

SOLAR POWER IN SUSTAINABLE DEVELOPMENT IN INDIA.

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ABSTRACT

The main traits of the Indian energy consumption are many rural households and the fact that most people rely on low-quality energy. Making growth and development long lasting for India depends on being sustainable. Solar energy is one of the major industries working to make India more sustainable.

Because India is in the tropical area, solar energy can play a big role. The report focuses on the latest uses of solar energy in helping India become more sustainable. The use of solar energy for sustainable development is covered in sectors related to buildings, mobile devices, restaurants, parking, public transport and lighting. The article covers existing solar energy uses, what solar energy looks like in India now, the reasons for its slow progress and advises on ideas for promoting it.

Keywords - Sustainable Development, Architecture, Solar energy

INTRODUCTION

A way to develop is called sustainable development when the needs of now are met, yet future generations are not prevented from doing so. Because of worries about global warming and climate change, more importance is being given to renewable energy for our future. Sustainable energy which is also known as alternative energy, is clean and long-

lasting, releasing almost no harmful gases. Geothermal, biomass, wind, sun and more renewable energy sources are examples of this kind of energy. One of the best ways to fight global warming is by using solar energy which helps cut greenhouse gas emissions. Over 5,000 trillion kWh of solar energy falls on India every year due to the many clear sunny days, but most of it is not used for helping people. The energy sector is a major factor in lifting people's living standards. A significant percentage of India's citizens in villages use energy sources that are not enough and not very good. The growth and development of India depends on being sustainable. It is recognized that India's future depends in part on solar energy. Because India falls within the tropical belt, the potential of solar energy is very strong.

Because of big losses during transportation and usage, most Indian power companies cannot meet the amount of renewable energy they agreed on. So, a possible way for these states is to shift their renewable energy contracts to customers who pay a lot for electricity and are getting close to grid parity. Power users requesting more solar energy is an important reason that the Indian solar market is growing. More barriers are being taken out which is powering the expansion of solar energy. It covers the ways solar energy supports a

sustainable India, looks at its present challenges and possible solutions and outlines how it could play a larger role in sustainability going forward.

For the moment, solar energy systems are not usually as affordable as others. Until

major policy steps are taken, solar energy cannot develop much. A lot of countries have acknowledged solar energy as a problem and put in many efforts to expand its use with aid from financial, governmental, advertising and other resources. A range of laws have been created by countries and internationally to

back renewable energy and solar in particular. The solar energy market is increasing as new rules are carefully introduced in both rich and poor nations, mainly for grid solar power and water heating systems. This study briefly mentions the main rules that help promote solar power for both electricity and heating use.

OBJECTIVES

The researcher has created a survey and obtained survey results from 400 consumers.

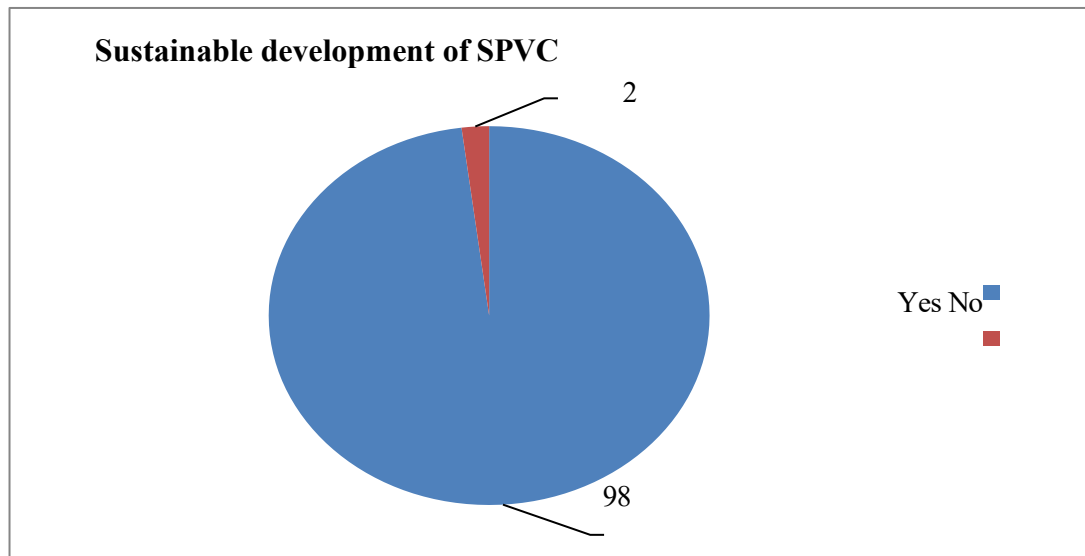
Table 1

1. Sustainable development of Solar Photovoltaic Cell Power in India

	Sustainable development of SPVC	Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	392	98	98	98
	No	8	02	02	100
	Total	400	100	100	

Source: Primary Source

Figure 1



The graph makes it obvious that 98% (392) of the respondents agree that Sustainable development of Solar Photovoltaic Cell is

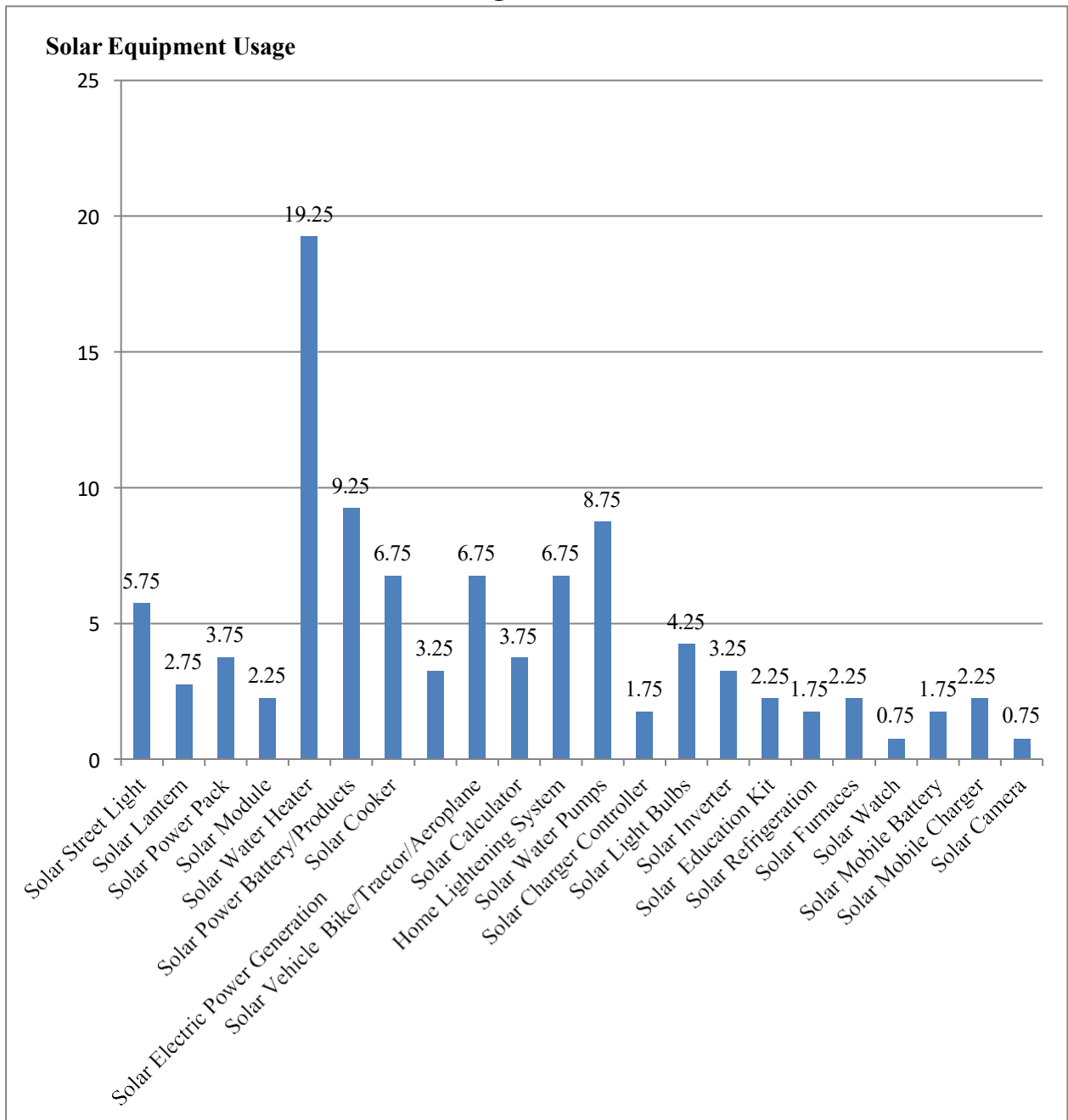
important, whereas the remaining 2% (8) think that it is not necessary.

Table 2 : To study Solar Appliance/ Equipment used in India

	Solar Equipment Usage	Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Solar Street Light	23	5.75	06	5.75
	Solar Lantern	11	2.75	03	8.50
	Solar Power Pack	15	3.75	04	12.25
	Solar Module	9	2.25	02	14.50
	Solar Water Heater	77	19.25	19	33.75
	Solar Power Battery/Products	37	9.25	09	42.50
	Solar Cooker	27	6.75	07	49.25
	Solar Electric Power Generation	13	3.25	03	52.50
	Solar Vehicle Bike/Tractor/Aeroplane	27	6.75	07	59.25
	Solar Calculator	15	3.75	04	63
	Home Lightening System	27	6.75	07	69.75
	Solar Water Pumps	35	8.75	09	78.50
	Solar Charger Controller	7	1.75	02	80.25
	Solar Light Bulbs	17	4.25	04	84.50
	Solar Inverter	13	3.25	03	87.75
	Solar Education Kit	9	2.25	02	90
	Solar Refrigeration	7	1.75	02	91.75
	Solar Furnaces	9	2.25	02	94
	Solar Watch	3	0.75	01	94.75
	Solar Mobile Battery	7	1.75	02	96.50
	Solar Mobile Charger	9	2.25	02	99.25
	Solar Camera	3	0.75	01	100
	Total	400	100	100	

Source: Primary Source

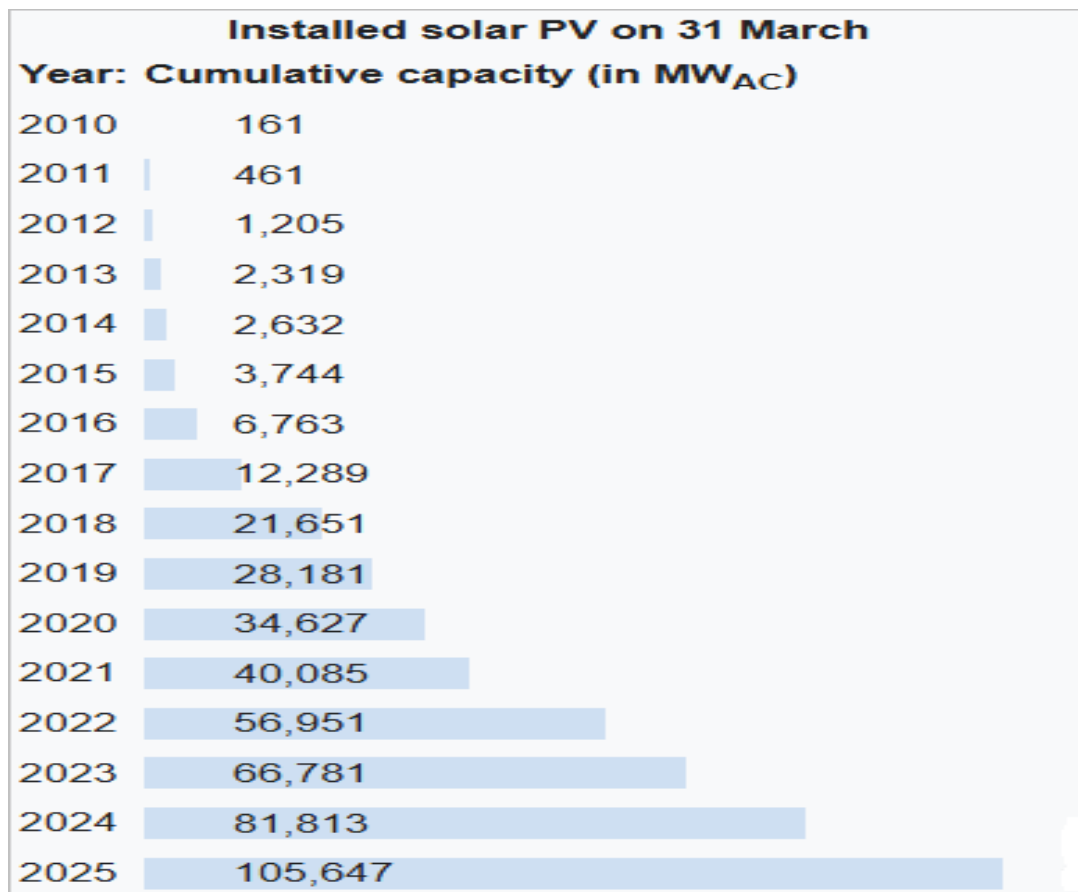
Figure 2



The majority of the consumers claim to use Solar Water Heaters regularly to warm-up water. Then, the sequence is begun with solar calculator, Solar Street Light, Solar, Power Battery, Solar Stove, Solar Lamp/ Flashlight, Solar Timepiece, Solar Oven, Solar Camera. People are knowledgeable and at ease with the decisions to include solar equipment in their routine daily

schedules. At the beginning, Solar Illumination systems, Solar Energy generation, Solar Vehicles, Solar Energy unit, Solar Inverters, Solar Learning Kits, Solar Coolers, Solar Heaters as well as solar water pumps must be implemented into everyday life at a lesser rate. The current Scenario of Solar Power in India.

Figure 3



Graph Installed Solar PVC on March 2025

Hypothesis:-

Hypothesis 1 Solar photovoltaic (PV) technology is vital for sustainable development.

H0: Solar photovoltaic (PV) technology is not vital for sustainable development.

H1: Solar photovoltaic (PV) technology is vital for sustainable development

Table 3

t-Test: Paired Two Sample for Means		
	<i>Variable 1</i>	<i>Variable 2</i>
Mean	1.0725	1.03
Variance	0.067412281	0.029172932
Observations	400	400
Pearson Correlation	0.629017482	
Hypothesized Mean Difference	0	
<u>df</u>	399	
t Stat	4.208346797	
P(T<=t) one-tail	1.59026E-05	
t Critical one-tail	1.648681534	
P(T<=t) two-tail	3.18052E-05	
t Critical two-tail	1.965927296	

Based on the outcomes displayed by the paired t-test: An outline of what was discovered. Both the two variables in question have 400 measures. The value of variable 1 is about 1.0725 and the value of variable 2 is about 1.03. Variance (variable 1) is 0.0674 and variance (variable 2) is 0.0292

The Pearson Correlation is approximately 0.629 so that casts an indication of moderate level of positive relationship.

Hypothesized Mean Difference: 0 (test on whether mean difference is equal to 0). The data set has 399 Degrees of Freedom.

t-Stat: approximately 4.208. p-Values:

One tailed p-value is approximately 1.59×10^{-5}

Two-tailed p-value: approximately 3.18×10^{-5} .

Interpretation:

Table 4

t-Test: Paired Two Sample for Means		
	<i>Variable 1</i>	<i>Variable 2</i>
Mean	1.0725	1.0575
Variance	0.067412281	0.054329574
Observations	400	400
Pearson Correlation	0.883448421	
Hypothesized Mean Difference	0	
df	399	
t Stat	2.464983191	
P(T<=t) one-tail	0.007061116	
t Critical one-tail	1.648681534	
P(T<=t) two-tail	0.014122233	
t Critical two-tail	1.965927296	

Their p-values are so small to insignificance level of 0.05 and thus are significant in proving that the null hypothesis is strongly rejected. It knows

that Solar photovoltaic (PV) technology plays a great role in getting sustainability.

Hypothesis 2:-

Solar Photovoltaic cell is Eco Friendly energy source for Adoption.

H0: Solar Photovoltaic cell is not Eco Friendly energy source for Adoption. ($\mu=0$)

H1: Solar Photovoltaic cell is Eco Friendly energy source for Adoption. ($\mu=0$) The test of difference between the means of the Variable 1 and Variable 2 was undertaken using observations of 400 pairs of variables with the help of t-test. The results that you will obtain after going through the process are the following ones:

The variance between sample means. $X_1 - X_2 = 0.015$ $X_1 - X_2 = 0.015$

t-Statistic: The degrees of freedom are 399 and the formula $t = 2.465$ $t = 2.465$

Two-tailed p-Value.

The likelihood will be $p = 0.0141$

Pr -Critical t-value assuming $P=0$ in a t-test.

$t_{crit} = \pm 1.966$

Given that:

$p = 0.0141 < 0.05$

The t value is 2.465 and this is greater than the value of 1.966. We will not take the null hypothesis that both means are equal.

Interpretation:

It can be determined through statistics that the average of Variable 1 does not equal (it is a bit bigger than) the average of Variable 2. Since the correlation of the two variables ($r = 0.8834$) is quite strong, it would be advisable to match up the two variables and the test is valid. So, since the null hypothesis was not accepted, it was concluded that Solar Photovoltaic cells is Eco Friendly and there should be promotion of Solar Photovoltaic cells.

Solar Energy and Sustainable Development –

Passive methods and active methods are the two main uses for solar energy in sustainable development. Passive solar energy uses heat and light as they are, without being converted into other forms. On the other side, it means capturing or saving solar energy for different uses. The active use of solar energy is generally categorized as photovoltaic (PV) or solar thermal.

As solar radiation triggers semiconductors, photovoltaic technology changes the radiation into electrical energy. Unlike solar photovoltaic, solar thermal uses the sun's heat to produce electricity and provides heat for home or building warm-up. Solar thermal systems can be sorted into non-electric and electric varieties.

Among solar thermal non-electric technologies are solar water heaters, solar air heaters, solar cooking systems, solar cooling systems and others. This uses solar energy to make steam that can produce electricity. The technique used here is called Concentrated Solar Power (CSP). Several CSPs are sold in the market such as the Power Tower, Fresnel Mirror, Solar Dish Collector and Parabolic Trough.

How solar energy is used in India at the moment.

In 2023, India generates more solar power than most countries except China and the USA. Last year, India got 5.8% of its electricity from solar power.

India increased its installed power capacity by 18 Terawatt hours, after China (+156 TWh), the United States (+33 TWh) and Brazil (+22 TWh).

By September 2024, Indian solar energy has gone up to 90.76 GW which is 30 times higher than what it was nine years earlier.

Problems in the Manufacturing of Solar Photovoltaic Cell in India:-

Having A Small-Scale Solar Project Is

Still More Costly Than Other Options, Even Though Solar Power Prices Are Declining.

Solar parks of a large scale struggle with land access and worry about big transmission losses and difficulties in joining the grid because solar power is not always available.

Projects for large solar parks are put on hold in Rajasthan and Gujarat because some endangered species could be disturbed.

Even though the amount of solar energy installed has grown, it still plays a minor role in electricity generation; expansion of rooftop solar is also very slow, far below its intended goal (18%).

Absence of Innovative financing options makes it difficult and costly for residential consumers and small businesses to choose rooftop solar.

High initial expenses are a problem for residential consumers and SMEs, since they do not have important innovations in how solar can be financed.

India imports most of its solar equipment since it does not produce solar wafers or polysilicon at home and it mainly relies on China for its trade (\$76.62 billion in 2021-22).

There will be 1.8 million tonnes of solar waste by 2050; however, e-waste rules now do not make manufacturers responsible for recycling or disposal.

Legal problems at the WTO prevent India from enforcing its requirement for locally made solar cells and modules.

Actions taken to promote Solar Energy in India:-

PM-KUSUM was created with the purpose of solar grid pump incentive and loan schemes connected to agricultural water pumps.

Through **Suryamitra Programme**, NISE offers solar project installation, operation and maintenance training.

Atal Jyoti Yojana: Brings solar street lights for public areas where electricity is not available.

SRISTI Scheme: Gives financial support to encourage people to install solar panels on their roofs.

The Green Energy Corridor Scheme: New transmission lines and sub-stations will be used to evacuate renewable energy.

Solar Parks Policy was introduced in 2014 to help create big solar parks.

Collaborating with the World: Joined the International Solar Alliance (ISA) and promotes the idea of combining solar energy from all countries into one system.

Worldwide Largest Solar Energy Generating Countries in 2024:-

Figure 4

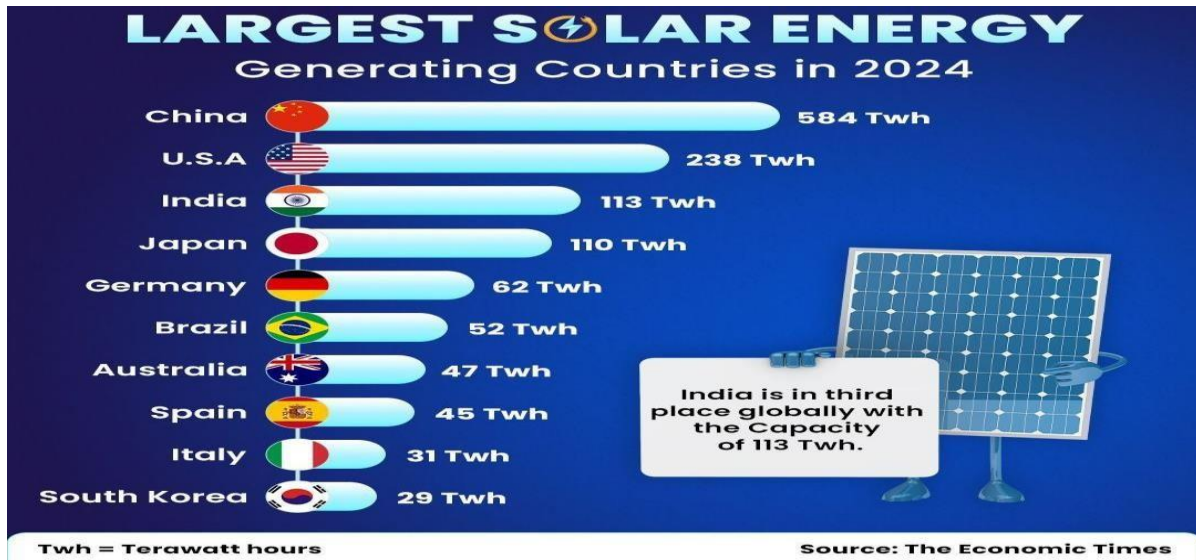
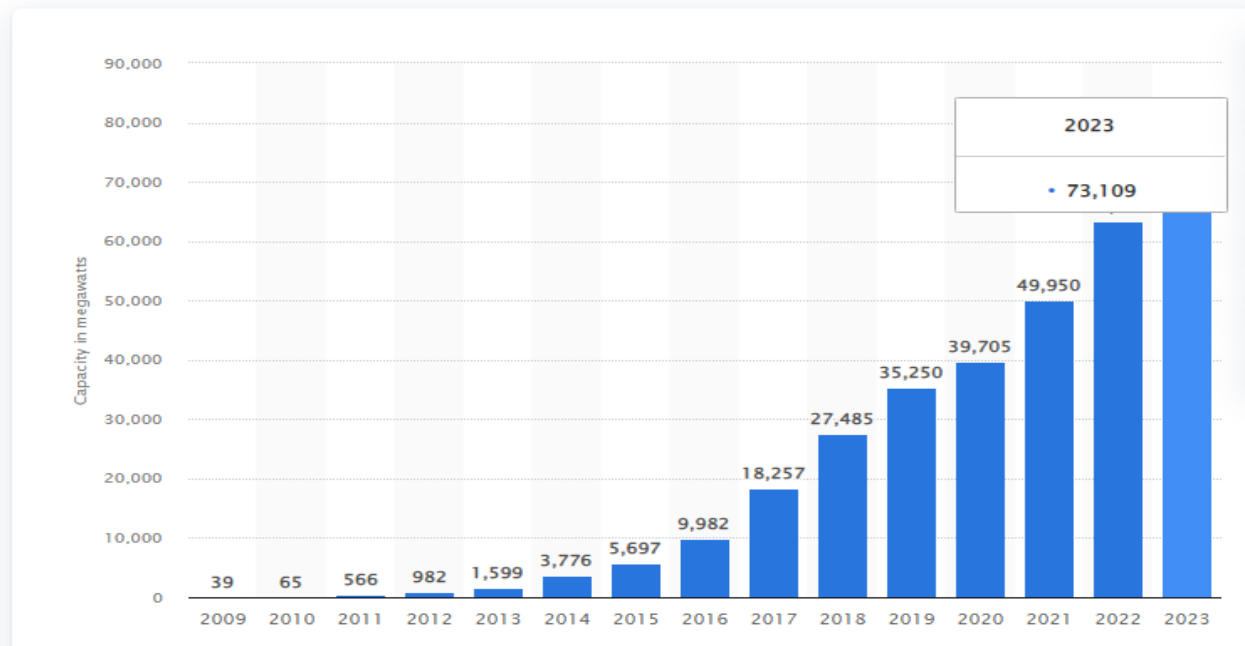


Figure 5

Solar energy capacity in India from 2009 to 2023 (in megawatts)



The government has introduced a number of steps designed to encourage solar energy in the country.

One measure is giving automatic permission for up to 100 percent Foreign Direct Investment (FDI). Additionally, there is no Inter State Transmission System (ISTS) fees charged on solar and wind energy sold across states for these projects that will be operational by June 30, 2025. A Renewable Purchase Obligation (RPO) plan has been set by the government for the years 2029-30. They have also issued guidelines to explain what is required for setting up solar photovoltaic systems/devices.

A Project Development Cell has been formed to motivate and back investments. To help prompt payment of renewable energy producers by distribution companies, the government needed documentation like a letter of credit (LC) or advance payment.

Implementation of the 'Electricity (Late Payment Surcharge and Related Matters) Rules 2002 (LPS Rules)' and Open Access to Green Energy Rules 2022 announced for promoting renewable energy.

To help sell solar energy from renewables more easily, the government set up the Green Term Ahead Market (GTAM).

Table 5 Using Solar Power Appliances Innovatively in Daily Living

Solar air conditioning	Solar-powered fan	Solar chimney
Solar-powered waste compacting bin	Solar cooker	Solar dryer
Solar charger (Strawberry Tree)	Solar inverter	Solar furnace
Solar keyboard	Solar lamp	Solar pond
Solar-powered Stirling engine	Solar road stud	Solar street light
Solar traffic light	Solar Tuki	Solar-powered flashlight
Solar-powered calculator	Solar-powered desalination unit	Solar-powered pump
Solar-powered radio	Solar still	Solar roadway
Solar-powered refrigerator	Solar balloon	Solar vehicle
Solar Spark Lighter	Solar-powered watch	Solar boat
Planet Solar	Solar sail	Solar golf cart
Solar bus	Solar-pumped laser	Solar Turanor
Solar car Stella (solar vehicles)	Solar panels on spacecraft	Solar thermal rocket

Solar Lighting

One of the most common and growing areas using solar power is for lighting. It can also be put to good use in lights for streets, in gardens, in restaurants with solar umbrellas and in palm tree lighting at institutes and industries.

Chargers That Run On Solar Energy

Solar chargers for phones and iPads are a very small way to make use of solar energy.

Especially since millions in India use mobile phones, this will reduce the amount of energy needed to keep them charged. It is quite a minor application, but it still works very effectively.

Parking Area with Solar Energy

In a Solar Car parking, cars are parked under solar panels placed at a height above the ground. Larger arrays spread over the parking area can create a larger amount of energy.

Restaurant in the Solar Kitchen

The main goal of the solar kitchen restaurant is to encourage using solar energy. All cooking at Solar Kitchen Restaurant happens through solar energy. The restaurant will centre on a solar kitchen, helping to make eating there both interesting and enjoyable. Using solar energy for cooking gives each dish a special and positive effect, making the meal taste and feel different in an interesting way.

Solar-Powered Advertising Billboard

In some situations, no electricity exists nearby or the nearest source is quite far which means billboards still need to be erected. Installation of a LED billboard using solar energy is considered a cheaper option rather than digging up the street for new cables or calling an electrician.

A Solar Bill Board

At times, billboards have to be put up in places without electricity close by or where the closest power is quite far. Having a LED billboard powered by solar energy avoids the expensive process of excavating trenches and employing electricians.

Solar Canal

Narmada Canal, Gujrat part of India, has witnessed the launch of the Canal Solar Power Project.

Sun-Linked Space Power Station

People refer to this concept as the solar space power station. Study on this has been conducted since the early 1970s. The Solar Space Power Station transforms sunlight into microwaves above the atmosphere, avoiding both the power losses and the momentary break caused by the Earth's rotation.

Solar Energy Used for Transportation

Many areas of transportation use solar energy in different ways. Solar-powered cars interest a lot of researchers at this time. When a solar vehicle draws electricity from solar power, it becomes 100% solar

vehicle.

Examples of solar vehicles are solar car, solar tracking bus, solar rail, solar boat, solar aircraft and solar space craft. Solar energy is used for supplying power to vehicles, especially for the ventilation system and vehicle cooling fans.

CONCLUSION: -

Solar Power reported a considerable rise in its business for Solar Photovoltaic Cell off-grid and On-Grid systems in India. Application of this technology has helped by supplying Solar vehicles, Railways, Boats, Planes and for on road vehicles to help move towards sustainability in India. Sustainable development innovations in India involve lighting and charging by solar energy, solar parking, solar restaurants, solar ads, solar irrigation systems throughout the country, solar stationed in outer space and solar elements used in constructions.

In the solar power sector, the problems include reducing manufacturing expenses, expanding R&D, educating consumers, no common standards and difficulties with financing. It is necessary to conquer. Fast growth and widespread adoption of technology raise these issues.

To help with research and solar energy development, it is important that the private sector plays a big role. Setting up the infrastructure for new solar projects will generate lots of new jobs. Promoting jobs created by clean energy, along with refunds for environmental and energy services, will give more weight to clean

energy policies and gain people's support.

If things go as intended, India would be able to compete globally in solar energy.

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