Comparison of Sino-US new energy transformation policies and analysis of regional economic synergy effects

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Abstract. As the core carrier of decentralization in the solar energy industry, the development quality of distributed photovoltaic (PV) directly affects the restructuring of the solar industry landscape in China and the United States (U.S.) as well as the global energy transition process. Focusing on distributed PV in China and the U.S. as the core research object, this study systematically analyzes the distributed power generation practices of the two countries by combining grounded theory. It compares differences in the intensity of policy subsidies, the logic of location layout, and power generation efficiency, conducts an in-depth exploration of common challenges and differentiated driving factors in the transition, and puts forward targeted optimization paths for the distributed PV and the overall solar energy industry in both countries. The research shows that policy flexibility, the stability of economic support, and public acceptance are the three core elements for the sustainable development of solar energy decentralization; due to differences in political systems and national conditions, China and the U.S. have formed distinct development paths characterized by government-led scaling and market-led innovation respectively, and need to break through the current development bottlenecks through policy mutual learning and mechanism innovation.

1. Introduction

Driven by the in-depth adjustment of the global energy structure and the dual carbon goals (carbon peaking and carbon neutrality), the decentralized transition of the power system has become a core path to advance energy security and low-carbon development. With its unique advantages of small-scale layout, nearby consumption, and low transmission loss, distributed photovoltaic (PV) has emerged as a strategic tool for China and the United States (U.S.) to expand solar energy application scenarios and optimize the energy supply structure. As the two largest core markets in the global solar energy industry, the development of distributed PV in China and the U.S. not only follows the common law of resource adaptation-policy guidance-market response but also exhibits distinct characteristics due to differences in political systems, resource endowments, and market maturity. Systematically sorting out their development logic, policy systems, and regional synergy mechanisms is not only directly valuable for promoting the transformation of the

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solar energy industry in both countries from scale expansion to quality and efficiency improvement but also provides theoretical and practical references for cross-institutional comparison in the global new energy decentralization process.

1.1 Background

From a global perspective, the decentralization of the power system has entered an accelerated phase characterized by technological iteration-policy intensification-market boom. Data from the International Energy Agency (IEA) shows that in 2022, the newly installed capacity of global distributed PV accounted for 45% of the total newly installed PV capacity, an increase of 27 percentage points compared with 2010 [1]. Distributed energy has become a core path to reduce reliance on centralized power grids and improve energy utilization efficiency. Among them, the U.S., as the economy that earliest laid out distributed PV, has achieved leapfrog growth in the proportion of distributed PV through more than three decades of policy exploration and market cultivation—this proportion was less than 1% in 1990, exceeded 5% in 2010, and reached 29% in 2022 [2]. It has formed a market-driven model centered on tax credits + net metering policies. Moreover, the Inflation Reduction Act (IRA) of 2022 further increased the solar tax credit rate to 30%, injecting new impetus into the market [3].

Although China's distributed PV industry started after 2010, it has achieved latecomer catch-up driven by strong policies. With the refinement of China's dual carbon goals and the intensification of local industrial policies, the growth potential of distributed PV will continue to be released.

Currently, both China and the U.S. have entered a critical transition period in the development of distributed PV. China is confronted with practical issues such as imbalanced consumption in the west (Gansu's PV curtailment rate was 3.8% in 2023), lagging promotion in rural areas (rural distributed PV accounting for less than 20%), and grid connection barriers for private enterprises; the U.S., on the other hand, is restricted by policy fluctuations, inter-state policy conflicts, and resistance from traditional power companies. The development of distributed PV in the two countries is not only related to the optimization of their own energy structures but also profoundly affects the technological path, market pattern, and low-carbon transition process of the global solar energy industry. This practical background highlights the urgency and necessity of this study.

1.2 Research gap

Existing studies on Sino-U.S. distributed PV have made some progress, but there are still two significant gaps, which make it difficult to fully support the high-quality development of distributed PV in both countries and the practical needs of global energy transition. Firstly, there is a lack of integrated analysis of political system-policy tools-regional synergy. Most existing literatures focus on the effect comparison of a single policy tool (e.g., China's per-kilowatt-hour subsidy, U.S. tax credits) or analyze regional layout characteristics in isolation. They fail to deeply link the policy-making mechanism with political system characteristics (e.g., China's central coordination vs. U.S. federalism) and do not systematically explain how policies affect industrial efficiency through regional synergy. As a result, the research conclusions cannot reflect the systematicness and complexity of distributed PV development. Secondly, there is insufficient exploration of the in-depth driving mechanisms behind the differentiated paths of the two countries. Most existing studies only stay at the superficial comparison of China being government-led and the U.S. being market-led, and fail to further analyze the institutional roots of questions

such as why China can quickly achieve large-scale expansion but lacks local innovation and why the U.S. market is flexible but policy stability is weak. In particular, there is a lack of theoretical explanation for core issues such as the balance between policy flexibility and stability and the division of powers and responsibilities between the central/federal and local/state governments, making it difficult to reveal the inherent laws of distributed PV development.

1.3 Research aim and questions

1.3.1 Research aim

This study takes Sino-U.S. distributed PV as the research object. Based on grounded theory and the policy-layout-efficiency analytical framework, it systematically compares the two countries' distributed PV transition policy system differences, quantitatively analyzes regional economic synergy effects, and reveals the institutional driving mechanisms of differentiated development paths. Ultimately, it provides theoretical support and practical references for both countries to break development bottlenecks, promote high-quality development of distributed PV and the solar energy industry, and advance the global new energy decentralization transition.

1.3.2 Research questions

First, what are the differences between China and the U.S. in distributed PV transition policy systems and their implementation effects? Specifically, how do the two differ in policy-making entities, core tools, and grid connection mechanisms? How do these differences affect policy efficiency and challenges?

Second, what are the differences in mechanisms and quantitative levels of distributed PV regional synergy between the two? Specifically, how do their synergy models differ in resource matching and industrial chain linkage? How to quantify synergy in typical regions?

Third, what drives their differentiated distributed PV development? How do political systems affect development via policy flexibility and economic support stability? What mediating roles do public acceptance and market entity participation play?

Fourth, what differentiated optimization paths address their bottlenecks? How to tap Sino-U.S. synergy in tech R&D and industrial chain complementarity?

1.4 Research significance

1.4.1 Theoretical significance

Through grounded theory analysis, this study integrates political system-policy tools-regional synergy into a unified analytical framework, making up for the limitation of single policy comparison in existing studies and enriching cross-country and cross-institutional comparative theories in the field of distributed energy. Meanwhile, the core issues focused on in this study, such as the balance between policy flexibility and stability and the division of powers and responsibilities between the central and local governments, also provide theoretical references for other countries around the world to promote the decentralized transition of solar energy.

1.4.2 Practical significance

Based on a Sino-U.S. comparative framework, this study puts forward optimization suggestions targeting specific problems in the development of distributed PV in the two countries. It not only provides a path for China to solve issues such as rigid local policies and slow progress in rural distributed PV but also offers references for the U.S. to alleviate problems like policy fluctuations and insufficient corporate investment confidence, directly serving the high-quality development of the solar energy industry in both countries.

2. Development foundation of Sino-US distributed PV industry

2.1 Definition of core concepts: distributed PV and decentralized energy

A distributed PV system refers to small-scale, scattered PV power generation facilities with the core feature of nearby power generation and nearby consumption, reducing long-distance transmission losses [4]. Decentralized energy emphasizes spatial matching of production and consumption to reduce reliance on a single grid. Distributed PV is a typical application of decentralized energy in solar power, with the former enabling energy production decentralization through layout optimization, while the latter drives PV technological iteration and scale expansion [5]. China's self-consumption with surplus electricity fed into the grid model exemplifies this connection by diversifying energy supply.

2.2 Overview of industry development

2.2.1 China's distributed PV industry

China's industry development relies on national policy guidance and state-owned enterprise leadership. By 2019, total PV installed capacity reached 204.3 GW, with distributed PV accounting for 62.63 GW (30.6%) following 12.2 GW of new installations that year [6]. Industry participation features state-owned enterprises leading + private enterprises supplementing, with private involvement expanding after the 2012 Measures for the Administration of Distributed Generation. Regionally, southwest China (e.g., Gansu, Qinghai) develops large-scale projects using abundant solar resources, while eastern provinces (e.g., Jiangsu, Zhejiang) promote rooftop and industrial park installations to meet high electricity demand.

2.2.2 U.S. distributed PV industry

The U.S. industry follows a enterprise leadership + policy empowerment model. Small-scale distributed solar capacity grew from under 10 GW in 2014 to nearly 40 GW by 2023, driven by market demand and policy support. Leading companies like Sunrun and Tesla/SolarCity dominate the residential market through innovative financing models such as Power Purchase Agreements. Regionally, California became the largest market after implementing mandatory rooftop PV policies for new residences in 2020, while Nevada and Arizona developed coordinated distributed-centralized PV systems leveraging solar resources.

2.3 Core advantages: economy and resources

Distributed PV's rapid growth stems from economic and resource utilization advantages. Economically, users reduce electricity costs through self-consumption and gain additional income from surplus grid sales. With stable unit investment costs across scales, it attracts small and medium investors.

In resource utilization, PV systems use idle spaces like rooftops and agricultural greenhouses. China's agricultural-PV complementary mode improves land efficiency by combining power generation with farming. The levelized cost of electricity (LCOE) of distributed PV is lower than industrial and residential electricity prices, enhancing market competitiveness when combined with subsidies [7].

3. Comparison of Sino-US distributed PV transformation policies

Differences in political systems and market environments between China and the U.S. determine the different logics of their distributed PV transformation policies: China focuses on centralized coordination and unified policies to ensure the efficiency of policy implementation [8]; the U.S. is characterized by market liberalization and state autonomy, emphasizing policy flexibility and market adaptability. Although the two paths are different, both aim to promote the development of distributed PV and face unique challenges in policy practice.

3.1 China's distributed PV transformation policy system

3.1.1 Policy framework and core measures

China's distributed PV policy adopts a structure of top-level design + implementation rules [9]. The core policy document includes the Measures for the Administration of Distributed Generation issued in 2012—which for the first time explicitly encouraged private enterprises and individuals to participate in distributed PV investment, breaking the previous monopoly of state-owned enterprises in the PV industry.

In terms of grid connection mechanisms, the policy provides two options. Self-consumption with surplus electricity fed into the grid and full grid connection [10]. The former allows users to prioritize self-consumption of generated electricity and sell the surplus electricity to the grid at an agreed price; the latter requires all generated electricity to be connected to the grid and settled at the benchmark electricity price for desulfurized coal-fired power. The flexible grid connection policy meets the needs of different users.

In addition, the central government also promotes the development of distributed PV through fiscal subsidies, land support, and other policies: for example, in the early stage, a per-kilowatt-hour subsidy (0.42 yuan/kWh) was implemented for distributed PV to reduce investment costs [11]; land use fee reductions were granted to distributed PV bases in western China to enhance the attractiveness of regional layout. Local governments formulated implementation rules based on central policies—for instance, eastern provinces such as Jiangsu and Zhejiang provided additional provincial-level subsidies for industrial and commercial distributed PV, further stimulating market vitality.

3.1.2 Challenges in policy implementation

Although China's policy system has the advantages of uniformity and efficiency, it still faces three challenges in implementation. Over-reliance on central directives and insufficient local implementation capacity: Local governments lack professionals in

distributed PV planning and management, leading to uneven policy implementation effects in some regions. For example, the approval process for distributed PV projects in rural areas is cumbersome, and technical services are insufficient. High grid connection thresholds for private enterprises: In some regions, grid companies give priority to ensuring the grid connection of state-owned enterprise projects, and private enterprises face problems of difficulty in grid connection and slow grid connection, which restricts fair market competition. Technical and financial gaps in rural areas: Rural residents have insufficient awareness of distributed PV and lack initial investment funds. At the same time, the local power grid infrastructure is weak, unable to bear the grid connection demand of distributed PV, resulting in the lagging development of rural distributed PV compared with urban areas.

3.2 The U.S. distributed PV transformation policy system

3.2.1 Policy framework and core measures

U.S. policy operates through federal legislation + state-level innovation with market liberalization foundations. The 1978 Public Utility Regulatory Policies Act (PURPA) broke traditional power company monopolies, while the 2005 Energy Policy Act introduced 20-30% solar tax credits to reduce investment costs [12]. State policies drive growth: California's net metering allows surplus electricity to offset future bills; Nevada's Renewable Portfolio Standard (RPS) mandates increasing renewable procurement. Third-party financing models (e.g., Sunrun) synergize with policies to lower user costs.

3.2.2 Challenges in policy implementation

Although the flexibility of U.S. policies has activated market vitality, it also faces two core challenges. First is the insufficient policy stability and high impact of partisan disputes. The other is the resistance from traditional power companies. Investor-Owned Utilities (IOUs) are concerned that distributed PV will divert their power sales business and lobby state governments to restrict the development of distributed PV [13]. For example, power companies in the San Francisco area once attempted to lower the benefit standards of the net metering policy, triggering protests from users and developers and delaying project progress.

4. Regional synergy effects and development challenges of Sino-US distributed PV

The regional layout of distributed PV is closely related to regional economy and resource endowments. Due to differences in resource characteristics and industrial foundations of distributed PV-concentrated regions, China and the U.S. have formed distinct regional synergy effects; at the same time, issues such as inter-regional interest coordination and technical adaptation have become key challenges restricting the further development of distributed PV.

4.1 Regional layout and synergy effects of China's distributed PV

4.1.1 Characteristics of regional layout

China's solar resources and terrain conditions determine the regional concentration of distributed PV: Southwest China (Gansu, Qinghai, Inner Mongolia) has become a core area for large-scale distributed PV layout due to abundant solar resources and open terrain [14]; eastern coastal provinces (Jiangsu, Zhejiang, Guangdong) promote the decentralized layout of distributed PV in industrial parks and commercial building rooftops relying on developed industrial and commercial sectors and high electricity demand, forming a pattern of centralized power generation in the west and decentralized consumption in the east. The formation of this layout not only stems from differences in resource endowments (superior solar conditions in the west than in the east) but also benefits from China's West-to-East Power Transmission Strategy—through ultra-high voltage (UHV) transmission lines, electricity from distributed PV bases in the west is transmitted to high-load regions in the east, realizing cross-regional resource allocation.

4.1.2 Regional synergy effects

The regional synergy of China's distributed PV is mainly reflected in three dimensions: resource-load-industry. The west converts solar resources into electricity through distributed PV development, alleviating the tight electricity supply-demand in the east. The high electricity load demand in the east provides a stable consumption market for distributed PV in the west, avoiding the problem of PV curtailment. Eastern PV module manufacturers (e.g., Longi, JinkoSolar) provide equipment support for distributed PV bases in the west, while the construction of western projects drives the growth of manufacturing orders in the east, forming an industrial chain synergy of eastern manufacturing - western power generation - eastern consumption.

Taking the Hainan Tibetan Autonomous Prefecture Distributed PV Base in Qinghai as an example, relying on local abundant solar resources, the base has built a distributed PV installed capacity of over 10 GW. Through the Qinghai-Henan UHVDC Project, electricity is transmitted to Henan Province, which not only drives local employment in Qinghai (creating more than 30,000 new jobs) but also alleviates Henan's electricity shortage [15]. In 2023, the electricity transmitted from this base accounted for 15% of Henan's renewable energy consumption, achieving a win-win situation for regional economy and energy.

4.2 Regional layout and synergy effects of U.S. distributed PV

4.2.1 Characteristics of regional layout

The regional layout of U.S. distributed PV is centered on state-level agglomeration, with California, Nevada, and Arizona as the three core regions:
California has become the core of the residential distributed PV market due to strong policy support (mandatory rooftop PV policy, high net metering benefits) and high electricity demand (residential electricity price: 13.28 cents/kWh, higher than the industrial electricity price of 6.41 cents/kWh).

Nevada and Arizona have formed a pattern of coordinated development of distributed PV and centralized PV relying on sufficient solar resources. The installed distributed PV capacity of these three states accounts for more than 60% of the U.S. total. Different from China, the U.S. distributed PV layout relies less on cross-state power transmission and achieves balance through intra-state consumption + cross-state transactions: due to excess installed distributed PV capacity, California sells surplus electricity to states such as Nevada and Arizona through the cross-state power market of the California Independent System Operator (CAISO), forming inter-regional power complementarity.

4.2.2 Regional synergy effects

The regional synergy of U.S. distributed PV is driven by market mechanisms + industrial clusters:

Market synergy: The CAISO cross-state power market allows distributed PV developers to bid for electricity sales across multiple states. Due to its low LCOE (0.03 USD/kWh), distributed PV in Nevada can sell electricity to California (electricity price: 0.2 USD/kWh) through market transactions to obtain price difference benefits. California has formed an industrial cluster of technology R&D - equipment manufacturing - installation and operation: Stanford University and the University of California, Berkeley provide technical support; Tesla/SolarCity is responsible for equipment manufacturing and installation; surrounding states (e.g., Nevada) provide lithium ore (raw material for energy storage batteries) for the cluster, forming a synergy model of California R&D and manufacturing - surrounding states' resource supply.

Taking the synergy between California and Nevada as an example, distributed PV in Nevada transmits electricity to California through the CAISO market, with a transmission scale of 15 billion kWh in 2023, accounting for 18% of California's distributed PV consumption. At the same time, Tesla's energy storage factory in California purchases lithium ore from Nevada, driving a 40% growth in the output value of Nevada's lithium ore industry and creating more than 20,000 new jobs, realizing the coordinated development of regional industry and energy.

4.3 Core challenges in the development of Sino-US distributed PV

For China, due to limited transmission channel capacity and protection of local coal-fired power in the east, distributed PV bases in the west still face the problem of PV curtailment. In 2023, the PV curtailment rate in Gansu was 3.8%, which, although lower than previous years, still restricts project. Distributed PV projects require multiple procedures, including NDRC filing - grid connection application - environmental impact assessment. The approval cycle for rural projects is as long as 6-8 months, and operation requires professional technical teams, which are difficult for SMEs to afford. Finally, rural residents have insufficient awareness of distributed PV and lack initial investment funds. At the same time, the local power grid infrastructure is weak, unable to bear the grid connection demand of distributed PV, resulting in rural distributed PV accounting for less than 20% of the national total. Challenges Faced by the U.S, first, in terms of insufficient policy stability, partisan disputes lead to fluctuations in federal solar policies. Policy volatility has made enterprises cautious in investment decisions. Also, there will be Inter-state policy conflicts. California requires 100% renewable energy supply by 2030, while Texas has not introduced mandatory distributed PV policies due to its reliance on the oil industry [16]. Inter-state policy differences have increased the cost of cross-state power transactions by 20%.

5. Conclusion

Taking distributed PV in China and the U.S. as the research object, this study systematically analyzes the industrial foundation, policy systems, regional synergy effects, and challenges of distributed PV in the two countries, and draws the following core conclusions. First, distributed PV has become the core carrier of the decentralized transition of solar energy in both China and the U.S., showing distinct development paths. Characterized by centralized coordination + state-owned enterprise leadership, China has achieved rapid scale expansion of distributed PV relying on policy consistency, with the

proportion of distributed PV reaching 30.9% in 2020. The U.S., focusing on market-driven + private enterprise leadership, has promoted market growth through tax credits and financing innovations, with distributed PV installed capacity reaching 40 GW in 2023. Both reflect the global trend of power decentralization, but the path differences stem from differences in political systems and market environments. Second, the distributed PV policies of China and the U.S. have their own advantages and disadvantages, and mutual learning is needed for optimization. China's policies have the advantages of high implementation efficiency and strong stability, but need to enhance local innovation capabilities and reduce barriers for private enterprise participation. The U.S. policies have the advantages of high market flexibility and many financing model innovations, but need to strengthen policy continuity and resolve resistance from traditional interest groups. In the future, China can learn from the U.S. market incentive mechanisms, and the U.S. can refer to China's central coordination experience to improve policy effectiveness. Third, regional synergy is the key to promoting the sustainable development of distributed PV, and China and the U.S. need to break through their respective synergy bottlenecks. China needs to improve the construction of West-to-East Power Transmission channels and balance the needs of resource development in the west and consumption in the east. The U.S. needs to strengthen inter-state policy coordination and reduce the cost of cross-state power transactions. At the same time, both countries need to strengthen the promotion of distributed PV in rural/remote areas to make up for regional development gaps.

Reference

1. Ashraf, Alia, and Muneeb Sagheer. 2025."Renewable Energy Capacity and Technological Innovations: A Review of Global Trends and Future Directions." doi:10.1002/ep.70071.
2. Tan, Xinying, Pengyu Zhu, and Renu Singh. 2024. "China's Model of Technology Leapfrog: A Case Study of Electric Vehicle Policies and the Development of Green Technology."doi:10.2139/ssrn.4743969.
3. Bartlett, J. (2023). Beyond subsidy levels: the effects of tax credit choice for solar and wind power in the Inflation Reduction Act. Resources for the Future Report, 23-20.
4. Liu, J., Liu, S., Li, M., Wu, X., Li, Z., Hao, X., 2025. Application of the distributed photovoltaic systems towards oil-gas field and its implications for carbon emission reduction in China: A review on current and novel perspective on engineering approaches. Cleaner Energy Systems 12, 100198. https://doi.org/10.1016/j.cles.2025.100198
5. Power to the People: On the Role of Districts in Decentralized Energy Systems [WWW Document], n.d. URL https://www.mdpi.com/1996-1073/17/7/1718 (accessed 8.31.25).
6. Wang, Y., He, J., Chen, W., 2021. Distributed solar photovoltaic development potential and a roadmap at the city level in China. Renewable and Sustainable Energy Reviews 141, 110772. https://doi.org/10.1016/j.rser.2021.110772
7. A Comprehensive Review of Solar PV Integration with Smart-Grids: Challenges, Standards, and Grid Codes [WWW Document], n.d. URL https://www.mdpi.com/1996-1073/18/9/2221 (accessed 8.31.25).
8. The politics of curtailment: multi-level governance and solar photovoltaic power generation in China: Environmental Politics: Vol 27, No 5 [WWW Document], n.d. URL https://www.tandfonline.com/doi/abs/10.1080/09644016.2018.1480920 (accessed 8.31.25).

9. Zhang, L., Qin, Q., Wei, Y.-M., 2019. China's distributed energy policies: Evolution, instruments and recommendation. Energy Policy 125, 55–64. https://doi.org/10.1016/j.enpol.2018.10.028
10. Dehler, J., Keles, D., Telsnig, T., Fleischer, B., Baumann, M., Fraboulet, D., Faure-Schuyer, A., Fichtner, W., 2017. Chapter 27 - Self-Consumption of Electricity from Renewable Sources, in: Welsch, M., Pye, S., Keles, D., Faure-Schuyer, A., Dobbins, A., Shivakumar, A., Deane, P., Howells, M. (Eds.), Europe's Energy Transition. Academic Press, pp. 225–236. https://doi.org/10.1016/B978-0-12-809806-6.00027-4
11. Shi, Y., Zuo, Y., 2016. Cost and Benefit Analysis of Distributed Photovoltaic System A Case of Beijing-Tianjin-Hebei Region. Presented at the 2016 2nd International Conference on Economy, Management, Law and Education (EMLE 2016), Atlantis Press, pp. 71–76. https://doi.org/10.2991/emle-16.2017.14
12. Electricity Competition and the Public Good: Rethinking Markets and Monopolies 90 University of Colorado Law Review 2019 [WWW Document], n.d. URL https://heinonline.org/HOL/LandingPage?handle=hein.journals/ucollr90&div=24&id=&page= (accessed 8.31.25).
13. Hess, D.J., 2016. The politics of niche-regime conflicts: Distributed solar energy in the United States. Environmental Innovation and Societal Transitions 19, 42–50. https://doi.org/10.1016/j.eist.2015.09.002
14. Wu, J., Xiao, J., Hou, J., Lyu, X., 2023. Development Potential Assessment for Wind and Photovoltaic Power Energy Resources in the Main Desert–Gobi–Wilderness Areas of China. Energies 16, 4559. https://doi.org/10.3390/en16124559
15. Ultra-High-Voltage Construction Projects and Total Factor Energy Efficiency: Empirical Evidence on Cross-Regional Power Dispatch in China [WWW Document], n.d. URL https://www.mdpi.com/2071-1050/16/18/8083 (accessed 8.31.25).
16. Mormann, F., Reicher, D., Hanna, V., 2016. A Tale of Three Markets: Comparing the Renewable Energy Experiences of California, Texas, and Germany. Stan. Envtl. L. J. 35, 55.