWH by 2026.

9.2 India

India is facing an acute energy scarcity which is hampering its industrial growth and economic progress of the country. In India there has been a continuous effort in the direction of the use of lesser amount of fossil fuels and increased supply of energy which can only be met by a planned harnessing of more renewable energy sources and the government is serious in the planned development of these sources. Therefore, India has set a goal to achieve 175 GW of renewable energy capacity by installing 100 GW of solar, 60 GW of wind, 10 GW of biomass, and 5 GW of small hydroelectric projects by 2022. Of the 100 GW target of solar, 40 GW is expected to be achieved through the deployment of rooftop projects, 40 GW through utility-scale plants, and 20 GW through ultra-mega solar parks. India wants to grow its solar capacity to not only provide electricity to remote areas but also to reduce the carbon emissions.

The chart below shows the increase in the solar power production from 0.01 TWH as on 2001 to 11.94 TWH as on 2016. It is expected to reach almost 16 TWH by the year 2026.

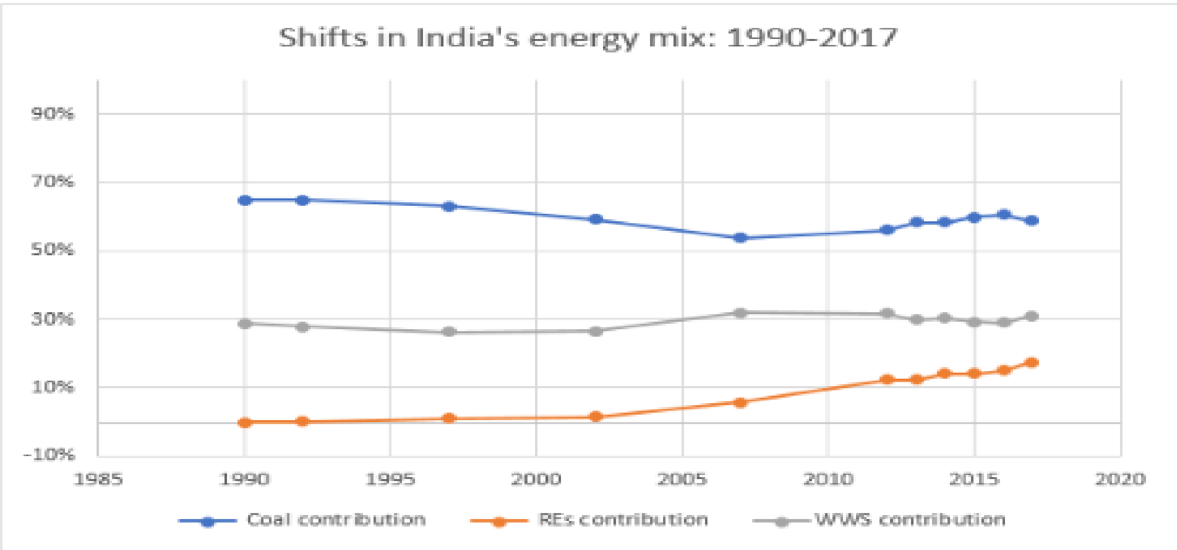

India's Production (TWH)
18
16
14
12
10
8
6
4
2
0
-2
-4
2001
2006
2011
2016
2021
2026
0.01
0.02
0.54
11.94

10 Outlook

10.1 Reduction in Carbon Emissions

Carbon Emissions is the total amount of greenhouse gases, especially carbon dioxide that are produced due to human activities like, burning fuel, industries, electricity, etc. This affects the temperature of earth's atmosphere. If the amount of greenhouse gases like carbon dioxide, carbon monoxide, methane, etc. increases, the average temperature of Earth would rise, thus posing a serious threat of melting of glaciers and polar ice-caps. The International Solar Alliance (ISA) is India's initiative to reduce the amount of carbon emissions in the country. With 19 countries already ratifying its framework and a total of 121 countries situated between Tropics of Cancer and Capricorn being a part of it, India seems to be taking lead in fighting against the carbon emissions. Despite the global warming changing the weather patterns, and global players fighting over who pollutes more in various climate summits organised over the years, nearly 41 percent of the electricity needs of the world are still fulfilled by coal, as per the World Coal Association. And India has decided to take substantial action in this regard and formed an organisation ISA which would utilise the solar energy to produce electricity which reduces carbon emission in the atmosphere and reduces the dependency on fossil fuels. India is leading here as well as it has set itself a target of installing an infrastructure that can produce 175 GW of power by renewable energy out of which 100 GW is to come from solar. ISA on total expects to facilitate the addition of 1,000 GW of solar energy by 2030 with an investment of almost $1200 billion. By 2022, India expects to reduce its carbon emissions by 33% - 35% by producing alternative source such as solar energy.[22]

10.2 Shift to renewables



Source: Based on CEA (2017)

India has been building a vast electric power system with heavy reliance on coal as primary fuel. New companies like Adani have emerged, with almost total focus on building coal-fired power stations and coal infrastructure. But in recent years there has been a marked shift to wind and solar power which have now together taken over as leading alternative to fossil fuels from hydro-power. Indeed, whereas in some countries like China and Germany the proportion of electric power generated from water, wind and sun (WWS) is rising, sometimes steeply, in India it is falling – largely because of declining

[22] https://www.indiatimes.com/news/india/india-leads-battle-against-carbon-emissions-through-global-solar-alliance-here-s-how-it-works-335111.html

hydropower generation. But there is a marked rise in the proportion of power generated from wind and sun – designated as Renewable Energy sources (REs) in the above chart.

The overall growth of renewable energy in India has been remarkable. This boom in clean energy has led to a slowdown in the growth of coal. Several Indian states have recently scrapped plans to build new coal-fired power plants and announced the cancelation of coal mining projects. Bloomberg New Energy Finance (BNEF) projects that be 2040, coal will no longer play a dominant role in India's power sector.

10.3 Advancement in Solar Technology

a) Advances in Solar Panel efficiency
The past few years in the solar industry have been a race to the top in terms of solar cell efficiency, and 2016 was no different. A number of achievements by various panel manufacturers have brought us to today's current record for solar panel efficiency: 23.5 percent, held by premium panel manufacturer, SunPower[23]. There is a solar cell design that is being touted as having a 50%[24] energy conversion efficiency in laboratory test. Unfortunately, the super-efficient solar cells typically require more costly materials which does not make them cost-effective for consumers.

b) Solar Tracking Mounts
Due to tracking mount technology, ground mounted solar is becoming is becoming a viable clean energy option. Trackers allow solar panels to maximize electricity production by following the sun as it moves across the sky. PV tracking system will tilt and shift the angle of a solar array as the day goes by to best match the location of sun.

c) Solar batteries
Another major focus of scientists is to find new ways to store energy produced by solar PV systems. Currently, electricity is largely a 'use it or lose it' type of resource, which is why it is important to find a way to store this electricity so that it can be used on demand. There are a number of batteries on the market, but they are still to be developed as they are expensive, inefficient and have low shelf life.

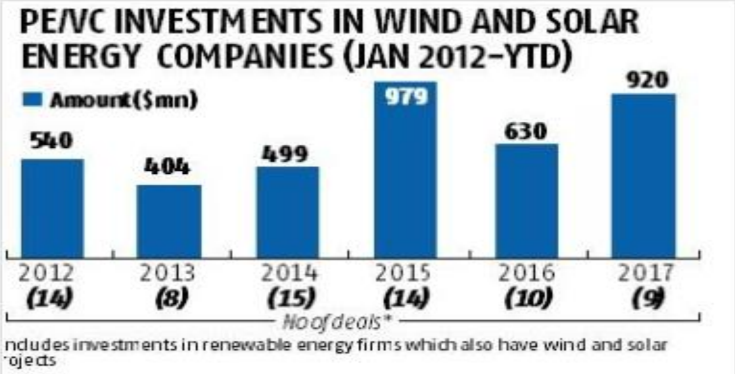
10.4 Cheaper Solar

In India and beyond, solar power is starting to displace coal as an energy source. The cost of electricity from solar photovoltaic (PV) is currently a quarter of what it was in 2009 and is set to fall another 66%[25] by 2040. That means a dollar will buy 2.3 times as much solar energy in 2040 than it does today.

With nearly 300 days of sunshine every year, India has among the best conditions in the world to capture and use solar energy. Clearly, the market agrees, as is evident from the significant drop in the cost of solar power. In its latest solar auction, the country achieved a record low tariff of INR 2.44/unit (4 cents/unit) for a project in the desert state of Rajasthan.

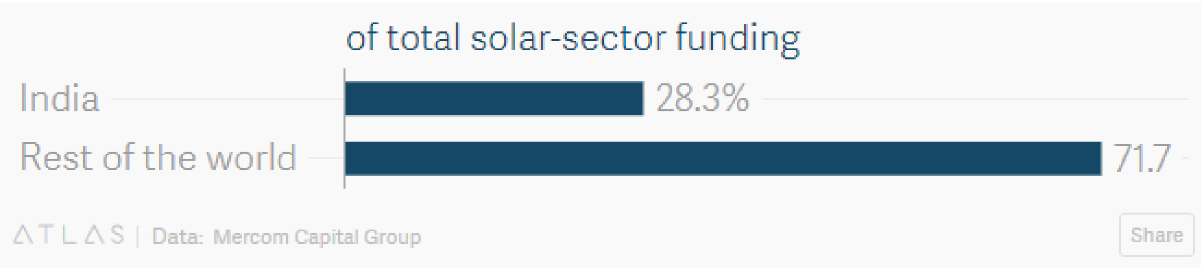
[23]https://news.energysage.com/solar-panel-technology-advances-solar-energy/
[24] https://www.pvbuzz.com/solar-panel-technology-boost/
[25] http://www.worldbank.org/en/news/immersive-story/2017/06/29/solar-powers-india-s-clean-energy-revolution

10.5 Easy Finance and Private Equity Funding



The renewable energy sector in India witnessed a spike in Private Equity (PE) flows in 2017. PE flows into wind and solar power jumped 47% to $920 million involving 9 deals in 2017, compared to $630 million involving 10 deals in 2016. 2017 was the second-best year after 2015, when it attracted $979 million across 14 deals.[26]

According to Mercom Capital Group, consulting and research firm, mentioned in a report that the corporate funding, including Private Equity (PE) and Venture Capital (VC) deals, debt funding, and public market funding, for India's solar sector touched $3.6 billion in 2017. Nearly 30% of global solar funds went to India in 2017.



Overall, Indian companies raised over $10 billion, up from around $4 billion in 2016. This includes project financing (funding specific long-term infrastructure projects) of around $6.4 billion, compared to $3.5 billion in 2016. These were the top five PE/VC funding deals in India last year, led by ReNew Power, a Goldman Sachs-backed clean energy start-up founded in 2011:[27]

COMPANY	AMOUNT RECEIVED
ReNew Power	$200 Million
ReNew Power	$200 Million
Greenko Energy	$155 Million
Hero Future Energies	$125 Million
CleanMax Solar	$100 Million

The investors were attracted by high growth prospects and supportive government policy framework of the Indian solar market. However, the funding activity and investments in solar sector are forecasted to slow down along with the installations in 2018. The delays in payments by power distribution firm (DISCOMs), the dropping per unit prices in solar, uncertainties created in the market by trade cases with possible Safeguard & Anti-Dumping Duty imposition, will have a negative impact

[26] http://www.business-standard.com/article/specials/pe-investment-in-wind-solar-up-47-in-2017-117092800018_1.html
[27] https://qz.com/1227640/india-drew-30-of-all-corporate-investments-into-the-solar-sector-in-2017/

on investments unless government acts fast to resolve these issues in a way that creates a confidence among the private equity players.

10.6 Ambitious targets and Financing

The Indian Government is setting ambitious targets that include 160 Gigawatts (GW) of wind and solar by 2022. Not only will this help hundreds of million people light their homes, it will also enable children to study at night, provide families with refrigerators to preserve their food or TVs to entertain themselves after a long day of work. It is also an incentive for international firms to invest in India's solar market.

The World Bank financed, routed State Bank of India, the rooftop solar power plants in India. This financing will help in expeditious adoption of distributed solar by Indian consumers and will act as a significant catalyst for the growth of the rooftop solar sector in India. The Indian solar power producers will work with the World Bank and SBI to create innovative credit structures so that benefits of this attractive credit scheme will reach the maximum number of end customers.

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