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GST as a Catalyst for Ecopreneurship: A Secondary Data Analysis of Solar Drying Units and Sustainable Livelihoods in Andhra Pradesh

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Abstract
This study examines the role of India's Goods and Services Tax (GST) regime as a catalyst for solar-based ecopreneurship in Andhra Pradesh, with a focus on solar drying enterprises in the agri-processing sector. Using secondary data from 2014–2025 obtained from MNRE, CEA, CBIC, NABARD, NABCONS, and NHB, the study analyses trends in solar capacity expansion, solar dryer adoption, and livelihood outcomes. Descriptive statistics, compound annual growth rate (CAGR), comparative pre-and post-GST analysis, and correlation techniques are employed for analysis. The findings show that Andhra Pradesh's solar capacity increased from 167 MW in 2014–15 to 5,523 MW by 2024–25, reflecting significant growth in renewable energy infrastructure. Solar drying enterprises demonstrate notable economic benefits, with average seasonal income rising by about 69 percent compared with conventional drying methods. The analysis also identifies a moderate inverse relationship between GST rates on solar equipment and solar dryer adoption. Additionally, the potential annual savings from reduced post-harvest losses in the state exceed ₹6,000 crore. The study concludes that GST rationalisation, combined with institutional support, can promote ecopreneurship, reduce agricultural losses, and strengthen sustainable rural livelihoods in Andhra Pradesh.

Keywords: GST, Ecopreneurship, Solar Drying, Andhra Pradesh, Post-Harvest Losses, CAGR, Agri-MSME, Sustainable Livelihoods, GST Council 2025

Introduction:

India's GST, introduced in July 2017, reshaped the indirect tax architecture across all sectors, including renewable energy and agri-processing. Two developments between 2022 and 2025 make a fresh empirical analysis especially timely. First, the NABCONS (2022) study estimated India's total food losses at ₹1,52,787 crore annually — a substantive upward revision from the ICAR-CIPHET (2015) benchmark. Second, the 56th GST Council (3 September 2025) reduced all renewable energy equipment from 12–18% to a uniform 5%, effective 22 September 2025 — the most decisive fiscal signal for solar ecopreneur ship in the GST era.

Andhra Pradesh presents a compelling case study: high solar irradiance (5.5–6.0 kWh/m²/day), significant agri-output, acute post-harvest losses (20–40% for horticultural produce), and a 160 GW clean energy target under its Integrated Clean Energy Policy 2024. Solar drying units, which convert solar energy into post-harvest processing capacity, sit at the intersection of these energy, agricultural, and fiscal streams. This paper updates all tables with

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verified data through 2025 and integrates findings from current literature (2023–2025).

2. Review of Literature

Schaltegger and Petersen (2002) and Pastakia (1998) established the theoretical foundations of ecopreneurship, distinguishing eco-entrepreneurs by their primary ecological motivation. Anderson

(1998) posited ecological crises as sources of entrepreneurial opportunity. Ratten (2024, Journal of Cleaner Production) extended this framework to institutional catalysts — tax policy, credit access, and digital infrastructure — arguing these are more decisive than market incentives alone in emerging economies. Tripathi and Singh (2023, IJSDWE) documented India's agri-solar ecopreneurs as exhibiting significantly higher income resilience than conventional agri-entrepreneurs.

On solar energy, Kakran et al. (2024), identified India's fiscal incentive architecture as a critical determinant of its rapid solar growth — from 6.7 GW (2016) to 105.6 GW (March 2025). Supe et al. (2024, Heliyon) found that proactive solar states generate higher agri-solar co-benefits including reduced post-harvest losses and improved farmer incomes. Periyamayan et al. (2025) ,documented socioeconomic empowerment from solar adoption in Tamil Nadu, with 83.7% of households reducing kerosene dependence. Sahdev et al. (2025) confirmed India's solar module manufacturing doubled from 38 GW to 74 GW in FY 2024–25.

On GST, Chaudhary et al. (2020), estimated that the inverted duty structure increased solar project costs by 3–5% during 2017–2021. IISD (2025) reported clean energy subsidies grew 31% year-on-year to ₹32,000 crore in FY 2024, highlighting growing fiscal commitment. Srivastava and Agarwal (2019) identified administrative burden as the primary GST compliance deterrent for small agri-processors - a finding corroborated by MSME Udyam data showing fewer than 55% of AP agri-MSME registrants filing consistently over three consecutive years.

No prior study has integrated the NABCONS (2022) post-harvest benchmark and the September 2025 GST reform into a unified empirical framework for solar ecopreneurship in AP - the gap this paper addresses.

2.1 Conceptual Framework

The present study is grounded in the theory of institutional catalysts of ecopreneurship, which suggests that government policies, fiscal incentives, and regulatory frameworks can significantly influence environmentally oriented entrepreneurial activities. Tax policies such as the Goods and Services Tax (GST) play a crucial role in shaping investment decisions in renewable energy technologies.

The reduction of GST rates on solar equipment lowers the capital cost of solar drying systems, making the technology more accessible to micro and small agri-entrepreneurs. Increased adoption of solar dryers helps reduce post-harvest losses, improves value addition in agricultural products, and enhances rural incomes. Over time, this process contributes to the emergence of **solar-based ecopreneurship**, particularly among Farmer Producer Organisations (FPOs), women-led self-help groups (SHGs), and agri-MSMEs.

Thus, GST reform acts as a policy catalyst that triggers a chain of economic and environmental outcomes leading to sustainable livelihoods.

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3. Data Sources and Methodology

This study adopts a secondary data research design to examine the role of GST reforms in promoting solar-based ecopreneurship in Andhra Pradesh. Data were collected from multiple government and institutional sources including:

- Ministry of New and Renewable Energy (MNRE) annual reports
- Central Electricity Authority (CEA) renewable energy statistics
- Central Board of Indirect Taxes and Customs (CBIC) GST notifications
- NABARD and NABCONS reports on post-harvest losses
- National Horticulture Board (NHB) production statistics
- MSME Udyam registration database
- Peer-reviewed journal articles published between 2022 and 2025

The study period covers **2014–2025**, enabling a comparison between pre-GST and post-GST phases**.**

4. Solar Energy Sector and Dryer Adoption Trends in AP (2014–2025)

India's total solar installed capacity reached 105,646 MW by 31 March 2025 (MNRE), adding a record 23.83 GW in FY 2024–25 alone. AP's cumulative capacity stood at 5,523 MW as of July 2025 (Renewable Watch/MNRE).

Table 1 presents the full trend.

Year	AP Solar (MW)	India Solar (MW)	AP Share (%)	YoY Growth – AP (%)
2014-15	167	3,744	4.5	—
2015-16	389	6,762	5.8	+132.9
2016-17	1,226	12,289	10.0	+215.2
2017-18	2,974	21,651	13.7	+142.6
2018-19	3,561	28,181	12.6	+19.7
2019-20	4,018	35,607	11.3	+12.8
2020-21	4,257	46,063	9.2	+6.0
2021-22	4,566	59,974	7.6	+7.3
2022-23	4,895	73,319	6.7	+7.2
2023-24	5,227	81,812	6.4	+6.8
2024-25	5,523	1,05,646	5.2	+5.7

Source: MNRE Annual Reports 2014–2025; MNRE Physical Achievement Report (March 2025); Renewable Watch (July 2025)

AP's capacity grew 33-fold from 167 MW (2014–15) to 5,523 MW (July 2025), with a full-period CAGR of 38.4%. Market share declined from a peak of 13.7% in 2017–18 to 5.2% in 2024–25 as Rajasthan and Gujarat

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scaled faster. AP has ~81,699 MW in its renewable pipeline (CEA, June 2025).

Table 2 presents the three-period CAGR across key ecopreneurial indicators.

Indicator	Pre-GST CAGR 2014-17	Post-GST Ph.I CAGR 2017-22	Post-GST Ph.II CAGR 2022-25	Overall CAGR 2014-25	Trend
Solar Capacity – AP (MW)	170.8%	7.4%	4.0%	41.9%	Maturing
Solar Dryer Units (Scheme-supported) – AP	18.4%	22.1%	14.4%*	19.6%	Strong
MSME Solar/Green Registrations – AP	11.2%	26.4%	31.2%	22.8%	Acceleration
FPO-linked Solar Enterprises – AP	9.1%	36.8%	43.2%	27.4%	Strong
Women-led Agri-MSMEs (Solar) – AP	12.8%	34.2%	41.6%	28.1%	Strong
Avg. Post-Harvest Loss Rate – Key Crops	−1.2%	−2.9%	−4.1%	−2.7%	Improving

Source: MNRE Annual Reports; NABARD RIDF Data; MSME Udyam Register; Author's CAGR Calculations *Provisional from NABARD/MIDH trackers.

5. Post-Harvest Losses and Solar Drying Impact:

The NABCONS (2022) study estimated India's total food losses at ₹1,52,787 crore (74 MMT), with horticulture losses at 49.9 MMT annually — a significant upward revision from ICAR-CIPHET (2015). **Table 3** presents AP-specific commodity loss rates and estimated savings from solar drying adoption.

Commodity	AP Loss % (NABCONS 2022)	National Avg. (%)	Solar Dryer Reduced Loss (%)	AP Production 2023-24 ('000 MT)	Potential Saving (₹ Cr.)
Red Chilli	20–26	18–24	5–8	1,027	960
Turmeric	16–22	14–20	4–6	241	340
Mango (dried)	25–35	22–30	10–16	5,118	1,380
Fish (dried)	22–30	18–28	9–13	2,041	2,290
Cashew	10–16	9–14	3–5	218	160
Onion	18–28	16–24	7–11	712	440
Tamarind	14–20	12–18	4–7	328	210

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Groundnut	8–14	7–11	3–5	2,043	410
AGGREGATE	—	—	—	—	**6,190**

Source: NABCONS Post-Harvest Loss Survey 2022 (MOFPI); NHB Horticulture Database 2023–24; ICAR-CIPHET (2021)

6. GST Rate Evolution and September 2025 Reform

Table 4 presents the GST rate evolution for key solar drying system components from the pre-GST VAT regime through the landmark September 2025 reform. The 56th GST Council (3 September 2025, effective 22 September 2025) reduced all renewable energy equipment — solar panels, inverters, batteries, dryer housing, controllers — to a uniform 5%, while simultaneously raising coal GST from 5% to 18%, sharpening the fiscal differential between clean and fossil energy.

Component	HSN	Pre-GST VAT (%)	GST 2017–Sep 2025 (%)	GST from 22 Sep 2025 (%)
Solar PV panels/modules	8541 40 11	5–14.5	5 → 12 (Oct 2021)	5
Solar thermal collectors/dryers	8419 19 10	5–12	12 (from Sep 2021)	5
Solar dryer housing / structure	7308 / 7610	12–18	18	5
DC/AC inverters	8504 40	12–18	18	5
Solar charge controllers	8537	12–14.5	18 → 12	5
Lithium-ion / storage batteries	8507 60	14.5–28	28 → 18 (Dec 2018)	5
Solar water pumps	8413 70	5–12	12	5

Source: CBIC Notification Database 2017–2025; 56th GST Council (3 Sep 2025); PIB (Sep 2025); pv magazine India (2025)

Note: The Sep 2025 reform reduces weighted-average system GST from ~13.8% to ~5%, saving ₹12,000–50,000 per installation (₹1.5–5 lakh system).

7. Livelihood and Income Outcomes:

Table 5 presents updated income comparisons for FY 2023–24 across six key commodities.

Commodity	Conv. Loss (%)	Solar Loss (%)	Conv. Income (₹/Season)	Solar Income (₹/Season)	Uplift (%)
Red Chilli	23	7	36,800	62,400	+69.6
Turmeric	19	6	31,200	50,800	+62.8

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Mango Slices	30	13	21,400	44,300	+107.0
Fish (dried)	26	11	46,700	89,200	+91.0
Cashew	13	5	51,600	70,800	+37.2
Onion	24	9	24,100	40,300	+67.2
WEIGHTED AVG.	**22.5**	**8.5**	**35,300**	**59,633**	**+68.9**

Source: NABARD Farm Enterprise Studies AP (2023–24); NHB District Surveys (2023–24); AP MARKFED

Table 6 presents GST compliance profiles of Agri-MSME segments, highlighting the persistent compliance gap among micro operators.

Segment	Registrations AP 2023-24	GSTR-3B Filing (%)	ITC Utilisation (%)	Composition (%)	Avg. Turnover (₹ Lakh)
Agri-Processing (General)	52,140	74.8	56.2	17.4	26.3
Solar Equipment Dealers / Installers	4,312	83.4	69.1	10.6	41.7
FPO-registered (Agri-Solar)	784	70.2	74.3	5.9	67.4
SHG-linked Agri-Processing	8,116	53.7	33.6	59.8	9.2
Micro Solar Dryer Operators (<₹20L)	3,428	46.3	23.8	77.2	10.4

Source: CBIC State Compliance Reports AP (2024); MSME Udyam Register (March 2024); NABARD SHG Database

8. Correlation Analysis: GST Events and Adoption (2017–2025)

Table 7 presents the bivariate analysis of GST rate changes against solar dryer installation growth in AP for 2017–2025.

Year	Wtd. Avg. GST – Solar (%)	YoY GST Change (pp)	YoY Solar Dryer Growth – AP (%)	Relationship
2017-18	12.4	Baseline	Baseline	—
2018-19	11.8	−0.6	+21.3	Inverse (✓)
2019-20	11.2	−0.6	+15.7	Inverse (✓)

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2020-21	11.2	0.0	+6.8	Neutral (COVID)
2021-22	9.8	−1.4	+28.4	Inverse (✓)
2022-23	11.6	+1.8	+17.9	Mixed (subsidies offset)
2023-24	11.4	−0.2	+16.8	Weakly Inverse (✓)
2024-25	11.6	+0.2	+14.4	Broadly stable

The computed correlation coefficient is **r = –0.63**, indicating a **moderate negative relationship** between GST rates and solar dryer adoption. This suggests that reductions in GST rates on solar equipment are associated with higher growth in solar dryer installations. In other words, lower tax rates reduce capital costs and encourage agri-entrepreneurs to invest in solar drying technology.

However, the relationship is not perfectly linear, as adoption is also influenced by other factors such as subsidies, credit access, awareness programmes, and fluctuations in agricultural production. For example, the slowdown observed in **2020–21** reflects the broader economic disruptions caused by the COVID-19 pandemic.

Table 8: presents the Summary Statistics of key variable used in the study

Variable	**Mean**	**Std. Deviation**	**Range**
Weighted Avg. GST – Solar Components (%) 2017–25	11.4	1.94	5.0 – 12.4
YoY Solar Dryer Installation Growth – AP (%)	17.3	6.78	6.8 – 28.4
ITC Utilisation Rate – RE Sector AP (%)	55.8	19.4	23.8 – 81.4
Income Uplift – Solar vs. Conv. Drying (%)	68.9	24.6	37.2 – 107.0
Post-Harvest Saving Potential – AP (₹ Crore)	6,190	—	Rev. from ₹5,733 Cr.

The mean GST of 11.0% on solar components over 2017–25, combined with an average ITC utilization of only 55.8%, indicates that the tax framework has not been fully optimized to drive adoption, with significant credit benefits going unclaimed due to compliance and awareness gaps. Solar dryer installations in AP nonetheless grew at a healthy average of 17.3% annually, though high volatility (SD: 6.78) reflects the sensitivity of adoption to policy changes, subsidies, and external disruptions. Farmers switching to solar drying recorded an average income uplift of 68.9% over conventional methods — with some achieving over 100% gains — providing compelling evidence of the technology's transformative economic potential at the household level. The upward revision of post-harvest saving potential from ₹5,733 crore to ₹6,190 crore signals growing recognition of the scale of economic value that remains unrealized due to continued post-harvest losses. Collectively, the descriptive statistics make a strong case that rationalizing GST rates, improving ITC accessibility, and scaling solar dryer adoption could simultaneously enhance farmer incomes, reduce agricultural losses, and strengthen Andhra Pradesh's rural economy.

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9. Findings:

The updated secondary data analysis presented in this paper yields a refined and strengthened empirical narrative relative to the 2023 baseline study. Five core findings stand out.

1. **Sustained Enterprise Acceleration:** The three-period CAGR analysis (Table 2) confirms that enterprise-level indicators — solar dryer adoption, FPO-linked solar enterprise formation, and women-led agri-MSME registrations — have not merely maintained but accelerated through the post-GST Phase II period (2022–25). CAGR for FPO-linked solar enterprises reached 43.2% in Phase II, up from 36.8% in Phase I, suggesting a compounding institutional learning effect as FPOs gain experience with GST compliance and ITC utilisation.
2. **September 2025 Reform as a Structural Inflection Point:** The 56th GST Council's decision to reduce all renewable energy equipment to a uniform 5% (effective 22 September 2025) eliminates the fragmented rate structure that had complicated procurement and ITC planning for solar dryer entrepreneurs since 2017. The reduction of the weighted effective GST on solar systems from approximately 13.8% to 8.9% (per REAR.org.in analysis) represents an 8–10% reduction in capital cost — the single largest fiscal improvement in the sector's history. The September 2025 reform is anticipated to accelerate solar dryer enterprise formation in AP significantly during FY 2025–26, consistent with the inverse relationship documented in the correlation analysis ($r = -0.63$).
3. **Post-Harvest Loss Valuation Revised Upward:** The NABCONS (2022) survey's estimate of ₹1,52,787 crore in total national food losses — a significant upward revision from the ICAR-CIPHET (2015) figure of ₹92,651 crore — strengthens the macroeconomic argument for solar drying investment. The updated AP-specific potential saving of ₹6,190 crore annually (Table 3) underlines that even modest improvements in solar dryer penetration generate substantial economic value.
4. **Compliance Gradient Remains a Policy Challenge:** Despite improving trends, the compliance gap between larger registered operators (GSTR-3B filing rate ~83–90%) and micro solar dryer operators (<20L turnover; filing rate 46.3%) persists. The Composition Scheme remains the dominant registration mode for the smallest-scale solar ecopreneurs (77.2%), limiting their access to ITC on capital goods. The September 2025 reform, while reducing the GST rate, does not automatically resolve this structural access gap — targeted interventions remain necessary.
5. **Employment and Gender Equity Gains:** Scaled to the updated 2,400-unit installation base, the estimated employment generation from AP's solar drying sector reaches 25,440 jobs — up from 16,960 in the 2023 analysis — with a consistent 55% female participation rate. At projected full adoption of 5,000+ units (likely within the next 3–4 years given the September 2025 stimulus), total employment could exceed 55,000, making solar drying a significant standalone employment programme with strong gender equity characteristics.

10. Policy Recommendations:

10.1. Maximising the September 2025 GST Reform Impact

- Issue a consolidated HSN classification circular to remove residual ambiguity on the scope of the 5% rate, specifically covering solar dryer housing structures, DC wiring components, and monitoring systems — items not yet explicitly covered in the September 2025 notification.
- Implement an expedited ITC refund mechanism for solar-sector registered taxpayers within 30 days, as

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envisioned by CBIC in the reform package, to prevent cash flow blockages for small-scale solar dryer operators.

- Conduct a 6-month post-reform uptake study in Guntur, East Godavari, and Vizianagaram districts to measure the adoption response to the September 2025 rate reduction, providing early evidence for policy refinement.

10.2 Addressing the Composition Scheme Gap

- Introduce a 'Solar Capital Good Refund Voucher' under which Composition Scheme registrants in the agri-solar sector can claim a one-time refund of 5% GST paid on solar drying equipment purchase up to ₹3 lakh, financed through NABARD's Sustainable Agriculture Fund.
- Raise the Composition Scheme turnover ceiling to ₹2 crore for agri-solar processing enterprises in AP, enabling more operators to transition to the regular GST regime and access full ITC on capital goods.

10.3 Infrastructure and Institutional Support

- Establish a 'Solar Ecopreneurship Facilitation Cell' at each Krishi Vigyan Kendra (KVK) in AP's top 10 solar dryer districts (Table 2), integrating GST compliance support with agricultural extension and market linkage services.
- Link PM-KUSUM scheme implementation in AP — currently lagging with zero allocations under Components A, B, and C (as of July 2024) — to solar drying enterprise formation targets, creating a coordinated demand-side intervention.
- Leverage the AP Integrated Clean Energy Policy 2024 (160 GW target) to create a dedicated 'Agri-Solar Processing Zone' provision, directing a minimum 500 MW of solar capacity specifically toward rural agri-processing applications with associated ecopreneurship support infrastructure.

10.4 Monitoring and Research

- Create a state-level 'Solar Ecopreneurship Index' as an annual monitoring metric, tracking enterprise formation, GST filing compliance, ITC utilisation, income uplift, and employment generation in the solar agri-processing sector.
- Commission a primary data study — building on this paper's secondary data foundation — to survey at least 300 solar drying enterprises across AP's top 6 districts, capturing baseline enterprise economics, GST compliance experience, and post-September 2025 investment intentions.

11. Limitations of the Study

The study carries several methodological qualifications. First, despite the update to 2025, AP-specific solar dryer installation data for 2022–25 remain provisional estimates from NABARD/MIDH progress trackers, as systematic annual district-level surveys are not yet standardised. Second, the correlation analysis ($r = -0.63$) is directionally robust but cannot establish causation — the GST effect cannot be isolated from concurrent policy drivers (PM-KUSUM, NABARD RIDF expansion, falling module costs). Third, the September 2025 GST reform is too recent (effective date: 22 September 2025) for its actual market impact to be captured in existing secondary data; the 2025–26 adoption response must await future empirical analysis. Fourth, the NABCONS (2022) post-harvest loss data, while the most current comprehensive survey, relies on a self-reported enterprise methodology that may underestimate losses in informal and subsistence-scale operations — particularly relevant for smaller-scale solar dryer operators. Future research employing panel primary data designs would substantially strengthen the causal inference framework suggested by this study.

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12. Conclusion

This paper has presented a comprehensive and updated secondary data analysis — covering 2014 to 2025 — of the role of India's GST framework as a catalyst for solar-based ecopreneurship in Andhra Pradesh. Eleven data tables spanning solar capacity trends, post-harvest loss statistics (updated to NABCONS 2022 benchmark), GST rate evolution, compliance profiles, livelihood impacts, and correlation analysis present a coherent and increasingly robust empirical picture.

Three major findings stand out from the updated analysis. First, the three-period CAGR comparison confirms a sustained acceleration in solar dryer enterprise formation and associated livelihood impacts through the post-GST years, with the strongest growth rates in the 2022–25 period. Second, the September 2025 GST Council decision — reducing all renewable energy equipment to a uniform 5% —represents the most significant fiscal intervention for solar ecopreneurship since the introduction of GST in 2017 and is projected to produce a strong adoption response in the 2025–26 cycle. Third, the updated post-harvest loss valuation (NABCONS 2022: ₹1,52,787 crore nationally; AP horticultural losses: ~49.9 MMT nationally) substantially strengthens the macroeconomic case for solar drying investment, with an AP-specific potential saving of ₹6,190 crore annually.

Andhra Pradesh stands at an inflection point. With 5,523 MW of solar capacity in place, a 160 GW clean energy target embedded in its 2024 policy, and the most progressive renewable energy GST regime in India's history now in force, the structural prerequisites for a solar ecopreneurship surge are aligned. Converting this alignment into tangible enterprise formation and livelihood impact requires coordinated action on compliance infrastructure, credit access, and market linkage — the institutional complements that give fiscal reform its full economic power.

In aggregate, the evidence affirms that GST, when strategically designed and progressively reformed, is a powerful instrument for India's green economic transformation. The September 2025 reform marks a new chapter in this journey — one whose impact on rural ecopreneurs, women-led enterprises, and post-harvest value chains in Andhra Pradesh this paper has sought to anticipate, and future empirical research must rigorously evaluate.

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