

SOLAR ENERGY CONSUMPTION IN INDIA AND SUSTAINABLE DEVELOPMENT

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ABSTRACT

This paper made a modest attempt to investigate the solar energy consumption in India and sustainable development. Energy demand is increasing day by day due to modernization and increasing population and it put pressure of the scarce natural resources and environment. It is very challenging to fulfill the energy needs of the people. Increasing energy demand is one of the important reasons for the environmental degradation by producing the electricity through the sources like coal, oil and natural gas which emits one-third of Global greenhouse gas emission. To mitigate the environmental impact of energy production, solar energy acted as an important source and as alternative to other form of energy. This paper uses the secondary data to analyze the solar energy consumption.

Keywords: Solar energy, sustainable development, solar energy production, consumption.

INTRODUCTION

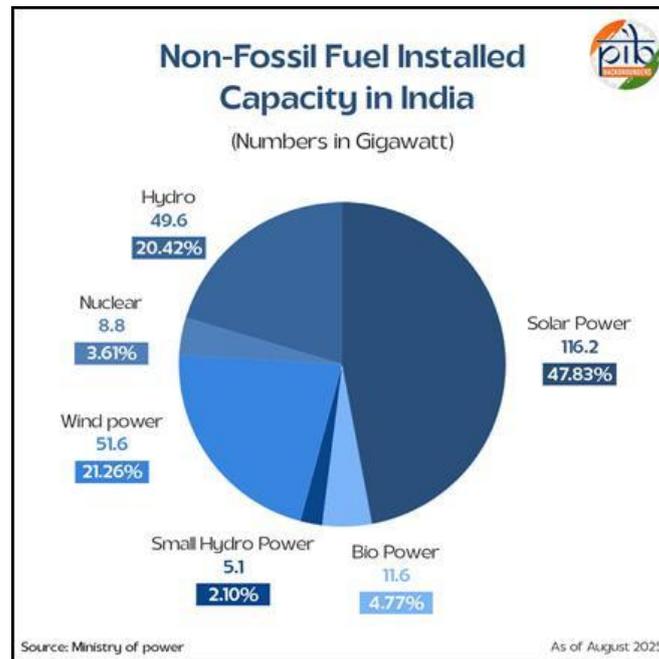
As a developing economy our nation is facing many challenges and the major one is growing population put strain on the natural resources and environment. Sustainable innovations give the way to tackle the environmental impact of humans and protect the planet from further damage. Every sector has the responsibility in reducing environmental harm, so innovations are important everywhere. Around US \$ 1.3 trillion is spent on climate related investment each year (Jessen, 2024). Energy is an essential need for the growth of people and to provide the standard of living as well as the economic growth of the nation. Solar energy emerged as the best renewable energy source towards the sustainable development. It is considered as cheap and affordable from small scale in homes and small Industrial facilities to large scale for the industry and distribution network. According to the IBEF report published says that India ranked fourth in wind power capacity and solar power capacity and fourth in renewable power installed capacity, as of 2021. India is only country among the G20 nations that on track to achieve the targets under the Paris Agreement (IBEF, 2025).

Solar energy is the most mature technology and it is widely used worldwide due to its lowest cost of production and installation. Solar technologies include solar thermal (concentrated and unconcentrated) and photovoltaics (PV). It is sustainable and clean source of energy that has gained significant attention due its potential to reduce the environmental impact (Heydari et.al.,2023). In recent years, the country has developed a sustainable path for its energy supply. Awareness of saving energy has been promoted among citizens to increase the use of solar, wind, biomass, waste, and hydropower energies. It is evident that clean energy is less harmful and often cheaper. India is aiming to attain 500 GW of electricity from non-fossil fuel sources by 2030, as a part of its commitments made at COP26. This includes a significant portion from renewable energy sources, with a target of achieving 50 percent of its total electricity needs from renewable by the same year. As of June 2025, India has already achieved 235.7 GW from non-fossil fuel sources, including 226.9 GW of renewable energy. This represents a substantial step towards India's decarbonization goal and its pledge for sustainable future (PIB, 2025).

HOW SOLAR ENERGY IS GENERATED?

The sun's energy can be converted into electricity through solar photovoltaic (PV) modules (photo = light, voltaic = electricity). Energy from the sun reaches our planet in one hour than is used by the entire population of the world in one year. PV modules absorb sunlight and convert the energy into usable form of electrical current. The rays reach all over the world and generating solar energy is viable anywhere. Solar modules have no moving parts making maintenance costs low, and they are highly reliable with a long service life of 25 plus years of guaranteed electricity (Remote Energy, 2021). Figure.1 shows the Non-Fossil fuel Installed capacity in India.

Figure 1: Non-Fossil Fuel Installed Capacity in India



Source: (PIB)Ministry of Power, 2025.

The Figure 1 shows Non-fossil fuel installed capacity in India, where solar energy stands the first position and it generates 47.8 percent of electricity and 116.2 GW. The wind power generates 21.2 percent and 51.6 GW, hydropower generates 20.42 percent with 49.9 GW capacity, the other sources like Bio Power (4.77%), Nuclear (3.61%) and Small Hydro power (2.10%).

TYPES OF SOLAR ENERGY

There are five types of solar energy that are using today and through which generation and usage of power is taking place. They are:

- Photovoltaic solar energy
- Solar thermal energy
- Concentrated solar power
- Passive solar energy
- Building integrated photovoltaics

Photovoltaic Solar Energy

A solar photovoltaic power plant harnesses sunlight to generate electricity through the photovoltaic effect. This process involves the use of solar panels, typically composed of semiconductor material such as silicon, which absorb photon from sunlight and release electrons creating an electric current. The solar panels are arranged in arrays and installed in open areas with ample sunlight exposure. As sunlight

reaches the panel, the generated direct current is then converted into alternating current using inverters, making it suitable for integration into electrical grid. This solar photovoltaic plant offers a clean and sustainable energy sources, producing electricity without emitting greenhouse gases or other pollutants (Solar Energy Definition, 2025).

Solar Thermal Energy

Solar thermal technologies use solar collectors to harness solar radiation to generate thermal or electrical energy for use in residential, commercial and industrial sectors. Solar thermal collector is classified as low, medium or high temperature. Low-temperature collectors are used for smaller nonrequirements. Medium-temperature collectors are used for heating water or air for residential and commercial use. High temperature collectors concentrate the sun's radiation using mirrors/lenses to meet heating requirements of up to 400 degrees C and for electric power production. As per the MNRE/GEF/UNDP Global Solar Water Heating Project Report, 40 million m² collector area is India's estimated exploitable techno-economic potential of solar water heaters (SWH) in India (Ministry of New and Renewable Energy, 2025).

Concentrated Solar Power

Concentrated solar power represents a solar thermal energy technology employing mirrors or lenses to concentrate sunlight onto a receiver, inducing the heating of fluid. This heated fluid is subsequently utilized to generate steam, propelling a turbine that produces electrical power. A distinctive feature of CSP lie in its ability to store the generated heat, enabling continuous operation even in absence of sunlight, during early morning or late evening hours.

This capacity ensures sustained power generation, overcoming the intermittency associated with traditional solar technologies. The versatility of CSP extends to its compatibility with hybrid power plants, where it can seamlessly integrate with other energy sources. This integration enhances reliability and grid stability by providing a consistent power supply, irrespective of weather conditions or time of day. The capacity to store thermal energy allows CSP system to function as a reliable and dispatchable energy solution, contributing to the overall resilience of the power grid (Solar Energy Definition, 2025).

Passive Solar Energy

Passive solar energy harnesses the natural light and warmth from the sun to naturally heat a building or space, eschewing reliance on active mechanical systems or technologies such as thermal active building systems (TABS) and solar collectors in solar thermal energy (STE) systems. This approach relies on strategic architectural design to optimize energy efficiency. In passive solar heating, buildings are intelligently crafted with features like expensive windows for optimal sun exposure, sun facing glass, and the incorporation of thermal mass materials. These materials absorb and retain heat during the day, releasing it gradually to maintain a comfortable temperature.

Conversely, Passive solar cooling systems employ range of tactics, including shading elements, thermal mass utilization and natural ventilation, to mitigate unwanted daytime heat. These systems also capitalize on the cool night air, storing it for subsequent use to regulate temperatures. The integration of passive solar principles not only fosters energy efficiency but also reduces reliance on active systems, contributing to environmentally conscious and resource efficient construction practices (Solar Energy Definition, 2025).

Building Integrated Photovoltaics

Building integrated photovoltaics involves seamlessly incorporating photovoltaic panel into key building elements like roofs, walls or windows. This innovative solar energy application transforms building components into electricity generating assets, significantly diminishing reliance on conventional power sources. Beyond enhancing energy efficiency and sustainability, BIPV contributes aesthetically to the architectural landscape, blending functionality with design appeal.

Moreover, the integration of solar panels directly into the building structure yields cost advantages. The initial installation cost mitigated by a reduction in both building materials and labour requirements, resulting in overall savings. This dual functionality of BIPV not only advances renewable energy adoption but also aligns with cost conscious and environmentally conscious construction practices, making it compelling choice for modern and sustainable building solutions (Solar Energy Definition, 2025).

SOLAR ENERGY AND SUSTAINABLE DEVELOPMENTS

Sustainable energy is defined as the development of the energy sector in terms of energy generating, distributing and utilizing that are based on sustainability rules (Radovanovic et. al.,2012). The energy sector contributes to environmental degradation primarily through air and water pollution, climate change from greenhouse gas emissions (especially from fossil fuels), habitat destruction from resource extraction and waste disposal issues (EEA, 2004). The steady increase in the global average temperature is making environment increasingly costly and physically difficult to live in, creating a great risk to public health across all countries, developed, or developing, and rich or poor (Watts et al., 2021, Gravili et al., 2020). The sustainable development goal is framed based on economic perspective. It also examines the all the activities should meet the shared long-term climatic benefits, good air quality and accessing energy targets.

BENEFITS OF SOLAR ENERGY

Solar energy offers numerous environmental, economical and social benefits. As it produces no greenhouse gas during operation and reduces dependence on fossil fuels. Some of the important benefits

of solar energy are as follows:

1. **Reduced air pollution**

In April 2025, solar power generated 10 percent of India's total electricity production, while clean energy contributed 22 percent overall. Solar power accounted for over 22 percent of India's total installed electricity capacity, a notable increase from 5.8 percent in 2023. The green energies can significantly reduce local carbon dioxide (CO₂), nitrous oxide (N₂O), sulfur dioxide (SO₂) and particulate matter emissions.

2. **Reduce Climate Change**

Carbon emissions and other greenhouse gasses are major contributors to the increase in global temperature, which is known as global warming. Some greenhouse gas emissions may be generated during manufacturing and transportation, solar photovoltaic panels do not produce any greenhouse gasses while generating electricity, making them a good source of clean energy.

3. **Cost Saving**

Financial returns and lower monthly utility bills are major incentives for going solar. As the solar panels generate free power from sun and also helps to gain long-term savings by avoiding rising utility rates, energy in dependence and stable energy costs for decades.

4. **Solar in Agriculture**

The Solar – powered irrigation systems are helping farmers cut their fuel costs and be more efficient. Greenhouse that have solar panels allow better temperature regulation, thereby yielding better crops. These are also beneficial in rural areas, where reliable energy sources may not be readily available.

Obstacles in Using Solar Energy

As the solar energy is considered as the clean energy source but it carries the obstacle too, the followings are the some of the obstacles.

1. **Overgeneration vs Under generation**

Solar energy generation follows a predictable routine – it rises throughout the day reaching a peak in the afternoon and the decreasing as night falls. The difficulty with its consumption is the supply and demands are mismatched due its nature because, there will less demand in the morning and huge demand will be at when sunsets. It is also not possible to store the energy.

2. **Environmental Impact**

Even though the solar energy is clean energy, but the solar cell is made up of silicon, which is made by heating quartz to extremely high temperature (1200 Celsius), releasing a lot of carbon emission in the process.

3. **Space Availability**

Solar panel installations require the large area, which becomes difficult in urban areas where space

become an issue. It is difficult to set up the solar panels in the large cities. The best way to use solar roofing or solar glass represents a great opportunity to start producing green energy locally.

METHODOLOGY

The present study uses the secondary data collection from various articles, journals, published and unpublished sources, Government reports and authentic websites like Public Information Bureau, Government of India.

RESULTS AND DISCUSSIONS

Table 1: Energy Use Per Person 2024 (KWh)

Sl.No.	Countries	Energy use by Per Person (KWh)
1.	United States	76,800
2.	China	34,514
3.	United Kingdom	28,016
4.	World	21,654
5.	South Africa	21,287
6.	Brazil	18,486
7.	India	7,813

Source: <https://ourworldindata.org/energy>

It is revealed from the Table 1. that United States is the high energy use nation, and next it is China is in second position followed by United Kingdom, South Africa, Brazil and India. Compare to other countries in India energy use by person for hour is less than other countries.

Table 2: Projected Primary Consumption of India (2016 to 2040)

Level (Mtoe)	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	1990 – 2016	2016 – 2040
Total	195	251	316	394	537	724	880	1118	1365	1624	1921	5.2%	4.2%
Oil (Mb/dl)	58	75	106	122	155	212	251	308	359	419	485	5.1%	3.5%
Gas (Bcf/dl)	11	17	24	32	54	45	57	72	89	106	128	5.6%	4.5%
Coal	110	140	164	211	290	412	485	593	710	824	955	5.2%	3.6%
Nuclear	1	2	4	4	5	9	11	16	27	35	44	7.1%	7.0%
Hydro	15	17	17	22	25	29	36	43	47	50	52	2.6%	2.5%
Renewables	0	0	1	2	7	17	41	86	133	191	256	35.1%	12.0%

Source: <https://www.bp.com/en/global/corporate/energy-economics/energy-outlook.html>.

Table 2. shows the projected primary consumption of India from 2016 to 2040. It is evident from the data

that up to 2040 the renewable energy consumption will be used widely consumed compare to other sources of energy which show the nation is growing towards the sustainable development and will achieve sustainability.

Table 3: Contribution of Renewable energy sources to the total energy demand

Expected Generation (Billion Unit)

Expected Generation (Billion Unit)

Year	Installed capacity of renewable energy sources	Solar	Wind	Biomass	Small hydropower	Total	Total Energy Requirement (Billion Unit)	% The contribution of Renewable energy source
2021-22	175	162	122	38	15	327	1611	20.3
2026-27	275	243	188	64	21	516	2132	24.2

Source: <https://energysustainsoc.biomedcentral.com/articles/10.1186/s13705-019-0232-1/tables/6>

It is evident from the Table 3, shows the contribution of renewable energy sources to the energy demand, in 2021-22 the percentage of total contribution shows 20.3 percent and it may increase further in the future 2026-27 it is predicted. Solar power has the highest contribution compare to other renewable sources.

CONCLUSION

Relying on renewable sources of energy such as solar and wind power, we can reduce using fossil fuels and decrease the carbon emission in the environment. Solar energy is clean, sustainable and renewable than other form of energy. It plays crucial role in promoting environmental sustainability and climate change, reduces the cost incurred for environment harm. As it is considered as the low cost for production and installation, it can be used widely to maintain sustainable development. In future it is also important to give awareness to the people and industries about these renewable resources and the future builders can build the building based on Building Integrated Photovoltaic techniques in their firms as well as the houses. Solar energy can prevent the earth from pollution and will be helpful in the path of sustainable development.

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