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Empowering Farmers through Solar Energy: An Analysis of PM-KUSUM and Renewable Energy Transformation in Telangana

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ABSTRACT

The growing demand for sustainable energy and climate-resilient agriculture has accelerated the adoption of renewable energy solutions across India. Among various renewable energy initiatives, solar energy has emerged as a transformative tool for improving rural livelihoods, enhancing energy security, and reducing environmental degradation. The Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM) scheme represents a significant policy intervention aimed at integrating solar power with the agricultural sector. This research article analyses the implementation and impact of PM-KUSUM in Telangana, with particular emphasis on farmer empowerment, renewable energy transformation, and sustainable rural development. The study examines the role of solar power plants, solarized agricultural pump sets, and decentralized energy generation in improving farmers' economic conditions. Telangana has demonstrated substantial progress in promoting renewable energy through policy incentives, long-term power purchase agreements (PPAs), subsidy support, and institutional coordination through TGREDCO and DISCOMs. The article highlights that solar energy not only reduces dependence on conventional fossil fuels but also creates an alternative and stable source of income for

farmers by enabling them to sell surplus electricity to the grid. The study further analyses district-wise progress of solar PPAs, financial feasibility, environmental benefits, and long-term sustainability outcomes. The findings indicate that PM-KUSUM contributes significantly toward carbon emission reduction, agricultural energy security, rural employment generation, and income diversification. However, challenges such as high initial investment, financing constraints, technical awareness gaps, and implementation delays continue to affect the pace of adoption. The article concludes that effective policy support, institutional strengthening, improved financing mechanisms, and farmer awareness programs are essential for accelerating agricultural solarization. Telangana's experience demonstrates that renewable energy integration in agriculture can serve as a sustainable model for rural economic transformation and green energy development in India.

1. Introduction

1.1 Energy Transition and Sustainable Development

The twenty-first century has witnessed a global transition toward sustainable energy systems due to increasing environmental concerns, rising energy demand, and the depletion of conventional fossil fuel resources. Rapid industrialization, urbanization, and agricultural expansion have significantly increased electricity consumption across developing countries such as India. Traditional energy generation based on coal, diesel, and other fossil fuels has contributed to environmental pollution, greenhouse gas emissions, and climate change. As a result, renewable energy has emerged as an essential component of sustainable economic development and environmental protection. Among various renewable energy sources, solar energy has gained considerable importance because of its abundant availability, clean nature, and long-term sustainability. India, being a tropical country with high solar irradiation, possesses immense potential for solar power generation. The Government of India has therefore prioritized solar energy as a strategic sector under its renewable energy and climate action policies.

1.2 Agriculture and Energy Challenges in India

Agriculture remains the backbone of the Indian economy, supporting rural livelihoods and food security. However, the agricultural sector faces multiple energy-related challenges such as irregular electricity supply, rising diesel costs, groundwater depletion, and dependence on subsidized power. Farmers often experience difficulties in accessing reliable and affordable electricity for irrigation and agricultural operations. Conventional electricity generation also places a heavy financial burden on state governments through agricultural power subsidies. The increasing dependence on fossil-fuel-based electricity not only affects environmental sustainability but also creates long-term energy security concerns. In this context, integrating renewable energy into agriculture has become essential for ensuring sustainable agricultural development and rural economic resilience.

1.3 Importance of Solar Energy in Agriculture

Solar energy offers a sustainable solution to the growing energy needs of the agricultural sector. Solar-powered irrigation systems and decentralized solar plants can provide uninterrupted daytime electricity while reducing dependence on grid power and diesel-operated pumps. Solar energy also supports environmentally friendly agricultural practices by reducing carbon emissions and promoting clean energy utilization.

The use of solar energy in agriculture provides several socio-economic benefits, including:

- Reduction in electricity and fuel costs,
- Improvement in irrigation efficiency,
- Additional income generation,
- Enhanced energy independence for farmers,
- Long-term environmental sustainability.

Solarization of agriculture has therefore become an important strategy for achieving energy security, climate resilience, and rural development.

1.4 PM-KUSUM Scheme and Farmer Empowerment

Recognizing the need for agricultural energy reforms, the Government of India launched the Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM) scheme in 2019. The scheme

aims to promote decentralized solar power generation, solar irrigation, and income enhancement for farmers through renewable energy adoption.

The PM-KUSUM scheme enables farmers to:

- Install solar power plants on agricultural land,
- Solarize existing agricultural pump sets,
- Generate electricity for self-consumption,
- Sell surplus electricity to distribution companies (DISCOMs),
- Obtain long-term financial benefits through Power Purchase Agreements (PPAs).

The scheme represents a transformational shift in agricultural energy governance by converting farmers from electricity consumers into renewable energy producers.

1.5 Telangana's Renewable Energy Initiatives

Telangana has emerged as one of the leading states in promoting renewable energy integration in agriculture. The state government, through the Telangana Renewable Energy Development Corporation (TGREDCO), has actively implemented PM-KUSUM Components A and C to encourage solarization of agricultural activities. Telangana's renewable energy policies focus on increasing solar power capacity, improving rural energy infrastructure, and promoting sustainable development.

The state has introduced several incentives such as:

- Subsidy support,
- Interest concessions,
- Tax exemptions,
- Long-term PPAs,
- Technical assistance for solar installations.

These initiatives have significantly accelerated the adoption of solar power in rural areas and contributed toward the state's renewable energy targets.

1.6 Need for the Present Study

Although PM-KUSUM has shown considerable potential in promoting renewable energy and farmer welfare, several implementation challenges remain. Issues relating to financing, technical awareness, infrastructure availability, and policy execution continue to affect the effectiveness of the scheme. Therefore, a detailed analysis of PM-KUSUM implementation and renewable energy transformation in Telangana is necessary to understand its socio-economic and environmental impact. The present study aims to examine how solar energy adoption under PM-KUSUM contributes to farmer empowerment, rural income generation, and sustainable agricultural development. The study also analyses the opportunities, challenges, and policy implications associated with agricultural solarization in Telangana.

2. Objectives of the Study

The study aims to:

1. Examine the importance of solar energy in agricultural development.
2. Analyse the implementation of PM-KUSUM in Telangana.
3. Evaluate the economic and environmental benefits of agricultural solarization.
4. Study district-wise progress in solar adoption.
5. Identify challenges and policy implications for renewable energy transformation.

3. Research Methodology

The study is based on:

- Secondary data,
- Government reports,
- TGREDCO publications,
- Ministry of New and Renewable Energy (MNRE) reports,
- Press Information Bureau releases,
- Renewable energy statistics and policy documents.

The analysis adopts a descriptive and analytical approach to understand renewable energy transformation in Telangana.

4. Conceptual Framework of PM-KUSUM

4.1 Overview of PM-KUSUM Scheme

The Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM) scheme was launched by the Government of India in 2019 to promote renewable energy integration in the agricultural sector. The scheme aims to enhance farmers' income, improve energy security, reduce dependence on fossil fuels, and encourage decentralized solar power generation. PM-KUSUM combines agriculture and renewable energy by enabling farmers to become both cultivators and energy producers.

The conceptual framework of PM-KUSUM is based on the integration of three major dimensions:

- Sustainable energy generation,
- Agricultural development,
- Rural economic empowerment.

4.2 Component A: Decentralized Solar Power Plants

Under Component A, farmers, cooperatives, and farmer producer organizations (FPOs) can establish decentralized solar power plants ranging from 0.5 MW to 2 MW on barren or agricultural land. The electricity generated is supplied to nearby DISCOM substations through long-term Power Purchase Agreements (PPAs). This component enables farmers to utilize unused land productively and earn stable long-term income through electricity sales.

4.3 Component B: Standalone Solar Pumps

Component B focuses on the installation of standalone solar-powered agricultural pumps in off-grid or remote areas. These pumps reduce dependence on diesel-powered irrigation systems and ensure reliable daytime electricity for agricultural operations. The component supports sustainable irrigation practices while lowering fuel and electricity expenses for farmers.

4.4 Component C: Solarization of Existing Pump Sets

Component C aims to solarize existing grid-connected agricultural pump sets. Farmers can generate electricity through solar panels installed near pump sets and utilize the required power for irrigation. Surplus electricity generated can be exported to the grid, thereby creating an additional source of annual income for farmers. This component strengthens decentralized renewable energy generation and improves rural energy sustainability.

4.5 Farmer Empowerment and Sustainable Development

The PM-KUSUM framework promotes inclusive rural development by linking renewable energy with farmer welfare. The scheme contributes to:

- Additional farmer income,
- Reduced carbon emissions,
- Improved irrigation efficiency,
- Energy self-reliance,
- Climate-resilient agriculture.

Thus, PM-KUSUM serves as a comprehensive policy model for achieving agricultural sustainability, renewable energy expansion, and rural economic transformation in India.

4.6 Table 1: Components of PM-KUSUM

Component	Description	Objective
Component A	Solar power plants (0.5–2 MW) on agricultural land	Additional farmer income
Component B	Standalone solar pumps	Reduce diesel dependence
Component C	Solarization of existing agricultural pumps	Grid-connected energy generation

5. Importance of Solar Energy in Agriculture

5.1 Renewable and Sustainable Energy Source

Solar energy is one of the most important renewable energy sources available for the agricultural sector. Unlike coal, diesel, and other fossil fuels, solar energy is clean, naturally available, and environmentally sustainable. India receives abundant sunlight throughout the year, making solar power highly suitable for

agricultural applications such as irrigation, lighting, and decentralized electricity generation. The adoption of solar energy reduces dependence on non-renewable energy resources and supports long-term energy sustainability.

5.2 Reduction in Agricultural Energy Costs

Agriculture requires a substantial amount of electricity and fuel for irrigation and farm operations. Farmers often face rising diesel prices and irregular electricity supply, which increase cultivation costs. Solar-powered irrigation systems help farmers reduce electricity and fuel expenses by generating their own energy. Once installed, solar systems require comparatively lower operational costs, thereby improving the economic viability of farming activities.

5.3 Improvement in Irrigation and Energy Access

Reliable irrigation is essential for improving agricultural productivity and crop yields. Solar-powered pump sets provide uninterrupted daytime electricity, enabling farmers to access water efficiently without depending on uncertain grid supply. This improves irrigation management, crop cultivation, and overall agricultural efficiency, especially in rural and remote areas.

5.4 Additional Income Generation for Farmers

Solar energy not only fulfills agricultural energy requirements but also creates opportunities for additional income generation. Under schemes such as PM-KUSUM, farmers can install solar plants and sell surplus electricity to DISCOMs through long-term Power Purchase Agreements (PPAs). This transforms farmers from energy consumers into energy producers and provides a stable supplementary source of income.

5.5 Environmental and Climate Benefits

The use of solar energy significantly reduces greenhouse gas emissions and environmental pollution caused by fossil-fuel-based electricity generation. Solarization of agriculture contributes to climate change mitigation, promotes clean energy utilization, and supports India’s renewable energy and carbon reduction goals. Thus, solar energy plays a crucial role in achieving sustainable agriculture and environmental protection.

6. Renewable Energy Transformation in Telangana

6.1 Growth of Renewable Energy in Telangana

Telangana has emerged as one of the progressive states in India in promoting renewable energy development and green energy transition. Increasing electricity demand from agriculture, industries, and urbanization has encouraged the state government to diversify its energy sources and reduce dependence on conventional fossil fuels. As part of its sustainable development strategy, Telangana has prioritized renewable energy expansion, particularly solar power, to ensure long-term energy security and environmental sustainability.

6.2 Expansion of Solar Energy Capacity

Solar energy forms the major component of Telangana's renewable energy policy. The state has achieved significant growth in installed solar capacity through utility-scale solar projects, decentralized solar plants, rooftop systems, and agricultural solarization initiatives. Telangana aims to substantially increase its renewable energy capacity by 2029–30, with solar energy contributing the largest share. The government has also promoted solar parks, floating solar projects, and distributed solar generation systems to strengthen clean energy infrastructure.

6.3 Role of Government Policies and Institutions

The Telangana Government, through agencies such as the Telangana Renewable Energy Development Corporation (TGREDCO), has implemented several renewable energy promotion programs. Policies supporting subsidies, tax incentives, Power Purchase Agreements (PPAs), and solar pump schemes have accelerated renewable energy adoption in rural and urban areas. The implementation of PM-KUSUM has further strengthened the integration of renewable energy with agricultural development and farmer empowerment.

6.4 Renewable Energy and Sustainable Development

Renewable energy transformation in Telangana contributes significantly to sustainable development goals by:

- Reducing carbon emissions,
- Promoting clean energy utilization,
- Improving rural energy access,
- Encouraging green industrial growth,
- Enhancing energy independence.

The transition toward renewable energy also supports climate resilience and environmental conservation while creating employment opportunities in the green energy sector.

6.5 Challenges in Renewable Energy Expansion

Despite substantial progress, Telangana faces challenges such as land availability, grid integration issues, financing constraints, and infrastructure development requirements. Effective policy implementation, technological innovation, and institutional coordination remain essential for achieving the state's long-term renewable energy targets and ensuring sustainable energy transformation.

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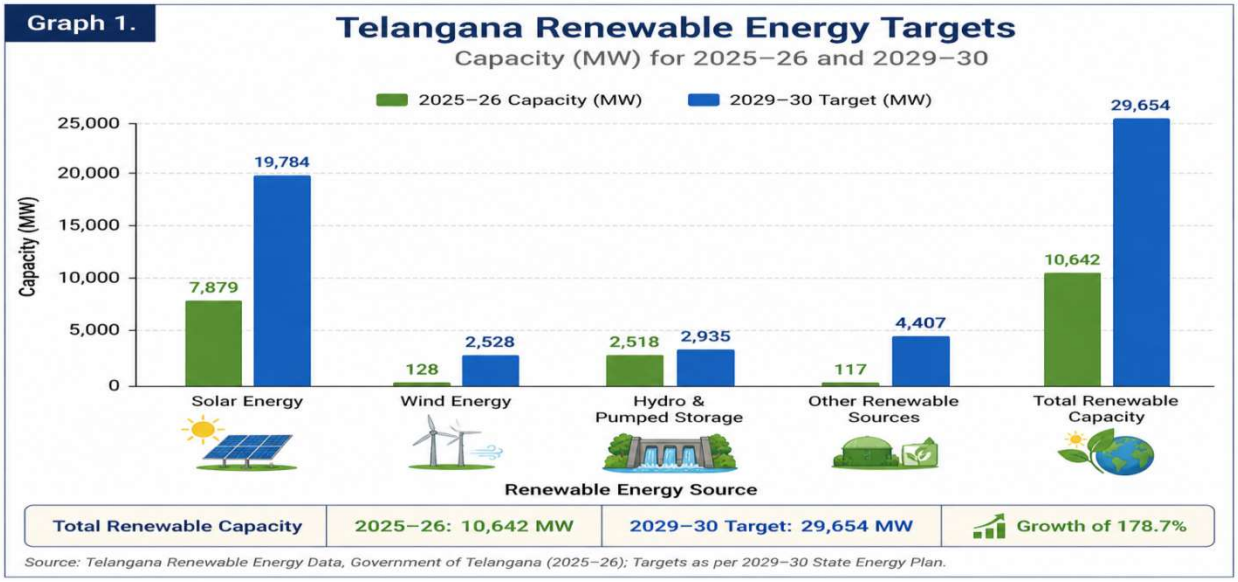
term renewable energy targets and ensuring sustainable energy transformation. Telangana has adopted an ambitious renewable energy expansion strategy.

Table 2: Renewable Energy Capacity Targets in Telangana

Renewable Source	2025-26 Capacity (MW)	2029-30 Target (MW)
Solar Energy	7,879	19,784
Wind Energy	128	2,528
Hydro & Pumped Storage	2,518	2,935
Other Renewable Sources	117	4,407
Total Renewable Capacity	**10,642**	**29,654**

Source: Telangana Renewable Energy Data



7. PM-KUSUM Component A: Solar Power Plants

7.1 Overview of Component A

PM-KUSUM Component A is designed to promote decentralized solar power generation in rural areas by enabling farmers to establish solar power plants on agricultural and barren lands. Under this component, farmers, cooperatives, Farmer Producer Organizations (FPOs), and village institutions can install solar plants with capacities ranging from 0.5 MW to 2 MW. The electricity generated from these plants is

supplied to nearby substations and purchased by DISCOMs through long-term Power Purchase Agreements (PPAs).

7.2 Income Generation for Farmers

One of the major objectives of Component A is to provide farmers with an additional and stable source of income. Farmers can either directly invest in solar plants or lease their land to private developers for solar project installation. The electricity generated is sold to DISCOMs for a period of up to 25 years, ensuring long-term financial returns. This model transforms farmers from traditional cultivators into renewable energy producers and improves rural economic stability.

7.3 Financial Assistance and Government Support

The scheme provides significant financial support for solar project implementation. Banks provide loans covering up to 85% of the project cost, while the remaining amount is contributed by farmers or developers. The government also offers incentives such as interest subsidies, tax exemptions, and simplified approval procedures. Telangana has further strengthened implementation through TGREDCO by providing technical guidance and institutional support for project execution.

7.4 Environmental and Energy Benefits

Component A contributes significantly to clean energy generation and reduction in carbon emissions. By replacing fossil-fuel-based electricity generation with solar energy, the scheme supports climate change mitigation and environmental sustainability. Decentralized solar plants also reduce transmission losses and improve local energy reliability in rural areas.

7.5 Challenges in Implementation

Despite its benefits, Component A faces challenges such as high initial investment, land-related issues, financing constraints, and lack of technical awareness among farmers. Delays in approvals and grid connectivity also affect implementation efficiency. Therefore, stronger institutional coordination and farmer awareness programs are necessary for achieving the full potential of the scheme.

7.6 Financial Structure

Table 3:

Particulars	Details

Particulars	Details
Cost of 1 MW Plant	3–3.5 Crore
Bank Loan Availability	Up to 85%
Farmer Contribution	15%
Loan Tenure	10 Years
Interest Subsidy	3% under AIF

Diagram 1: PM-KUSUM Solar Income Model

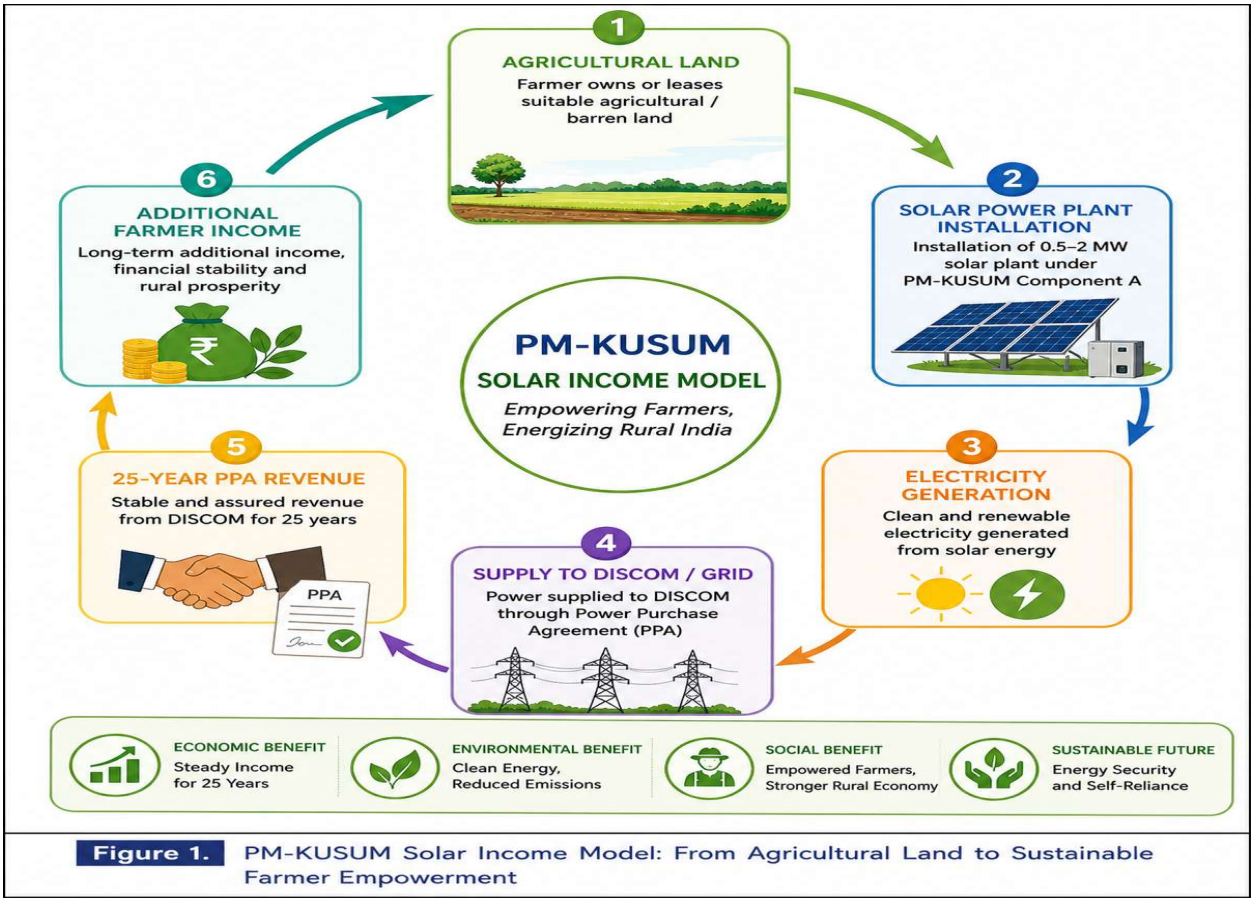


Figure 1. PM-KUSUM Solar Income Model: From Agricultural Land to Sustainable Farmer Empowerment

8. Income Generation Potential

8.1 Solar Energy as an Additional Source of Income

One of the most significant advantages of the PM-KUSUM scheme is its ability to generate stable and long-term income for farmers. Traditionally, farmers depend mainly on agricultural production, which is often affected by market fluctuations, climate variability, and water availability. Solar energy provides an

alternative and reliable source of revenue by enabling farmers to generate and sell electricity to DISCOMs through long-term Power Purchase Agreements (PPAs).

8.2 Revenue from Solar Power Plants

Under PM-KUSUM Component A, farmers can establish solar power plants ranging from 0.5 MW to 2 MW on agricultural or barren lands. A 1 MW solar power plant in Telangana can generate approximately 16.5 to 18 lakh units of electricity annually. By supplying this electricity to DISCOMs, farmers can earn nearly ₹50 lakh per year depending on tariff rates and electricity generation efficiency. Since solar plants generally have a lifespan of about 25 years, they provide long-term economic security and regular annual income.

8.3 Reduction in Agricultural Expenditure

Solarization also reduces the financial burden associated with agricultural electricity and diesel usage. Farmers using solar-powered pump sets can significantly reduce irrigation costs by utilizing self-generated electricity. Lower expenditure on diesel and electricity improves net agricultural income and enhances financial sustainability in farming operations.

8.4 Surplus Power Export and Additional Earnings

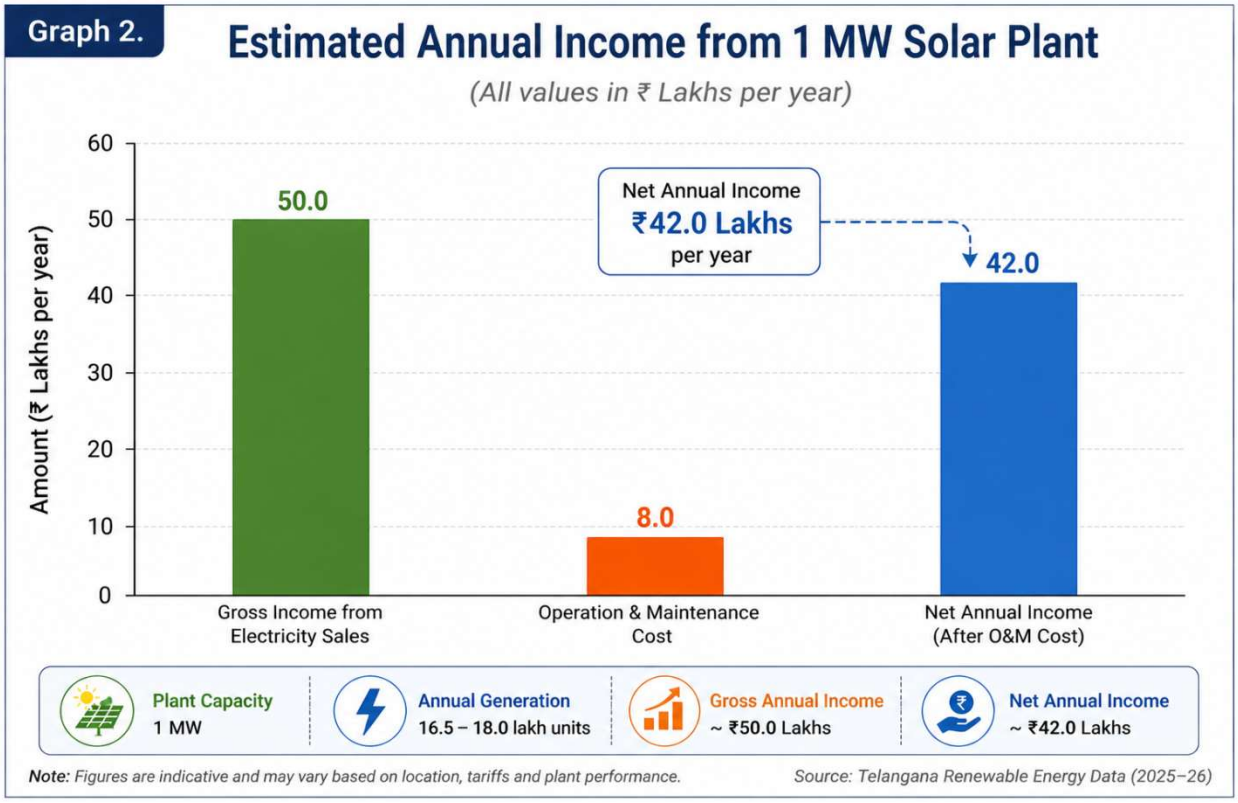
Under PM-KUSUM Component C, farmers can export surplus electricity generated from solarized agricultural pump sets to the power grid. After meeting irrigation requirements, excess electricity is purchased by DISCOMs, creating an additional source of annual income for farmers. This decentralized energy model promotes both energy efficiency and rural economic empowerment.

8.5 Long-Term Rural Economic Benefits

The income generation potential of solar energy contributes to:

- Diversification of rural livelihoods,
- Financial stability for farming households,
- Reduction in rural indebtedness,
- Promotion of sustainable rural development.

Thus, solar energy not only supports agricultural productivity but also strengthens the socio-economic condition of farmers through continuous and environmentally sustainable income generation.



9. District-wise Progress of Solar PPAs

9.1 Expansion of Solar PPAs in Telangana

The implementation of PM-KUSUM in Telangana has shown considerable progress through the expansion of district-wise solar Power Purchase Agreements (PPAs). These PPAs are agreements between farmers or solar developers and Distribution Companies (DISCOMs) for the long-term purchase of electricity generated from decentralized solar power plants. The district-wise distribution of PPAs reflects the growing adoption of solar energy across rural regions of Telangana.

9.2 Progress under TGNPDCL

The Telangana Northern Power Distribution Company Limited (TGNPDCL) has achieved substantial progress in promoting decentralized solar projects in northern districts of the state. Several districts such as Khammam, Nizamabad, Karimnagar, and Jangaon have recorded higher solar capacities due to increased farmer participation and better infrastructure availability. Under TGNPDCL, approximately

436 PPAs with a total capacity of around 631.9 MW have been implemented. This indicates significant expansion of renewable energy infrastructure in rural agricultural areas.

Table 4: District-wise Solar PPAs under TGNPDCL

District	PPAs	Capacity (MW)
Khammam	54	90
Nizamabad	51	78.4
Karimnagar	46	66.2
Jangaon	56	83.2
Total	436	631.9

Source: Telangana Renewable Energy Data

9.3 Progress under TGSPDCL

The Telangana Southern Power Distribution Company Limited (TGSPDCL) has also played a major role in implementing solar PPAs across southern Telangana districts. Districts such as Suryapet, Nalgonda, Gadwal, and Yadadri have shown remarkable progress in solar power generation projects. TGSPDCL has implemented nearly 720 PPAs with a total capacity of approximately 1164.4 MW, which is considerably higher than the northern region. The strong performance reflects growing awareness and institutional support for renewable energy adoption.

Table 5: District-wise Solar PPAs under TGSPDCL

District	PPAs	Capacity (MW)
Suryapet	106	186.5
Gadwal	80	144
Yadadri	76	125
Nalgonda	95	144.2
Total	720	1164.4

Source: Telangana Renewable Energy Data

9.4 Regional Significance of Solar Expansion

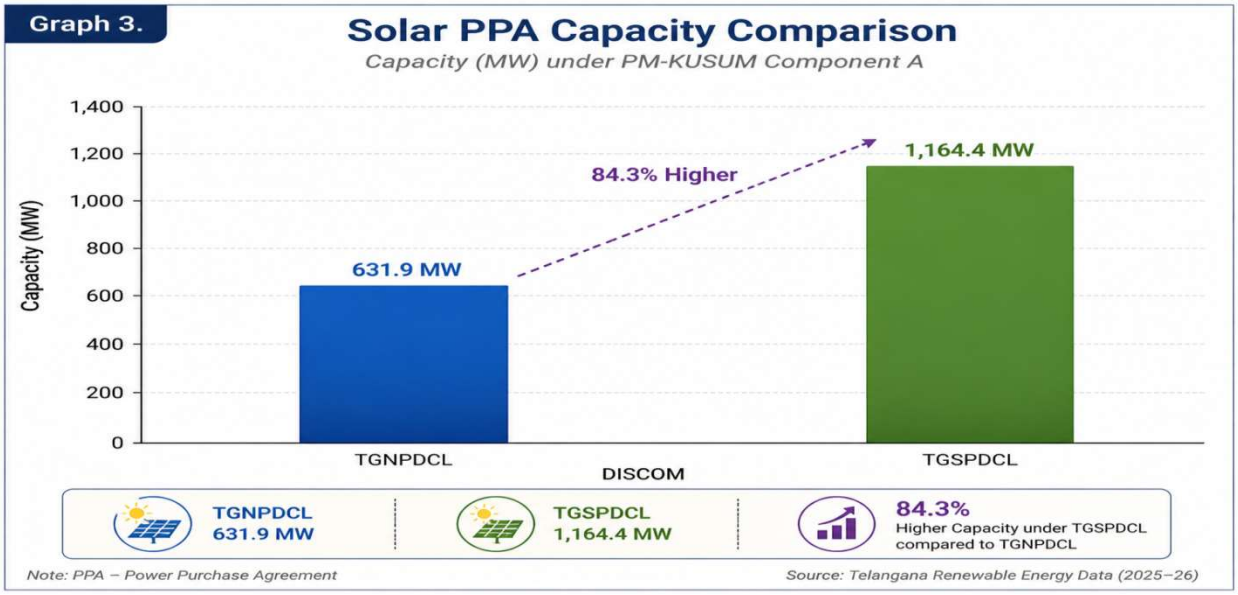
District-wise implementation demonstrates that decentralized solar energy projects are becoming an important component of rural economic development. The expansion of solar PPAs:

- Enhances local electricity generation,
- Reduces transmission losses,
- Provides additional income opportunities for farmers,
- Strengthens rural energy security.

The regional spread of solar projects also indicates the increasing acceptance of renewable energy technologies among farming communities.

9.5 Challenges and Future Scope

Despite substantial progress, disparities exist among districts due to differences in infrastructure, financing access, and farmer awareness. Some regions continue to face delays in approvals, grid connectivity, and project execution. Therefore, balanced regional development, improved institutional coordination, and targeted awareness programs are essential for expanding solar PPAs across all districts of Telangana.



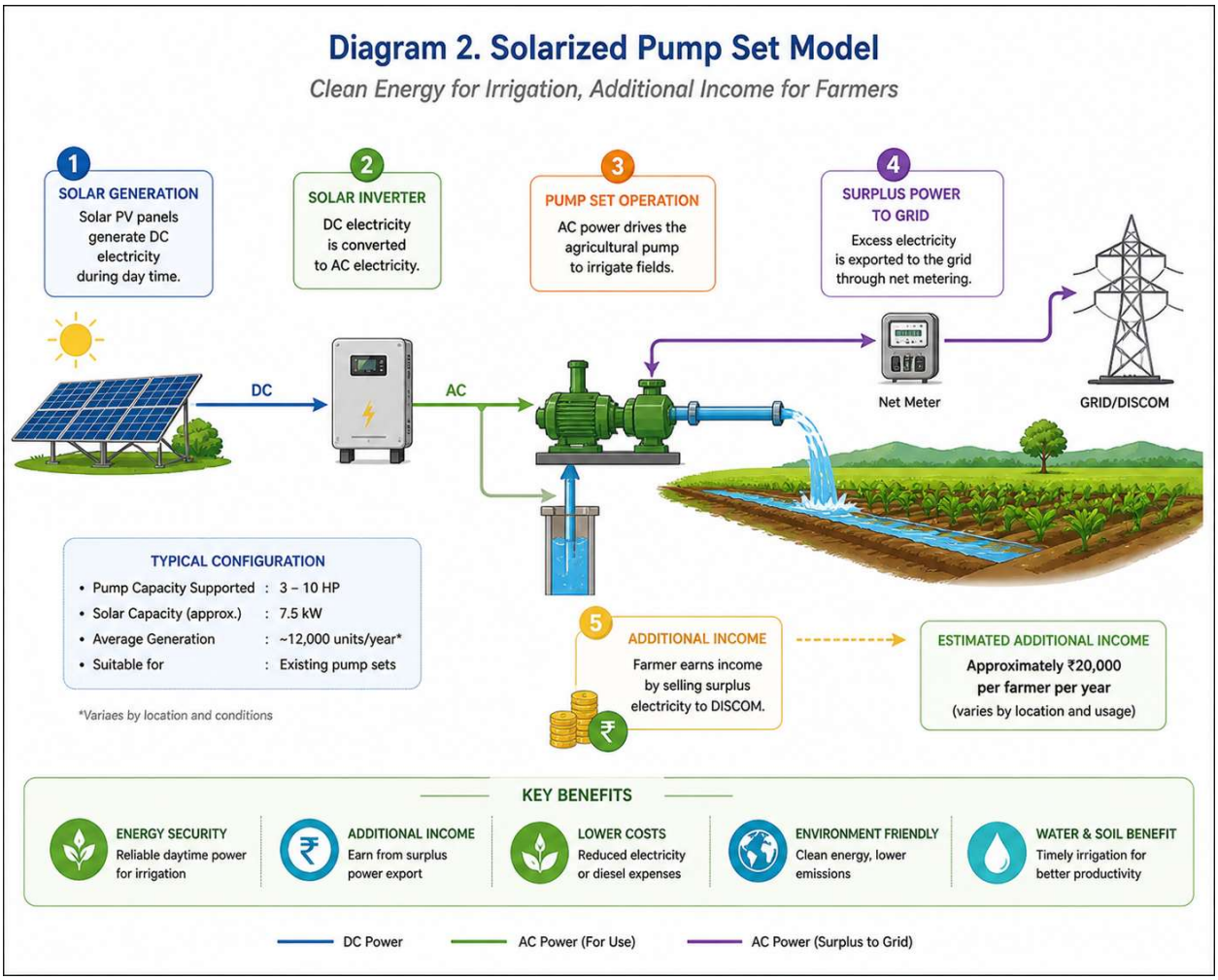
10. Solarization of Agricultural Pump Sets

Under PM-KUSUM Component C:

- Existing agricultural pumps are connected to solar systems.
- Each pump receives approximately 7.5 kW solar capacity.
- Farmers can export surplus electricity to the grid.

Benefits

Benefit	Impact
Reduced Electricity Dependence	Energy Security
Surplus Power Export	Additional Income
Reduced Diesel Usage	Lower Pollution
Daytime Electricity Availability	Improved Irrigation



11. Environmental Impact

Solarization contributes significantly to climate sustainability.

Major Environmental Benefits

- Reduction in greenhouse gas emissions,
- Lower fossil fuel consumption,
- Promotion of green energy,
- Reduction in air pollution,
- Support for India's net-zero commitments.

India crossed 10 GW of PM-KUSUM-related solar installations by late 2025, benefiting more than 21 lakh farmers nationally.

12. Challenges in PM-KUSUM Implementation

Despite substantial progress, several challenges remain:

a) High Initial Investment

Although loans are available, farmers still require capital contribution.

b) Slow Implementation

Reports indicate delays in project grounding and approvals in several regions.

c) Technical Awareness

Many farmers lack technical understanding regarding:

- EPC selection,
- Solar technology,
- Grid connectivity,
- Maintenance practices.

d) Payment and PPA Concerns

Farmer discussions on public forums indicate concerns regarding:

- Subsidy disbursement,
- DISCOM payment delays,
- Financing complexities.

13. Policy Implications

Strengthening Renewable Energy Governance

The successful implementation of PM-KUSUM highlights the importance of strong renewable energy governance and institutional coordination. Effective collaboration between government agencies, DISCOMs, financial institutions, and renewable energy organizations is essential for accelerating agricultural solarization. Telangana's experience demonstrates that supportive policies, streamlined approvals, and transparent implementation mechanisms can significantly improve renewable energy adoption in rural areas.

13.1 Improving Financial Accessibility

Although PM-KUSUM provides subsidies and loan facilities, many farmers still face difficulties in arranging initial capital investment. Policymakers should therefore strengthen rural financing systems by expanding low-interest loans, increasing subsidy support, and simplifying credit procedures. Special financial assistance for small and marginal farmers would improve inclusiveness and ensure wider participation in solar energy programs.

13.2 Enhancing Farmer Awareness and Technical Support

Technical awareness and knowledge gaps remain major barriers in the adoption of solar technologies. The government should organize training programs, awareness campaigns, and technical guidance initiatives to educate farmers regarding:

- Solar plant installation,
- Maintenance practices,
- Grid connectivity,

- Financial management,
- Energy generation monitoring.

Strengthening extension services and local technical support systems can improve operational efficiency and long-term sustainability of solar projects.

13.3 Strengthening Rural Energy Infrastructure

Expansion of decentralized solar energy requires strong rural infrastructure, including substations, transmission lines, and grid connectivity systems. Policymakers should prioritize investment in rural power infrastructure to reduce implementation delays and improve integration of solar-generated electricity into the grid. Efficient infrastructure development will enhance the reliability and scalability of renewable energy projects.

13.4 Promoting Sustainable Agricultural Development

PM-KUSUM has significant potential to support climate-resilient and sustainable agriculture. Policymakers should integrate renewable energy initiatives with broader rural development programs related to water conservation, sustainable irrigation, and environmental protection. Encouraging farmer cooperatives, FPOs, and community-based solar projects can further strengthen inclusive rural economic development and support India's long-term green energy transition objectives.

14. Discussion

14.1 Renewable Energy and Agricultural Transformation

The findings of the study indicate that PM-KUSUM has emerged as a significant initiative for integrating renewable energy with agricultural development in Telangana. The scheme has created opportunities for farmers to participate in decentralized solar power generation while improving rural energy security and economic stability. By promoting solarization of agricultural activities, Telangana has taken an important step toward sustainable and climate-resilient agriculture.

14.2 Farmer Empowerment through Solarization

One of the major outcomes of PM-KUSUM is the transformation of farmers from electricity consumers into renewable energy producers. The establishment of solar power plants and solarized pump sets enables farmers to generate additional income through electricity sales to DISCOMs. Long-term Power

Purchase Agreements (PPAs) provide stable financial returns and reduce dependence on uncertain agricultural income. This contributes significantly to rural livelihood diversification and financial empowerment.

14.3 Environmental and Sustainability Implications

The adoption of solar energy in agriculture contributes positively toward environmental sustainability. The replacement of fossil-fuel-based electricity with solar power reduces greenhouse gas emissions, air pollution, and dependence on conventional energy resources. The scheme supports India's renewable energy goals and climate commitments by encouraging clean energy utilization at the grassroots level.

14.4 Institutional Support and Policy Effectiveness

The implementation of PM-KUSUM in Telangana demonstrates the importance of strong institutional coordination and supportive government policies. Agencies such as TGREDCO and DISCOMs have played a crucial role in facilitating project approvals, PPAs, technical assistance, and financial support. Subsidies, interest concessions, and infrastructure support have further accelerated renewable energy adoption among farmers.

14.5 Existing Challenges and Future Considerations

Despite the positive outcomes, several challenges continue to affect the effective implementation of the scheme. High initial investment, limited technical awareness, financing constraints, and delays in project approvals remain significant barriers for many farmers. Regional disparities in infrastructure and grid connectivity also influence implementation efficiency. Therefore, strengthening institutional mechanisms, improving awareness programs, and simplifying financing procedures are essential for maximizing the long-term success of agricultural solarization initiatives in Telangana.

15. Conclusion

The transition toward renewable energy has become essential for achieving sustainable agricultural development, rural economic stability, and environmental protection in India. The PM-KUSUM scheme represents a transformative initiative that integrates solar energy with the agricultural sector by enabling farmers to generate clean energy and earn additional income. Telangana has emerged as one of the leading states in implementing agricultural solarization through effective policy support, institutional coordination, and renewable energy promotion initiatives. The implementation of PM-KUSUM

Components A and C has contributed significantly toward decentralized solar power generation, reduction in fossil fuel dependence, and improvement in rural energy security.

The study reveals that solar energy provides multiple socio-economic and environmental benefits for farmers. Solar power plants and solarized pump sets not only reduce irrigation and electricity costs but also create long-term income opportunities through Power Purchase Agreements (PPAs) with DISCOMs. The scheme has strengthened farmer empowerment by transforming agricultural land into a productive renewable energy asset. Furthermore, the adoption of solar energy contributes to reduction in greenhouse gas emissions, promotion of climate-resilient agriculture, and advancement of India's renewable energy goals.

Despite substantial progress, challenges such as high initial investment, financing constraints, technical awareness gaps, and implementation delays continue to affect the pace of solar adoption. Addressing these issues through simplified procedures, stronger institutional support, improved financing mechanisms, and farmer awareness programs is essential for maximizing the benefits of the scheme. Overall, Telangana's experience demonstrates that renewable energy integration in agriculture can serve as an effective model for sustainable rural development, environmental sustainability, and inclusive economic transformation. The PM-KUSUM scheme therefore holds significant potential for strengthening India's green energy transition while improving the socio-economic conditions of farmers.

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