Comparative Analysis of Solar Energy Initiatives of Pakistan, India and Germany: Lessons for Pakistan

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Abstract:

Solar energy, introduced in the 1980s, has emerged as a pivotal component of the global energy mix, offering renewable, sustainable power harnessed directly from sunlight through technologies such as photovoltaic and thermal collectors. Solar installations entail minimal operational costs and boast a lifespan of nearly three decades, contributing to reduced emissions and mitigated greenhouse effects. The sun's radiation, available universally albeit variably, holds immense potential, with just one and a half hours of sunlight capable of meeting global energy needs for a year. Despite these advantages, Pakistan remains in the early stages of solar adoption, heavily reliant on fossil fuels. To overcome this energy dilemma, robust legislative support is essential to facilitate a transition towards solarization. Policy interventions should prioritize subsidies, technology transfers, and streamlined procedures to attract both local and foreign investment. Drawing lessons from successful models in India and Germany, Pakistan should focus on comprehensive energy reforms, integrating solar power into its national agenda to ensure sustainability and economic stability.

Key words:

solar energy, renewable energy, Pakistan, energy policy, solarization

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Introduction

Solar energy was introduced in the 1980s into the world energy mix. Solar energy is renewable and generated from the sun. Technologies are available for harvesting it directly from sunlight. Active technology includes photovoltaic and thermal collectors. Once the solar technology is installed for the generation of electricity, it does not require fuel for operation, and the maintenance cost is almost negligible. The lifespan of solar panels is nearly three decades. It reduces toxic material emissions; the greenhouse effect is diminished. Solar energy is radiation from sunlight. It is also known as electromagnetic radiation. These are emitted by the sun during the day around the globe. Earth receives these radiations at all locations with varying amounts. It depends on various factors, i.e., geographic location, weather patterns, day and night timings, etc. The amount of sunlight that reaches Earth in one and a half hours is sufficient for the world's energy requirement for one year. This is the potential of solar energy. The only requirement is to install its equipment efficiently and make use of this natural renewable source of energy. Solar technologies convert sunlight into electrical energy either through PV or through mirrors that concentrate solar radiation. Solar energy provides electricity, heat, cooling, and lighting for various applications. It is the most abundant of all the renewable sources in the world. The cost of solar panels has decreased over time. The technology has been upgraded due to research and development on solar panels and thermal collectors. Solar energy is contributing to electricity generation; it is cost-effective and contributing to economic growth. It is effective in small and large-scale installations.

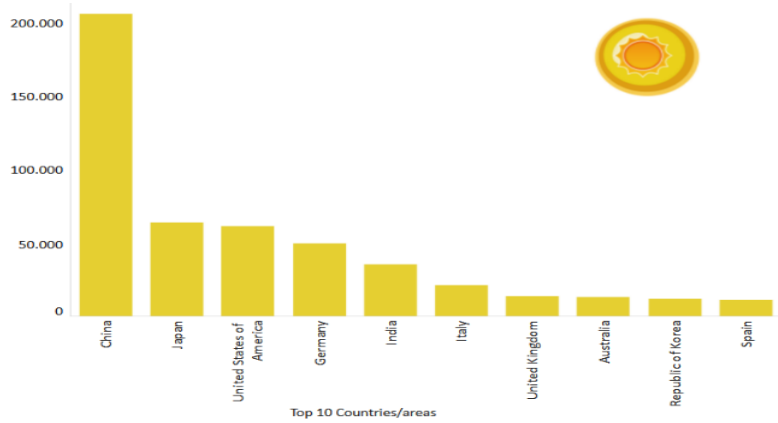

Figure 1: Installed Capacity of Solar Energy in World

Statement of the Problem

Solar energy generation has increased worldwide as energy production from renewable sources is not fulfilling the requirements, and prices are increasing globally. All countries are trying to enrich their energy baskets with renewable sources, especially solar. Pakistan's energy mix is dominated by traditional fossil fuels, which are expensive and the main cause of the energy crisis in the country, while solar production is very negligible. Countries like Germany and India have increased production from solar energy, but Pakistan is still struggling, despite having great potential for solar energy generation. What are the reasons that solar energy generation trends have not been followed by Pakistan in the last decades? How can this deficiency be overcome, and solar energy generation increased in Pakistan by critically analyzing gaps and suggesting ways forward?

Methodology

This study uses a quantitative analysis and secondary data, strengthened by some primary data in the form of interviews with key stakeholders in the Planning and Finance departments of the Government of KP and the Economic Affairs Division of the federal government. Available literature on the history, evolution, nature, and effects of foreign aid is studied. Experiences of different countries and the impact of FA on the economic health of recipient countries are examined. Pakistan's experience with FA is probed, followed by an overview of KP's foreign aid portfolio over the last ten years. The focus then shifts to the FA portfolio for FY 2021-22, to analyze the terms and conditions attached to foreign aid and to carry out a cost-benefit analysis. A true cost-benefit analysis was not possible for several reasons, including the portfolio being ongoing with no evaluation conducted, having sixty projects from different donors aimed at several sectors with entirely different outcomes and procedural requirements, which could be identified in project documents available for some projects, whereas in most cases they could be guessed from the nomenclature of the projects. Literature is silent on the modalities of conducting a cost-benefit analysis including Net Present Value, Internal Rate of Return, Economic Rate of Return, and Sensitivity Analysis of a diverse mix of projects in one place. As such, there was no analytical framework available for conducting a cost-benefit analysis of a mix of projects. Moreover, most of the project documents made available by the Planning & Development Department Khyber Pakhtunkhwa do not contain any kind of cost-benefit analysis.

As a way out, this research paper considers all the projects financed through foreign assistance, including both grants and loans, and analyzes their nature and sectors of intervention. Based on the available project documents, this study tries to obtain the targeted activities and outcomes to form an opinion

if both grants and loans entail costs and, if there are costs, to juxtapose these with the planned benefits. For loan-based projects, this research will try to ascertain if the loans are utilized in productive sectors with the potential for generating economic growth and the ability to pay back the principal amount and interest involved, and the cost of these loans as compared to domestic borrowing. In addition, this study also tries to ascertain the financial status of the province vis-a-vis these loans.

Scope of study

The scope of the study is to analyze the existing potential of solar energy in Pakistan in comparison with India and Germany. It aims to highlight the initiatives taken by India and Germany that led to success in the solar energy sector and identify the gaps regarding Pakistan's failure to tap into its solar potential. The paper also critically scrutinizes the issues and challenges faced by Pakistan in solar energy expansion in comparison with India and Germany.

Literature review

The main reliance for the research was on the energy policies of the three countries. The study examined how these policies were framed, the reasons and vision of the governments for investing in solar technology, and the implementation phases of these policies, with a special focus on the challenges faced by each country. Key initiatives were investigated to understand how the shift from thermal and oil-based energy generation to solar generation was achieved. Lessons learned were studied in comparison with the poor performance of the Pakistani system.

Organization of the Paper

The paper is organized into sections and subsections. It is divided into three main sections. Section I deals with solar energy initiatives in Pakistan. Section II focuses on solar energy initiatives in India. Section III provides an overview of solar energy initiatives in Germany. These three sections are followed by a conclusion and recommendations.

Solar Energy in Pakistan

In Pakistan, the total installed capacity of electricity is 41,557 MW. However, the installed capacity for solar energy is only 600 MW. The breakdown of installed capacity by fuel type is as follows: Hydel accounts for 24.7%, RLNG for 23.8%, RFO for 14.3%, Coal for 12.8%, Gas for 8.5%, Nuclear for 8.8%, Wind for 4.8%, and Bagasse for 0.9%. In Pakistan, the total installed capacity

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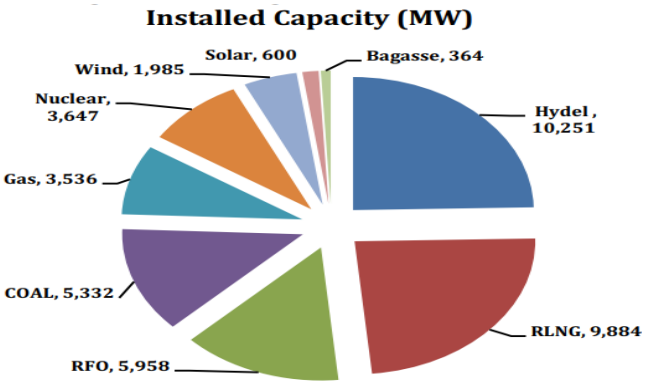
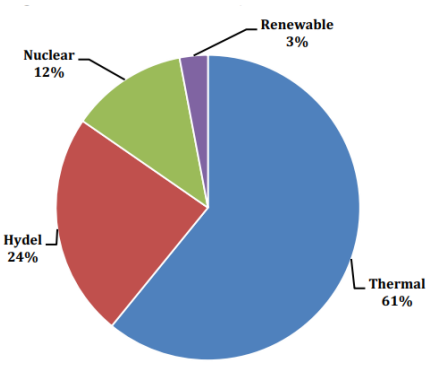


Figure 2: Installed Capacity (MW) in Pakistan from Survey of Pakistan 2021-22

Electricity Generation

Electricity generation in Pakistan is dominated by thermal sources, followed by hydel, nuclear, and a very small share from renewable sources. The detailed breakdown of each source's share in electricity generation in Pakistan is as follows:



Source: Ministry of Energy, (Power Division)

Figure 3: Electricity Generation patterns in Pakistan

As reflected, the renewable share is only 3%, which is significantly lower compared to other countries worldwide. Pakistan possesses abundant potential for solar energy generation, with ample sunlight available, yet this potential remains largely untapped.

Energy Crisis in Pakistan

Pakistan is facing an energy crisis characterized by increasing energy demand that exerts pressure on the national economy. With limited resources, particularly in light of Pakistan's heavy reliance on oil for energy generation, the recent surge in oil prices has severely impacted the economy. The oil import bill surged by 100%, exceeding US$ 17 billion in the previous financial year alone, depleting Pakistan's foreign exchange reserves. The country is experiencing a red alert due to energy insecurity. It is imperative to reduce dependence on fossil fuels and transition to renewable sources such as solar and wind energy. The current energy mix and distribution systems are beset with issues stemming from neglect in energy planning. Consequently, Pakistan faces energy shortages, expensive electricity, hindrances to industrialization, escalating imports, negligible exports, and a rising unit price that has surpassed Rs 22 for domestic and commercial use. These factors collectively threaten Pakistan's economy and national well-being, stalling economic growth and industry while contributing to deficit budgets.

Solar Potential

Pakistan boasts enormous potential for solar energy generation, estimated at over 100,000 MW. According to a World Bank report, Pakistan utilizes a mere 0.071% of its land for solar production. Southern Punjab, Balochistan, and Sindh regions exhibit particularly high solar potential, receiving approximately 10 hours of sunlight daily. In these areas, a 100m² space can generate between 45-85 MW of solar energy per month.

Major Issues

- Thermal power plants reliant on imported fuel.
- Inadequate development of alternative energy sources like hydel, solar, and wind.
- High cost of electricity generation.
- Rising international oil prices.
- Accumulation of circular debt in the power sector, reaching up to 2.5 trillion.
- Power distribution system losses due to aging infrastructure.
- Electricity theft.
- Take-or-pay contracts with Independent Power Producers (IPPs).
- Insufficient local gas availability for industry and new power plants.
- Inefficient electricity usage.

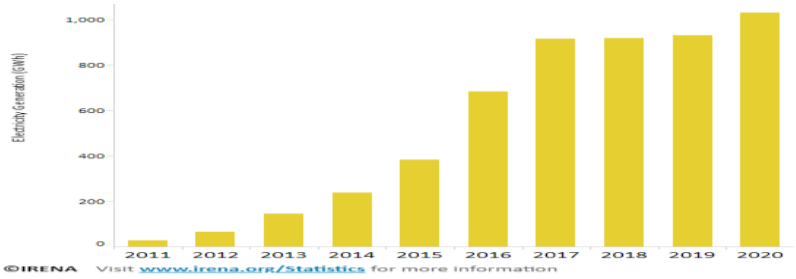


Figure 4: Electricity Generation Trends

Renewable Energy Policies

To promote renewable energy (RE), Pakistan introduced the Alternate and Renewable Energy Policy in 2020, aiming to shift 20% of energy generation to RE sources by 2025 and 30% by 2030. Achieving these targets requires substantial investment in the energy sector. As of December 31, 2021, there were 17,950 net-metering based solar installations with a cumulative capacity of 305.79 MW.

Integrated Generation Capacity Expansion Plan (IGCEP)

Prepared by NTDC in line with Grid Codes and approved by the Council of Common Interest (CCI), IGCEP is a dynamic document for Pakistan's future energy needs. It undergoes annual reviews to adapt to the country's evolving energy dynamics. IGCEP outlines increasing generation capacity to 61,112 MV by 2030, encompassing power generation, tariff determination, power evacuation, and distribution. It serves as a comprehensive policy document and a vision for the power sector, emphasizing structural changes in planning and execution to prioritize least-cost factors for RE generation. IGCEP focuses on solar, wind, and hydel power, leveraging local resources aligned with international best practices. With 73 approved projects and 148 on the waiting list, IGCEP targets 7,932 MW from solar and 5,005 MW from wind projects by 2030. The plan aims to reduce reliance on imported oil, coal, and gas, lowering energy production costs through affordable and renewable sources, thus conserving foreign exchange reserves.

India's Solar Energy Initiatives

India ranks fifth globally in installed solar capacity, with a total installed capacity of 56.951 GW. The country holds immense potential for solar energy

generation. A significant initiative in this realm is the National Solar Mission (NSM) launched in 2010. NSM urged states to address the country's energy needs amidst environmental changes sustainably, focusing on energy security by shifting to solar energy. Initially targeting 20 GW by 2022, India achieved this milestone in 2018, subsequently raising the target to 100 GW by 2022. The mission aimed to attract US$ 100 billion in investments to the sector.

To assess its solar potential comprehensively, India invested significantly in solar resource assessment (SRRA), introducing a Solar Radiation Atlas for data collection, storage, and analysis. States like Andhra Pradesh, Delhi, Gujarat, Haryana, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Rajasthan, Tamil Nadu, and Telangana exhibit substantial solar energy potential. India's waste lands alone could potentially generate 748 GW of solar energy, covering only 3% of such areas. Notably, India ranked third globally in the Renewable Energy Attractive Index 2021, with investments in the renewable energy sector reaching US$ 14.5 billion in FY 2022.

Year	Installed RE Capacity (in GW)	% Share of RE in total Installed Capacity	Generation from Renewable Sources (in BU)	Total Generation from all sources (in BU)	% Share of RE in Generation
2014-15	**39.55**	**14.36**	61.78	1110.18	**5.56**
2015-16	46.58	15.23	65.78	1172.98	5.60
2016-17	57.90	17.68	81.54	1241.38	6.56
2017-18	69.77	20.24	101.83	1303.37	7.81
2018-19	78.31	21.95	126.76	1375.96	9.21
2019-20	87.07	23.52	138.32	1390.93	9.95
2020-21	**92.54**	**24.53**	111.92	1017.81	**11.00**
	(Up to Jan, 2021)	(Up to Jan, 2021)	(Up to Dec, 2020)	(Up to Dec, 2020)	(Up to Dec, 2020)

Figure 5: India RE Sector at a glance

One Sun One World One Grid

India has taken the lead in utilizing solar energy globally and proposed the International Solar Alliance (ISA) for solar development. The alliance, headquartered in India, elaborates the concept of One Sun One World One Grid. Its goal is to harness the potential of solar energy economically for electricity generation, advocating for a World Solar Bank on a global scale. The alliance includes over 120 countries, highlighting India's commitment to solar energy development. Following the implementation of the NSM policy in 2010, India attracted more than $64.2 billion in FDI in this sector from 2014 to 2019. The installed capacity of solar energy has rapidly increased since 2010, detailed as follows:

Year	Installed Capacity in (MV)
2010	161
2011	461
2012	1,205
2013	2,319
2014	2,632
2015	3,744
2016	67,63
2017	12,289
2018	21,651
2019	28,181
2020	34,627
2021	40,085
2022	56,951

Policy Measures

The Government of India has introduced numerous schemes for solar energy development, such as tax-free loans, Solar Parks, Rooftop installations, Smart Cities initiatives, Canal Top projects, the Green Energy Corridor Scheme, and improvements in transmission and evacuation infrastructure. Policy steps were taken to encourage investors, including exemptions for Interstate Transmission System (ISTS) from loss charges, imposition of Renewable Purchase Obligation (RPO), streamlined procurement processes for solar projects, and protection of investments through must-run status. Competitive bidding processes were implemented, and laws were amended to mandate solar installations on rooftops of new buildings. Long-term loans were sanctioned for higher capacity solar plants. These measures have led to achieving grid parity in solar tariffs, reducing the unit price from ₹6.47/KWh to less than ₹2/KWh. The installed solar capacity has increased more than elevenfold in the past five years. In 2013, an autonomous institution was established to implement solar policies, while initiatives like discouraging kerosene lamps and promoting solar lanterns and home lights were also undertaken. India has committed to the Paris Agreement (2021-2030) and aims to reduce CO2 emissions by 33-35% while ensuring 40% of electricity generation comes from renewable sources.

Off-Grid Initiatives

India, the seventh-largest country by area and the second-most populous with around 1.4 billion people, faces electricity shortages in rural areas where extending on-grid systems is challenging due to terrain and logistical constraints. To address this, the government initiated solarization of villages, establishing small solar grids to provide affordable electricity and alleviate poverty. More than 2.5 million solar lighting systems and 3.2 million solar lamps/lanterns were distributed, benefiting commercial activities and enhancing living standards. Solar energy is also used for irrigation systems through solar pumps, replacing expensive diesel pumps used previously by farmers. The government provided interest-free loans under the PM scheme "Kisan Urja Suraksha Evam Utthan Mahabjiyan (KUSUM)" to promote solar pumps, which surpassed 3.5 million installations by 2022. The National Solar Mission planned three phases for off-grid areas: the first aimed at 200MW from 2010-2013, the second targeted 500MW from 2013-2017, and the third aimed for 118 MW.

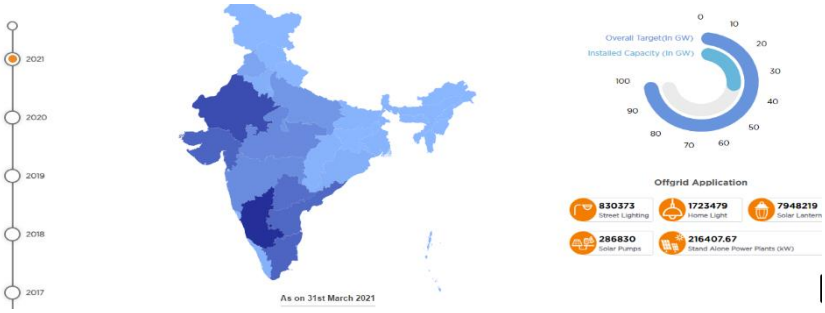


Figure 6: Off Grid Applications data in India

On-Grid Initiatives

The solar power sector in India is playing a crucial role in alleviating the energy crisis by supplying electricity to the national grid at a low cost. India has established manufacturing capabilities for solar PV cells and modules with capacities of around 3GW and 10GW, respectively. The Ministry of Information Technology provides a 20-25% subsidy to investors in electronic systems manufacturing, and manufacturing units receive reimbursements on excise duties. The cost of electricity production per megawatt from solar is globally competitive in India. Currently, thermal power plants operate round-the-clock to provide electricity, which is costly. The government is working to convert these plants into storage-type plants to lower generation costs and stabilize the grid. Hybrid solar plants are integrated into the grid to provide cheaper electricity during daylight hours. Net metering is actively promoted, with small and medium solar systems connected to the grid. Large solar parks have been established and connected to the grids, with the solar park scheme expanded from 20GW to 40GW by the government in 2017. A total of 50 solar parks are planned for construction. The current cost of solar-generated electricity is less than 18% of the average generation cost from other

sources in the country, benefiting Indian industries by reducing production costs and ensuring reliable electricity supply.

The government has implemented a 12,000MW grid-connected scheme for personal, government, or distribution company use. It is mandatory to install locally manufactured solar PV systems under this scheme, which has been allocated Rs 48,000 crores, amounting to Rs 4 crore per MW.

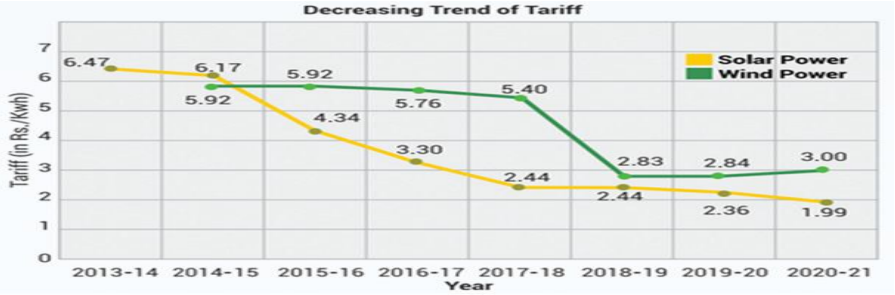


Figure 7: Decreasing trend in Tariff in India

Challenges

The cost of land is prohibitive for installing large solar systems, as it requires 1 square kilometer for a 40-60 MW system. Alternatives include installing solar PV on canals, lakes, reservoirs, etc., which not only utilizes otherwise unused spaces but also enhances the generation capacity of solar panels and ensures sustainability. Water naturally cleans these panels. Indian Railways is also planning to install solar panels on its tracks.

PM KUSUM Scheme

Through the PM KUSUM scheme, the Government aims to achieve a target of 30.80GW of solar energy through several initiatives under financial assistance programs. It is mandatory to use locally manufactured solar PV in these subsidized schemes. The initiatives include:

- Providing 3.5 million farmers with agricultural solar pumps.
- Connecting solar power plants with a cumulative capacity of 10GW, with each power plant up to 2MW connected to grids.
- Installing 2,000,000 solar pumps and solarizing 1,500,000.

Rooftop Scheme

Introduced in 2015, the Rooftop Scheme has achieved a target of 3.7GW of solar energy generation through subsidies. More than 2.6GW capacity has been committed and is due for installation as per the incentives of this scheme.

Target Sector	Subsidy (Percentage)
Systems up to 3Kw	40%
Systems beyond 3KW and up to 10KW	20%
Group Housing Societies	20%

Solar Park Initiative

The government has planned to achieve a target of 40GW through this scheme, establishing 50 solar parks across all states of the country. These are mega schemes aimed at benefiting all states. They operate on a plug-and-play model, allowing the private sector to enter into Joint Ventures (JVs) with the Union government under a Public-Private Partnership (PPP) model for development. Solar parks have capacities exceeding 500KW, ideally requiring 4 to 5 acres of land. The government has announced financial assistance based on project indicators: the first tranche provides Rs 25,00,000 for feasibility studies, followed by Rs 12,00,000 per MW for development, and finally Rs 8,00,000 for power evacuation from the solar park.

Green Energy Corridors

Launched in 2015, this initiative aims to evacuate 20,000 MV of energy from renewable sources across 8 states with significant potential for energy production from renewables. These states include Tamil Nadu, Rajasthan, Karnataka, Andhra Pradesh, Maharashtra, Gujarat, Himachal Pradesh, and Madhya Pradesh. The scheme involves installing a 3200 km transmission line, encouraging potential investors to invest in projects feasible for power evacuation. Such investments attract foreign direct investment (FDI) and include sub-grids.

Power Balancing by Distribution Companies

To address transmission issues, the Indian government introduced bundling to ensure round-the-clock power supply to distribution companies. Renewable energy (RE) sources are integrated with other sources to balance required power and prevent voltage issues.

Hybrid Projects in Renewable Energy (RE)

Projects totaling 1440 MW in Rajasthan and Tamil Nadu are in the construction phase, uniquely combining solar and wind power for generation. In states where wind is abundant at night when solar generation is limited, these projects complement each other, ensuring stable power supply while optimizing land and transmission systems collectively.

Manufacturing Facilities

To reduce imports, India supports domestic manufacturing of solar PV

panels. Local plants are encouraged to manufacture panels, and to protect the local industry, import duties have been increased and the market kept captive. A special cell facilitates investor facilitation, and tax exemptions are provided to local manufacturers.

Solar Power Projects in Cantonments

Estimated in 2015, around 5000 MW of potential exists in cantonments and approximately 950 MW in ordnance factories in India. These solar systems are to be installed on rooftops and free lands, with each project not less than 1 MW. They are constructed under the Engineering Procurement and Construction (EPC) mode, with a fixed tariff of Rs 5.50 per unit for investors for 25 years.

Solar Energy Initiatives of Germany

Germany embraced solar energy in its early years, focusing on grid-scale PV power since 2004. Alongside Japan, Germany installed 1 GW of PV solar energy in 2004. Since then, Germany has consistently worked to improve its energy mix by transitioning to renewables, particularly solar. Germany implemented the German Renewable Sources Act to reduce the cost of PV, which succeeded in cutting PV costs by up to 50% within a few years. By 2011, Germany was generating 18 TWh of electricity from solar, constituting 3% of its total energy mix.

From 2010 to 2013, the installation of solar PV systems peaked, and Germany's installed capacity reached 22.5 GW, accounting for almost 30% of global installations at that time. During these years, over 7 GW of solar energy was installed in Germany. By 2015, solar production had reached 22.5 GW, spread across all 16 federal states of Germany. Most installations are concentrated in southern states, with nearly half of the installations located in Bavaria and Baden-Württemberg.

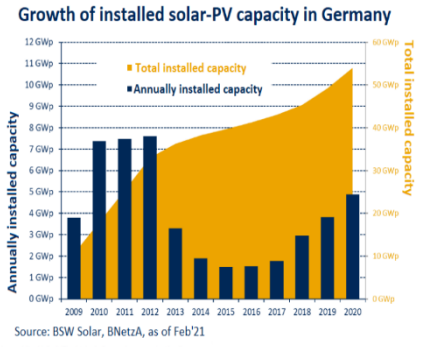


Figure 8: Germany solar PV installed Capacity

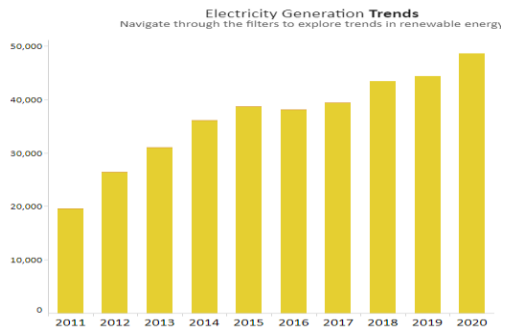


Figure 9: Electricity Generation Trends in Germany

Feed-in-Tariff Policy

Government policies played a crucial role in Germany's solar power development. The government introduced a feed-in-tariff policy to promote solar power generation in the country. Feed-in-tariffs provide guaranteed returns to investors on their solar sector investments, also known as CLEAN contracts. This policy incentivized significant investment in solar energy generation.

Compared to high tax credits, the cost of installation under feed-in-tariffs is relatively low. Tax credits are distributed over several years among all consumers. These incentives compelled investors to enter the solar power energy generation business, helping the government achieve its renewable energy goals, particularly from solar sources.

Initially planned to support up to 52 GW of solar energy generation, the German government later removed this limit and continued the policy, aiming for annual growth of 2.5 GW to 3.5 GW. Legislative reforms were introduced to ensure that 40-45% of energy comes from renewable sources by 2025, and 55-60% by 2035. These reforms simplified processes, deregulated utilities, and provided incentives for establishing small-scale solar energy systems. Government policy also reduced fees on licensing, permitting, and distribution, underscoring its commitment to renewable energy. As a result, Germany's installed capacity of solar PV steadily increased, showing significant growth.

Year	Capacity (MV)	Net Annual Generation (GWh)	% of gross electricity consumption	Capacity Factor (%)
1995	18	7	0.0001	4.4
2000	114	60	0.01	6.0
2005	2056	1282	0.21	7.1
2010	18006	11729	1.9	7.4
2015	39224	37330	6.5	11.3
2019	48914	44334	8.2	11.1

Source: Federal Ministry of Economic Affairs and Energy, Germany

Solar PV Obligation

In 2022, two states announced the implementation of Solar PV obligations for certain construction projects, making it mandatory to install solar PV systems. Other states are following suit by enacting laws that require rooftop solar systems for new buildings, termed as a rule. These steps are positioning Germany as a global leader in adopting and utilizing renewable energy sources.

The German government is also allocating more agricultural lands to encourage investors to install large-scale commercial solar units in the country. Many citizens are attracted to these initiatives; according to the Renewable Energy Agency (AEE), one out of three households in Germany is considering using solar systems for power and heat generation in their homes.

A 2017 study by the Transport and Infrastructure Country indicated that only 300 square kilometers were occupied by solar PV in Germany, generating 43 GW of energy. Increasing this to 1000 square kilometers would increase solar PV installed generation capacity to 143 GW, utilizing just 2% of the country's entire land area.

Companies are offering solutions to store excess solar energy at home and reducing the prices of storage technology to enable homeowners to sell it to their neighbors. This trend is promoting self-sustainability and initiating widespread solar investment in the country.

Farmers are also participating in alternative energy generation methods. The government's policy emphasizes that the solution to energy transformation toward renewables is decentralized and achievable through individual contributions and transitions. This approach is expected to bring about social and economic changes, as farmers are encouraged to install rooftop solar systems to increase their income by utilizing otherwise unusable land. This initiative aims to reduce electricity costs and ensure long-term profitability.

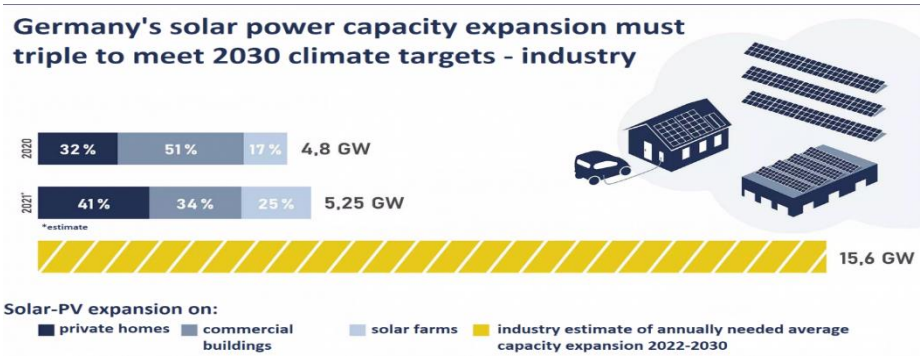


Figure 10: Germany's Solar power expansion diagram

Challenges

Strict labor and environmental laws in Germany lead to increased production costs for solar PV. Consequently, solar panels are imported from China due to lower costs. A study indicates that only 2% of panels installed in the European Union (EU) are domestically produced. Following the government's Renewable Energy Act 2000 (EEG) incentives, the solar energy sector experienced a boom until 2012, creating over 150,000 jobs. However,

between 2013 and 2015, the market declined, reducing jobs to 45,000, with major German companies like Q-Cells, Solon, and Conergy forced to close operations.

Cost Management

In 2018, the EU Commission introduced trade limitations, leading to increased production of solar panels in Germany and the EU. Solar panels emerged as a cheaper mode of electricity generation in Germany, with costs decreasing by about 90% to 3.7 eurocents per kW, making them more affordable than coal and gas power generation. This shift has contributed to the growth of renewable energy plants, potentially displacing existing non-renewable sources. The reduction in prices of domestically manufactured panels has also fostered sustainability in the renewable energy sector, opening avenues for research and development. As a result, 2021 was termed a productive year for Germany's solar production industry, with 60% of installations driven by small households seeking energy independence from high market prices. The country is advancing technologically, with record numbers of households installing solar systems coupled with batteries.

Lessons Learned from Germany:

- Germany boasts the world's largest solar PV market, driven by Feed-in-Tariff or clean contracts, ensuring reasonable returns for energy producers.
- The transparent and effective Feed-in-Tariff policy has been pivotal in solar energy development.
- Germany's policy mandates the installation of solar PV on rooftops.
- Support for local renewable energy producers is a cornerstone of Germany's renewable energy policy.
- German farmers have significantly contributed to solar energy production, earning 25% of their income from selling renewable energy to grids.
- Community empowerment and grassroots-level energy generation have been prioritized.
- The government has fostered an enabling business environment in the solar energy sector through streamlined processes, deregulation, and incentives.
- Government initiatives have reduced soft costs such as licensing, permitting, inspection, and interconnection.
- Germany has pursued an aggressive energy shift from non-renewable to renewable sources through its "Energiewende" policy, reflecting national commitment.

Lesson Learned from India:

- Over 3.5 million agriculture solar pumps have been solarized.
- By 2022, India achieved over 40,000 MW of installed capacity of solar energy from rooftops.
- The policy aims to designate one city in each state as a solar city to promote solar energy development.
- Incentives have been provided to encourage domestic manufacturing of solar equipment, particularly PV panels, despite current manufacturing capacity meeting only 9-10 GW of a 30 GW requirement.
- The Indian government launched programs to train labor in solar manufacturing, installation, and maintenance.
- The national budget allocated $2.57 billion USD to enhance high-grade solar panel manufacturing domestically, aiming for higher efficiency and reduced dependence on imported panels.
- Research and development in solar technology are supported through centers of excellence.
- The government is distributing 70,000 solar study lamps across 5 states to discourage kerosene lamps, subsidized so each student pays only Rs. 100.
- Quality control of solar panels is ensured through the Approved List of Models and Manufacturers (ALMM) issued in 2019.
- India is focusing on manufacturing electric vehicles and allows investors to claim 40% depreciation in the first year.
- A 15% subsidy is available for rooftop systems up to 500 kW.

Conclusion

It has been established that solar energy generation in Pakistan is in its initial stages. The solar potential has not been utilized in the country for cheap, clean, and affordable energy production. The energy mix is still dominated by fossil fuels, with very little reliance on solar energy, which is a dilemma. There is a need for proper supporting legislation in Pakistan to facilitate a realistic energy shift towards solarization. Concrete practical steps in law-making through policies are necessary. It is the government's responsibility to create an environment that attracts local and foreign investors to invest in the solar sector by providing guarantees and assurances for profitable returns.

Subsidies should be provided, and technology transfers should be ensured to avoid imports and conserve foreign reserves. In India and Germany, the governments had plans that included ease of doing business, training labor, and installing manufacturing plants. For Pakistan, it is essential to simplify procedures, provide subsidies on technology transfers, train labor, and ensure that the solar business receives full government support to overcome the energy crisis. On-grid and off-grid installation of solar PVs should be ensured, making solarization a national agenda and goal.

Recommendations

During the past decades, there has been underinvestment in the solar energy sector in Pakistan. Due to the increase in population and industrial growth, the demand for energy has been rising. Surprisingly, power generation was tackled with emergency capacity development in the 1990s. Inefficient and expensive thermal power plants were installed with take-or-pay payment methods, and capacity payment agreements were signed. This development led to economic disaster, affecting industrialization, GDP growth, and depleting foreign exchange reserves due to oil and gas imports for expensive electricity generation. The unit price of electricity has increased, leading to an imbalance in imports and exports, resulting in budget deficits and increased debt. Now, the time has come to avoid such mistakes and shift to renewable generation, especially solar. These are no-regrets solutions for energy generation from solar.

The government must provide an environment for investment in the solar sector by framing policies. Policy-making is even more important than government investment. Both India and Germany have increased solar energy generation through effective planning, policy-making focused on solar expansion, ease of doing business, and executing policies with technology transfer and labor training. Decision-makers must ensure drastic changes in energy generation patterns, exploring alternative sources. Affordable and renewable sources would lead to sustainability and economic stability. Conventional electricity generation sources should be replaced with renewable ones. Pakistan has an estimated potential of 2900 GW from solar energy. The timelines and road map given in IGCEP regarding changing energy mix patterns should be followed effectively, balancing the energy mix by including solar generation. Energy conservation and efficiency improvement mechanisms should be adopted.

The abundant solar potential across the country should be exploited. The government should take immediate steps to promote solar energy initiatives, requiring more investments in the solar sector. Operational changes are necessary for system security, quality of power supply, and system strengthening. Solar expansion should be pursued through competitive bidding to decrease prices. Rooftop solarization should be a compulsory part of building plans, and the net metering mechanism should be simplified, with all government taxes waived. Waste lands with solar energy potential should be identified, and solar parks should be installed. A public-private partnership model of development should be adopted in the solar sector. For mega solar projects, LOIs should be issued to local and foreign investors for potential sites, with government-provided facilities in terms of financing and attractive energy purchase agreement tariffs.

The government should conduct proper studies to plan distribution networks and grid connectivity for solar energy evacuation and interconnections in the national grid. Irrigation system pumping should be shifted to solar. Solar manufacturing plants should be established within the country to provide solar panels, with the government ensuring quality control and utilization of these locally made panels in subsidized schemes, as was successfully done in India, with the sole purpose of boosting the local manufacturing industry.

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