

SOLAR ENERGY AS SUSTAINABLE ENERGY VISION FOR POWER GENERATION

Dr. Kurapati.Swarnalatha¹, Dr. C.A. Jyothirmayee², Dr. M. Rama³, Dr. V. Nagalakshmi⁴, Dr. N. Gayatri Devi⁵, Dr.K. Srilatha⁶, Dr.S. Prathima kumari⁷, K. Subhashini⁸, P. Madhavi⁹

¹Associate Professor, Department of Chemistry, Ch.S. D.St. Theresa's College for Women

²Associate Professor, Department of Chemistry, Ch.S. D.St. Theresa's College for Women

³Associate Professor, Department of Chemistry, Faculty of Department of Chemistry, Ch.S. D.St. Theresa's College for Women

⁴Associate Professor, Ch.S. D.St. Theresa's College for Women Faculty of Hindi

⁵Associate Professor, Department of Chemistry, Ch.S. D.St. Theresa's College for Women

⁶Associate Professor, Faculty of Department of Physics, Ch.S. D.St. Theresa's College for Women

⁷Associate Professor, Department of Zoology, Ch.S. D.St. Theresa's College for Women

⁸Assistant Professor, Department of Chemistry, Ch.S. D.St. Theresa's College for Women

⁹Assistant Professor, Department of Chemistry, Ch.S. D.St. Theresa's College for Women

Abstract:

The growing global demand for clean, reliable, and renewable sources of energy has brought solar energy to the forefront as a sustainable solution for power generation. Solar energy, derived from the sun's radiation, offers an abundant and environmentally friendly alternative to fossil fuels. The vision of solar energy as a cornerstone of sustainable energy systems, emphasizing its role in reducing carbon emissions, enhancing energy security, and supporting economic development. The integration of photovoltaic (PV) and solar thermal technologies in residential, commercial, and utility-scale applications has demonstrated significant potential in transforming the energy landscape. With advancements in storage systems, smart grids, and supportive government policies, solar energy is poised to become a dominant force in global power generation. It is highlighting the need for continued investment, innovation, and policy reform to ensure solar energy's long-term contribution to a clean and sustainable energy future?

Keywords: sustainable energy systems, energy security, solar thermal technologies, sustainable energy future

1. Introduction:

India, recognized as one of the fastest-growing economies globally and the third-largest consumer of energy, confronts a dual challenge securing energy while reducing environmental impacts. In this regard, solar energy stands out as a viable and sustainable solution to address the nation's escalating power requirements. With more than 300 sunny days each year, India possesses significant potential to utilize solar energy as a clean, renewable, and inexhaustible resource¹

The objective of incorporating solar energy into India's power generation system is in harmony with the country's dedication to sustainable development and climate action objectives as outlined in international agreements such as the Paris Climate Accord². The Government of India has launched ambitious initiatives like the Jawaharlal Nehru National Solar Mission (JNNSM) and aims to reach 500 GW of non-fossil fuel-based capacity by 2030, with solar energy playing a pivotal role³.

Solar energy provides numerous advantages: it mitigates greenhouse gas emissions, reduces dependence on imported fossil fuels, and decreases long-term energy expenses.

Additionally, the decentralized characteristics of solar power systems including rooftop solar panels and off-grid solar setups are essential for rural electrification and energy accessibility in isolated regions, thereby addressing the urban-rural energy gap⁴.

India has also positioned itself as a global frontrunner in solar energy diplomacy through initiatives such as the International Solar Alliance (ISA), which fosters international cooperation for solar implementation in tropical nations. This not only enhances India's geopolitical influence but also creates opportunities for technology transfer, investment, and innovation within the clean energy domain⁵.

With ongoing policy backing, falling solar panel prices, and a rise in public-private collaborations, India is strategically poised to revolutionize its energy framework. Consequently, the vision of solar energy as a sustainable energy solution is not just a policy goal, but a vital pathway towards achieving energy autonomy, environmental sustainability, and economic resilience in the years ahead.

2. PRODUCTION OF SOLAR ENERGY

2.1. Photovoltaic (PV) System – Direct Conversion

This is the most common and widely used method of generating electricity from solar⁶ energy

Working Principle:

Solar panels (made of semiconductor materials like silicon) absorb sunlight.

The photons in sunlight strike the solar cells and knock electrons loose.

These free electrons create an electric current, which is collected by wires and directed⁷ into a usable form.

Main Components:

Solar panels (PV cells): Convert sunlight directly into DC electricity.

Inverter: Converts DC (direct current) into AC (alternating current), which is used in homes and industries.

Battery (optional): Stores excess energy for use at night or during cloudy periods.

Charge controller: Regulates voltage and current to prevent battery damage (in off-grid systems).

Grid connection (optional): Allows surplus electricity to be fed into the national⁷ grid.

Types of PV Systems:

On-grid system: Connected to the electricity grid.

Off-grid system: Works independently with battery storage.

Hybrid system: Combines both grid and battery (SEIA, n.d.).

2.2. Solar Thermal Power Plants – Indirect Conversion

This method uses sunlight to generate heat, which is then used to produce electricity⁸.

Working Principle:

1. Mirrors or lenses concentrate sunlight onto a receiver.
2. The heat is used to boil water and produce steam.
3. The steam drives a turbine connected to a generator, producing electricity.

Types of Solar Thermal Systems:

Parabolic Trough Systems

Solar Power Tower

Dish Stirling Engines

These are mostly used for large-scale power generation in solar farms (IRENA, 2020).

Advantages of Solar Power:

1. Renewable and inexhaustible
2. Reduces electricity bills
3. Low maintenance costs
4. Environmentally friendly (no emissions)
5. Ideal for remote or off-grid⁹ locations.

3. Production of Electricity from Solar Energy – In Detail

3.1. The Principle – The Photovoltaic Effect

The photovoltaic effect is the process by which solar energy (sunlight) is converted directly into electrical energy using semiconductor materials.

When sunlight hits the surface of a solar cell, the photons (light particles) carry energy that is absorbed by semiconducting materials, usually silicon.

This energy excites electrons, allowing them to break free from atoms.

These free electrons flow through the material, creating direct current (DC) electricity (U.S. Department of Energy, 2023).

3.2. Main Components of a Solar PV System

a. Solar Panel (Solar Module)

Made up of many solar cells connected together.

Each solar cell is made of a p-n junction diode using silicon.

When sunlight hits the cell, it generates DC electricity.

b. Inverter

Converts DC electricity (from solar panels) into AC electricity, which is required for most household appliances and for feeding into the power grid.

c. Charge Controller (Optional for Off-Grid Systems)

Regulates the voltage and current coming from the solar panels to the battery.

Prevents overcharging or deep discharging of the battery.

d. Battery (Optional)

Stores excess electricity for use during night time or cloudy days.

Useful in off-grid or hybrid systems.

e. Metering System

Measures the amount of electricity generated and/or consumed.

In grid-connected systems, a net meter records both import and export of power to/from the grid (SEIA, n.d.).

3.3. Step-by-Step Process of Electricity Generation

Step 1: Sunlight Hits the Solar Panels

Solar radiation strikes the photovoltaic cells in the solar panel.

Step 2: Generation of Electron Flow

The energy from sunlight excites electrons in the semiconductor material (usually silicon).

These electrons begin to move, generating a direct current (DC).

Step 3: Conversion of DC to AC

The generated DC electricity is sent to an inverter.

The inverter converts DC into AC, which can be used by home appliances or fed into the electrical grid.

Step 4: Power Usage, Storage, or Export

The electricity can be:

1. Used immediately in homes, schools, or industries.

2. Stored in batteries (in off-grid systems).
3. Exported to the grid (in grid-tied systems), reducing electricity bills through net metering (U.S. Department of Energy, 2023).

4. Types of Solar Energy Systems

Type	Description
On-Grid	Connected to the main power grid. No battery storage. Net metering available.
Off-Grid	Works independently. Requires batteries to store power.
Hybrid	Combines grid supply and battery storage.

Solar Thermal Method (Alternative Way)

1. In solar thermal power plants, sunlight is used to produce heat, not electricity directly.
2. Large mirrors focus sunlight onto a central receiver.
3. The heat boils water to create steam, which runs a steam turbine.
4. The turbine drives a generator, producing electricity (IRENA, 2020).

This method is suitable for large-scale utility power generation, not home use.

India's Role in Solar Electricity Generation

1. India receives 4–7 kWh/m²/day of solar energy.

Leading initiatives include:

2. National Solar Mission (launched in 2010)
3. International Solar Alliance (ISA)
4. Target of 280+ GW solar capacity by 2030 (Ministry of New and Renewable Energy [MNRE], 2023)¹⁰.

States like Rajasthan, Gujarat, and Tamil Nadu are solar power leaders.

Advantages of Solar Power Systems

1. Zero pollution or emissions
2. Low operating cost after installation
3. Energy independence
4. Long lifespan (25+ years for panels)
5. Supports sustainable¹⁰ development.

Electricity and Solar Energy in India

Reliable power supply to all households is a national goal, with rooftop solar installations encouraged for sustainable energy solutions (MNRE, 2023).

5. PLAN FOR SUSTAINED SOCIO-ECONOMIC DEVELOPMENT IN ELURU DIST ANDHRAPRADESH FOCUSING SOLAR ENERGY

The energy sector in Andhrapradesh will undergo major upgrades to ensure reliable power supply, expand electricity infrastructure, and promote renewable energy solutions. The vision focuses on strengthening power distribution networks, increasing substation capacity, and advancing solar energy adoption.

APEPDCL aims to supply 24x7 quality power at global standards to all consumers. In its drive towards enhanced customer service, APEPDCL offers its customers several forms of Customer Management Centers (CMCs) across its operational area, comprising:

ECC (Electricity Call Centers) CSC (Customer Service Centers)

CCC (Computerized Collection Centers) These centers deal with issues related to:

Fuse-off calls and supply

Billing and metering-related complaints

Bill payment and other related issues.

6. Vision:

To supply 24x7 quality power at global standards to all consumers.

To render world class services to the consumers through continual innovation and adoption of latest IT tools embedded with communication technologies.

To enhance operational efficiency and financial viability of power utilities for ensuring affordable cost-effective power supply to the end consumers.

To promote energy efficiency measures for achieving energy security and in the interests of environmental protection.

Providing of Solar Roof Top for Domestic consumers under PM Surya Ghar to help provide free/low-cost electricity up to 300 units per month through solar rooftop, to enhance the production of renewable electricity and in turn leading to reduction in emissions and to aid in achievement of India's climate commitments.

7. Present Status:

24 Hrs. Supply is being extending to District Head Quarters (DHQs), Corporations, Municipal Towns, MHQs, Rural Villages and Industries.

9hrs. 3 Ph. supply is being extending to all Agriculture Consumer during the day time to the agricultural services.

Maintenance is being carrying out on electrical network time to time to Provide uninterrupted and quality Power Supply.

Individual power supply complaints are being attending with the Ward and Village Secretariats staff.

Power supply is being monitoring in online to minimize the interruption time.

All the staff members were alerted to attend the emergency on war footing basis.

District level load monitoring cell will monitor the 24x7hrs. Power supply position. Ph No. 9440902926

All the customer complaints are attending through Customer Call centre at APEPDCL Head Qrts Visakhapatnam - Call Centre Toll free No.1912

Free Power supply is being extended to service connections of SC&ST house holds up to 200 units per month under "BabuJagajjeevan Ram JeevanaJyothi Scheme"

Free 9 Hours 3 Phase continuous quality power supply is being extended during day to Agriculture consumers.

Power supply is being extended to Aqua Farmers @ 1.50 paise per unit.

8.Strategies to improve energy efficiency:**T&D Losses:**

Conduct energy audits: Identify areas of high energy loss.

Install high-accuracy meters: Replace old meters with smart meters.

Seal meters: Prevent tampering and energy theft.

Inspect services: Regularly inspect transmission lines, substations, and distribution net works

Renewable Energy improvement

PM Surya Ghar muft bijili yojana scheme under phase-1 was targeted to less than 300 units consumption consumers based on the last 3 months average.

Energy Assistants will be trained as "Surya Mitras" by conducting awareness programmes, mobilization of consumers, door to door campaigning for outreach of applications registrations in PM Surya Ghar Yojan Scheme.

Meetings shall be conducted with stake holders, vendors, public for promoting PM Surya Ghar Yojan Scheme.

District Level Committee will be formed under the Chairmanship of District Collector for monitoring the Scheme.

9Hr Supply to Agriculture Consumers:

At present all feeders having agriculture services are being supplied by 9 Hrs. 3-Phase supply on daytime. Whenever an application registered and paid the estimate charges service will be released within 30 days.

EV Charging Stations:

All registered applications were released and no paid pending EV charging stations for release. Whenever, an application registered and paid charges, service will be released within 30 days.

Sl. No	Parameter	Physical Unit	target	Achievement (2023-24)	Physical Target					Total (2024-29)	Indicative Financial Plan - Expected sources of funding
					2024-25	2025-26	2026-27	2027-28	2028-29		
1	T& D Losses	%	8.94	8.67	8.39	8.14	8.02	7.94	7.78	-	EPDCL
2	Renewable Energy										
2a	PM Surya Ghar Solarisation of Domestic Consumers	Nos.	2500	35	165	1000	1000	300	0	2465	Central Government
2b	PM Surya Ghar Solarisation of Government Buildings	Nos.	143	0	23	60	60	0	0	143	Central Government
2c	Feeder Solarisation under PM Kusum	Nos.	8	0	0	3	3	2	0	8	Central Government
3	9 Hrs free Supply to Agriculture Feeders	Nos.	368	368	0	0	0	0	0	0	EPDCL
4	EV Charging stations	Nos.	30	10	2	5	5	5	3	20	-

Perspective Plan for solar energy- 2024-29

9.CONCLUSION

Energy infrastructure will be strengthened. The PM Surya Ghar scheme will facilitate the adoption of 5.0 MW of solar energy, reducing dependency on conventional energy sources and ensuring sustainable power solutions for the region.

The Government is committed to implement the Vision Plan 2024- 2029 to drive sustainable growth, modern infrastructure, and inclusive development. By strengthening Agriculture, Industry, Education, Healthcare and Tourism, Government aims to create **Happy, Healthy, Wealthy and Sustainable Society, making India a model for progress and prosperity.**

REFERENCES

1. The Energy and Resources Institute. (2022). Harnessing solar power for sustainable development in India. <https://www.teriin.org>
2. United Nations Framework Convention on Climate Change. (2015). India's intended nationally determined contributions (INDC). <https://unfccc.int>
3. Ministry of New and Renewable Energy. (2023). Annual report 2022–23. Government of India. <https://mnre.gov.in>
4. International Energy Agency. (2021). India energy outlook 2021. <https://www.iea.org/reports/india-energy-outlook-2021>
5. International Solar Alliance. (2023). ISA strategic plan and framework for action. <https://isolaralliance.org>
6. U.S. Department of Energy. (2023). How does solar work? Office of Energy Efficiency & Renewable Energy. <https://www.energy.gov/eere/solar/how-does-solar-work>
7. Solar Energy Industries Association. (n.d.). Photovoltaic (PV) solar energy. <https://www.seia.org/initiatives/photovoltaics>
8. International Renewable Energy Agency. (2020). Innovation outlook: Thermal energy storage. <https://www.irena.org/publications>
9. International Energy Agency. (2021). Renewables 2021: Analysis and forecast to 2026. <https://www.iea.org/reports/renewables-2021>
10. Ministry of New and Renewable Energy. (2023). India solar energy overview and initiatives. Government of India. <https://mnre.gov.in>