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Research Article

Challenges and Opportunities in Residential Solar Power Subsidies: A Case Study of India

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ABSTRACT

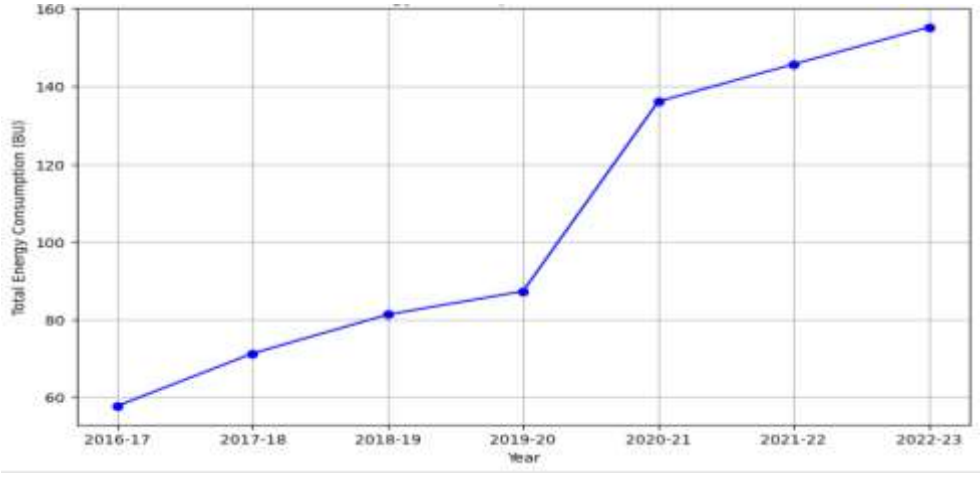
This study investigates the opportunities and problems related to solar power subsidies for homes in India. Through an examination of secondary data from official government reports, scholarly research, industry publications, and other reliable sources, the study illustrates how different subsidy programs have evolved and affected the expansion of solar power in the residential market. The usefulness of various subsidies, including feed-in tariffs, tax breaks, and capital cost subsidies, in encouraging the use of solar power is the main topic of this article. Important findings show that installed solar capacity has increased significantly, and solar technology efficiency has improved. However, issues including funding obstacles, delays in subsidy disbursement, and regional differences still exist. The study ends with policy proposals to improve the efficacy of subsidy schemes and hasten India's switch to sustainable energy.

Keywords: Subsidies, Renewable Energy, Policy Analysis.

Introduction:

As one of the economies with the fastest rate of growth in the world, India has a lot of work ahead of it to satisfy its energy needs and transition to a low-carbon, sustainable future. Traditional and contemporary energy sources coexist in the nation's energy landscape, with a focus on increasing the capacity of renewable energy sources. India's overall energy consumption has been rising over time due to the country's fast urbanization and economic expansion. As illustrated in Figure 1, the Central Electricity Authority (CEA) estimates that India's overall energy consumption for the 2022 –23 fiscal year was 155.2billion units (BU).

Figure 1. India Total Energy Consumption Trend (2016-17 to 2022-23)



Ref. Central Electricity Authority (CEA) Annual Report 2022-23

Fossil fuels, especially coal, make up most of India's energy mix and provide over 58% of the country's total energy consumption. Nonetheless, a deliberate attempt has been made to raise the proportion of renewable

energy sources in the mixture. The energy landscape of India is changing, with a shift towards cleaner and more sustainable sources. While renewable energy is growing, fossil fuels—especially coal, which accounts for 58% of the country's energy mix—remain important in meeting the country's energy needs. The country's commitment to lowering its carbon footprint and boosting energy security through diversification is reflected in the notable increase in the share of renewable energy sources, which is expected to reach 26% in 2022–2023.

The addition of hydropower at 6% and natural gas at 7%, respectively, demonstrates efforts to diversify the energy mix. Natural gas can be used as a transitional fuel for a more sustainable future because it is cleaner than coal. With nuclear energy continuing to provide 3% of the energy mix, it shows that it is a dependable and low-carbon source of power. According to the data, India's energy mix is trending in the right direction toward becoming cleaner and more varied. This transition may be accelerated by continuing to invest in clean fuel policy and renewable energy infrastructure, which would lessen the need for fossil fuels and promote environmental sustainability.

Renewable Energy Growth:

In recent times, India has achieved noteworthy progress in increasing its capacity for renewable energy. According to Table 1, the total capacity of renewable energy was 155.2 gig watts (GW) in 2022–23, up from 57.8 GW in 2016–17.

Table 1. Growth of Renewable Energy Capacity

Year	Energy Capacity (GW)
2016-17	57.8
2017-18	71.3
2018-19	81.3
2019-20	87.3
2020-21	136.1
2021-22	145.7
2022-23	155.2

Ref. MNRE Annual Reports 2016-17 to 2022-23

India has made considerable strides in the last seven years to increase its capacity for renewable energy, as shown by the figures in Table 1. India's capacity to produce renewable energy rose annually between 2016–17 and 2019–20. The capacity increased from 57.8 GW in 2016–17 to 87.3 GW in 2019–20. Consistent efforts and expenditures in renewable energy infrastructure are indicated by this continuous rise. The capacity of renewable energy increased significantly in 2020–21, rising from 87.3 GW to 136.1 GW. This indicates a significant shift towards renewable energy, perhaps caused by supporting regulations, more investments, and quicker project completions. It also shows an increase of about 48.8 GW in a single year.

Though more slowly than during the peak in 2020–21, the trend of growing capacity persisted in 2021–22 and 2022–23. The capacity increased to 155.2 GW in 2022–2023 and 145.7 GW in 2021–2022. This steady expansion indicates a continued dedication to improving the infrastructure for renewable energy. India's total renewable energy capacity expanded by 97.4 GW over the seven-year period, rising from 57.8 GW in 2016–17 to 155.2 GW in 2022–23. This indicates a about 168% cumulative growth rate. The nation's strategic aim on diversifying its energy mix and lowering reliance on fossil fuels is highlighted by such a large increase.

India's energy security is enhanced by the fast growth of renewable energy generation, which lessens the country's dependency on imported fossil fuels. By encouraging the use of cleaner energy sources and reducing greenhouse gas emissions, it also advances environmental sustainability goals. Despite the remarkable expansion, there are still issues with maintaining a steady supply of energy, integrating this renewable capacity into the current power infrastructure, and drawing in new investment. To maintain and accelerate this economic trajectory, the future forecast points to the necessity of ongoing legislative support, technical breakthroughs, and infrastructure development.

Solar Power as a Renewable Energy Source:

One of the most abundant and sustainable forms of renewable energy on Earth is solar electricity, which is generated by the sun. Although it has been used for millennia in many forms, technological developments in the last few decades have greatly increased its affordability and efficiency, making it a crucial part of the world's energy landscape.

1. **Sufficient and Easily Reachable**: The sun's immense energy supply, which exceeds the Earth's annual energy consumption, makes solar energy an appealing possibility for addressing the rising energy requirements world population.
2. **Advantages for the Environment:** Solar energy has a lower environmental impact than typical fossil fuels, lowering greenhouse gas emissions and mitigating climate change effects. It also does not deplete local water resources or contaminate the air or water.
3. **Technological Progress:** Advancements in technology have significantly boosted solar energy growth, with photovoltaic cells becoming more efficient and concentrated solar power systems expanding their applications.CSP systems employ mirrors or lenses to focus sunlight into a small area to produce steam and electricity.
4. **Financial Gains:** Solar energy has various financial benefits, including simplicity of purchase for governments, organizations, and individuals, greater employment, and energy security by lowering reliance on imported fuels and volatile energy markets.
5. **Safety of Energy:** Solar power improves energy security by distributing output across multiple sites, decreasing the need for big infrastructure and making it a viable choice for off-grid and rural communities.

One important renewable energy source that has the ability to provide the world's energy demands fairly and sustainably is solar electricity. It is a crucial part of the contemporary energy portfolio due to its advantages in terms of economics, energy security, and the environment. To overcome the obstacles, we have now and to fully utilize solar energy in the future, research and investment in solar technology must continue.

Research Objectives: The following are the main objectives of the research study.

- To determine the obstacles that domestic solar power subsidies must overcome to be implemented.
- To explore the opportunities that these subsidies offer to households as well as the larger energy market.

Indian Government Policies and Initiatives for Solar Power:

Driven by a combination of aggressive targets, strong support systems, and proactive policies, India has become a global leader in the adoption and promotion of solar power. The Indian government's commitment to increasing solar energy capacity is a component of a larger strategy to improve energy security, lower carbon emissions, and promote sustainable development. This article summarizes major policies and initiatives through 2022–2023.

1. The National Solar Mission: The Jawaharlal Nehru National Solar Mission (JNNSM), launched in 2010 as part of the National Action Plan on Climate Change, aims to make India a global leader in solar energy. The mission initially aimed to generate 20 gigawatts of solar electricity by 2022, but has since made significant progress with over 60 GW of installed solar capacity.
2. Solar Parks and Extensive Solar Power Initiatives: The Solar Park initiative, launched in 2014, aims to boost large-scale solar power projects by providing infrastructure and land, aiming to increase efficiency and reduce costs. The initiative aims to build 50 solar parks, including the world-record Bhadla Solar Park in Rajasthan.
3. Program for Rooftop Solar: The government has backed rooftop solar installations since 2015, aiming for 40 GW of capacity by 2022. The Grid-Connected Rooftop Solar Program provides incentives and subsidies to commercial, industrial, and residential sectors, with state nodal agencies receiving financial support and various financing options.
4. Alliance Solar International (ISA): India, along with France, played a key role in the formation of the International Solar Alliance (ISA) in 2015, aiming to increase solar energy utilization by raising over $1 trillion in capital by 2030 through collaborative efforts and capacity development.
5. KUSUM Scheme: The Kisan Urja Suraksha evam Utthan Mahabhiyan (KUSUM) project, launched in 2019, aims to empower farmers by utilizing solar energy through freestanding solar pumps, grid-connected solar power plant setups, and agriculture pump solarization. The project aims to increase income, reduce diesel dependency, and promote sustainable irrigation techniques.
6. Guidelines for R&D and Manufacturing: The Indian government has implemented various programs to boost domestic solar equipment production and reduce import reliance. In 2020, the Production Linked Incentive scheme was introduced, offering financial incentives to high-efficiency solar module producers. The government also supports innovation and technical advancement through grants and initiatives.
7. Renewable Energy Certificates (RECs) and Renewable Purchase Obligations (RPOs): The government mandates distribution firms and other entities to meet Renewable Purchase Obligations (RPOs) to meet renewable energy targets. RPOs mandate entities to obtain a specific portion of their energy from renewable sources, like solar energy. Renewable Energy Certificates (RECs) promote accountability and openness in renewable energy procurement.
8. The Green Energy Corridors project, initiated in 2013, aims to strengthen the transmission system to accommodate the increasing use of renewable energy in the national grid. It involves building specific transmission lines and substations to transport electricity from states with abundant renewable energy sources to demand centers, ensuring efficient and reliable transport of solar power.

India has grown its solar power capacity to over 60 GW by 2023, thanks to government policies, large investments, and public-private partnerships. However, challenges remain in project financial feasibility, grid connectivity, and land acquisition, despite India's impressive progress.

Subsidy Models and their Impact:

By increasing the economic viability of solar power for households, companies, and utilities, subsidies are essential in fostering its acceptance and growth. Feed-in tariffs (FiTs), tax incentives, and capital cost subsidies are only a few of the several forms of subsidies that governments and regulatory agencies use to encourage the development of solar power.

1. **Capital Cost Subsidies:** Upfront subsidies sometimes referred to as capital cost subsidies, lower the initial outlay needed to establish solar-generating installations. Usually, these subsidies come in the form of direct cash support or refunds to help with part of the equipment and installation expenses.

a. Commercial and Residential Solar Systems: The Indian government's Grid-Connected Rooftop Solar Program provides capital subsidies for residential rooftop solar installations, covering up to 40% of installation expenses for systems up to 3 kW and 20% for systems between 3 kW and 10 kW, starting in December 2023.

b. Agricultural Sector: Farmers who install solar pumps and grid-connected solar power plants are eligible for subsidies under the Kisan Urja Suraksha evamUtthanMahabhiyan (KUSUM) scheme. The program provides a federal subsidy of 30%, state and local government subsidies of 30%, and bank loans for the remaining 40%.

2. **Feed-in-Tariffs for (FiTs):**By guaranteeing a set, premium price for electricity produced from renewable sources for a predetermined amount of time, feed-in tariffs are a type of policy instrument intended to promote the use of renewable energy sources. These tariffs increase the appeal of investing in renewable energy sources and offer long-term price stability.

a. State-Level Feed-in Tariff schemes in India: To encourage solar energy, several Indian states have put in place feed-in tariff schemes. Tamil Nadu, Gujarat, and Karnataka, for example, provide appealing FiTs for solar power projects. State-by-state variations in these tariffs are made to account for shifting market dynamics and the cost of technology.

b. Global Examples: FiTs have been effectively utilized by Germany and Spain to propel a notable increase in their solar power capacity. By December 2023, Germany will still provide varying FiTs depending on the kind and size of solar systems, making sure that both major utility-scale projects and small-scale residential projects get the assistance they need.

3. **Tax Incentives:** Another significant type of subsidy that lowers the overall cost of solar power projects is tax incentives, such as tax credits, deductions, and exemptions. These minimize the tax burden of individuals and corporations who invest in solar energy.

a. Accelerated Depreciation: Investors in solar power in India are allowed to deduct a larger amount of the investment cost from their taxable income in the first years by claiming accelerated depreciation on their solar assets, thanks to a government policy that permits this. Businesses that implement solar power projects might benefit from an accelerated depreciation rate of 40% as of December 2023.

b. Income Tax Benefits: Section 80-IA, which allows a tax holiday for a predetermined duration, is one of the incentives offered by the Income Tax Act, 1961, for solar generating plants. With this benefit, developers can claim all income and gains from the company for ten out of the fifteen years that they are in operation, beginning in the year that the firm is commissioned.

c. Goods and Services Tax (GST) Relief: The Indian government has imposed a concessional GST rate of 5% on solar power generating systems and components to further alleviate the financial burden.

Table 2. Comparative Analysis of Solar Power Subsidies

Subsidy Type	Example Program	Coverage/Benefits	Year of Implementation
Capital Cost Subsidies	Grid-Connected Rooftop Solar Programme	Up to 40% subsidy for residential rooftop systems	2015-Present
	KUSUM Scheme (Component A)	Up to 60% subsidy for farmers installing solar pumps	2019-Present
	Maharashtra State Solar Agricultural Feeder Program	Up to 40% subsidy for solarizing agricultural feeders	2017-Present
Feed-in Tariffs (FiTs)	Tamil Nadu Solar Policy	FiTs for solar power projects, periodically revised	Ongoing
	Gujarat Solar Policy	Attractive FiTs for solar projects, enabling rapid	Ongoing

		capacity expansion	
	Karnataka Solar Policy	FiTs with specific tariffs for different capacities and technologies	Ongoing
Tax Incentives	Accelerated Depreciation	40% accelerated depreciation on solar assets	Current as of 2023
	Section 80-IA	Tax holiday for infrastructure projects including solar power plants	Current as of 2023
	Custom and Excise Duty Exemptions	Exemptions on import duties for solar PV cells and modules	2012-Present

Table 2 above compares capital cost subsidies, feed-in tariffs (FiTs), and tax incentives across various locations and programs, along with their coverage, benefits, and year of implementation, to show the impact of these subsidies.

Specific Impact of the Subsidy scheme for solar power:

Subsidy schemes including feed-in tariffs (FiTs), tax incentives, and capital cost subsidies have significantly impacted the solar power industry in India and around the world. These effects can be divided into four main categories: technological developments, capacity expansion, economic advantages, and environmental improvements.

1. Capacity Expansion

Table 3. India's growth in both rooftop and total installed solar capacity between 2014 and 2023

Year	Total Installed Capacity (GW)	Rooftop Solar Capacity (GW)
2014	2.63	0.26
2015	4.88	0.39
2016	9.03	0.76
2017	18.45	1.32
2018	25.21	1.82
2019	34.45	3.21
2020	39.24	4.32
2021	49.35	6.11
2022	57.97	8.17
2023	67.82	10.25

Ref. MNRE Annual Reports 2014 to 2023

The information demonstrates the noteworthy advancements in rooftop solar capacity and overall installed solar capacity between 2014 and 2023. India had 2.63 GW of installed solar capacity as of 2014. This number increased to 67.82 GW by 2023, a more than 25-fold growth in just nine years. The largest increases, from 9.03 GW to 18.45 GW in 2016 and from 49.35 GW to 57.97 GW in 2022, respectively, denoted periods of faster development in solar energy installation.Significant growth was also seen in the rooftop solar capacity, which increased from 0.26 GW in 2014 to 10.25 GW by 2023—an almost 40-fold increase.Rooftop solar system adoption appears to have increased as seen by the notable growth periods in rooftop installations between 2018 and 2019 (from 1.82 GW to 3.21 GW) and between 2021 and 2022 (from 6.11 GW to 8.17 GW).

2. Economic Benefits:

Table 4. Job Creation and Cost Reduction in the Solar Sector in India (2014-2023)

Year	Jobs Created (Thousands)	Cost of Solar Power Generation (INR per kWh)
2014	24	7.0
2015	30	6.2
2016	36	5.0
2017	52	4.5
2018	65	3.8
2019	78	3.5
2020	85	3.0
2021	95	2.8
2022	110	2.4
2023	120	2.0

Ref: Report of MNRE, NSEFI, IRENA, CEA etc.

The table shows a steady rise in employment creation in India's solar industry between 2014 and 2023. The number of positions increased five-fold during the decade, from 24,000 in 2014 to 120,000 in 2023. This pattern shows how increasing solar capacity can boost jobs through increased production, installations, maintenance, and other auxiliary services. AS per the table data in India, the cost of producing solar power decreased significantly between 2014 and 2023. The cost has decreased from INR 7.0 per kWh in 2014 to INR 2.0 per kWh in 2023, exhibiting an impressive 71% decrease. Many causes, such as the development of solar technology, economies of scale, competitive bidding procedures, and government incentives, might be blamed for this decline. In the Indian market, solar energy has become increasingly competitive and appealing due to its decreasing costs.

3. Environmental Improvement:

Table 4. Annual CO_2 Emissions Avoided bySolar Power in India (2014-2023)

Year	CO_2 Emissions Avoided (Million Tonnes)
2014	3.27
2015	6.08
2016	11.25
2017	22.99
2018	31.45
2019	43.05
2020	49.07
2021	61.71
2022	73.07
2023	85.48

Ref: MNRE, Indian Network for Climate Change Assessment

The table illustrates how India's growing solar power installations have had a favorable environmental impact over the past ten years. Between 2014 and 2023, the amount of CO_2 emissions prevented increased significantly, from 3.27 million tonnes to 85.48 million tonnes. This pattern emphasizes how important solar energy is to India's efforts to lessen its carbon footprint and combat climate change. The installed capacity of solar power has been growing rapidly due to government policies, technological breakthroughs, and greater investments in the renewable energy sector, which has resulted in a significant reduction in CO_2 emissions.

4. Technological advancements:

Table 5. Improvement in the Efficiency of Solar PV Cells and the Growth ofDomestic Manufacturing Capacity for Solar Components in India (2014-2023)

Year	Efficiency of Solar PV Cells (%)	Domestic Manufacturing Capacity (GW)
2014	14	1.2
2015	15	2.0
2016	16	3.5
2017	17	5.0
2018	18	8.0
2019	18.5	10.0
2020	19	12.5
2021	19.5	15.0
2022	20	20.0
2023	20.5	25.0

Ref: National Institute of Solar Energy, India

Over the previous ten years, India has consistently seen a growth in the efficiency of solar PV cells. The efficiency increased from 14% in 2014 to 20.5% in 2023. The following are highlighted by this trend:The consistent increase in efficiency reflects substantial advances in technology and improved manufacturing techniques. More efficient solar cells have been produced because of ongoing research and development investments. This growth has been attributed to the emergence and use of cutting-edge technologies like bifacial cells and PERC, among other advancements.

India's domestic solar component production capacity increased dramatically between 2014 and 2023, from 1.2 GW to 25 GW. This expansion is explained by that local manufacturing has been stimulated by programs such as 'Make in India' and production-linked incentives (PLI). A strong domestic manufacturing base is now more important than ever due to the growing demand for solar power installations. To fulfil the rising demand, a large amount of money has been invested in the establishment of new manufacturing facilities and the expansion of existing ones.

Conclusion:

The study indicates that although numerous subsidy plans have helped India's home solar power market make a great development, there are still several obstacles to overcome. Feed-in tariffs, tax breaks, and capital cost subsidies have all helped to drive down the cost of producing solar power and increase the number of solar installations. Widespread adoption is hampered, meanwhile, by problems with solar system affordability, financing choices, and subsidy disbursement delays. Significant obstacles also include quality and reliability issues, integrating with the current electricity infrastructure, and regional differences in the application of subsidies.

The study's result emphasizes how important government regulations and financial aid are in encouraging the use of solar energy in homes. India can accelerate the transition to a sustainable and independent energy future by tackling the issues that have been identified and seizing the chances that present themselves.

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