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How Price Signals Reshape Renewable Energy Investment and Revenue Logic: A Case Study of China's Electricity Market

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ABSTRACT

China's renewable energy sector is entering a new phase of market-oriented transformation. As renewable energy pricing reform deepens and electricity market participation expands, price signals are playing a greater role in project investment, revenue formation and asset operations. This paper examines how these changes reshape the investment and revenue logic of renewable energy projects in China from a market-participant perspective. The study adopts a qualitative case-study approach combining policy, institutional and market-mechanism analysis. It examines the evolution of China's renewable energy pricing framework and the transmission of national reform through provincial electricity markets into project-level price, contract and settlement arrangements. Provincial market data and anonymised project settlement materials are used as supporting evidence to illustrate how market conditions are reflected in project revenues and risks. The analysis shows that market reform does not change the basic financial principles of project valuation, but changes the revenue assumptions underlying investment decisions. Project value increasingly depends on generation profiles, market prices, contract structures, mechanism coverage and settlement rules. Revenue is therefore no longer adequately represented by a single on-grid tariff, but by a constrained combination of market electricity revenue, revenue stabilisation arrangements and other settlement components. This also changes the focus of asset management. Generation volume and equipment availability remain fundamental, while forecasting, contract management, production–trading coordination, settlement analysis and risk management increasingly affect the value and cash flow realised by renewable energy assets. The paper characterises China's current renewable energy market as a hybrid transition in which stronger market-based price discovery coexists with revenue stabilisation mechanisms. The findings provide practical implications for policymakers, investors and market participants seeking to balance effective price signals, project risk management and the predictability required for long-term renewable energy investment.

KEYWORDS Electricity market reform, Electricity price signals, Renewable energy investment, Renewable energy asset operations, Energy policy and management

1. Introduction

1.1. Research Background: Structural Transformation of China's Power Sector

China's power sector is undergoing simultaneous changes in its generation mix and market design. Over the past decade, policy support, technological progress and declining costs have driven rapid growth in wind and solar power. By the end of 2025, China's installed renewable energy generation capacity had reached 2.34 billion kilowatts, accounting for approximately 60 per cent of the country's total installed generation capacity. Wind and solar power together accounted for 1.84 billion kilowatts, or approximately 47 per cent of the national total. During the same period, renewable

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energy generation reached 3.99 trillion kilowatt-hours, accounting for approximately 38 per cent of the country's total electricity generation (National Energy Administration 2026). As renewable capacity expands, the policy and commercial challenge is increasingly how large volumes of wind and solar power can realise economic value within the electricity system and market.

Capacity growth does not necessarily translate into equivalent growth in market value per MWh. Electricity has a time-dependent value, which becomes increasingly relevant as variable renewable generation expands (Bhattacharyya 2019, pp. 231-232). When similar renewable resources generate simultaneously, the additional supply can depress prices during those hours, reducing the output-weighted price received by the technology (Hirth 2013, pp. 218-220). Resource conditions and utilisation hours remain important, but they are no longer sufficient on their own to assess project value in a market environment.

In tandem with the expansion of renewable energy capacity, market-based electricity trading has expanded alongside renewable energy deployment. In 2025, the volume of electricity traded on the market nationwide reached 6.64 trillion kilowatt-hours, accounting for 64 per cent of total electricity consumption (China Electricity Council 2026). The development of markets such as medium- and long-term, spot and green electricity markets has led to electricity prices increasingly reflecting supply-and-demand dynamics, delivery time slots and regional conditions. The 2025 Notice on Deepening the Market-oriented Reform of Renewable Energy On-grid Pricing and Promoting High-quality Renewable Energy Development (Document No. 136) requires renewable generation, in principle, to participate in the electricity market and introduces a difference-settlement mechanism for eligible electricity volumes (National Development and Reform Commission and National Energy Administration 2025). This reform changes the revenue assumptions used in project valuation. Under relatively fixed feed-in tariffs, expected cash flow depended largely on generation volume, tariff levels, construction costs and financing terms. Market-based pricing adds generation timing, regional prices, mechanism coverage, contract structures and residual market exposure to the valuation process. This paper examines how national renewable energy pricing reform is translated through provincial electricity markets into project-level price, contract and settlement exposure. It then considers how these signals affect investment evaluation, revenue structures and asset operations.

1.2. Literature Review and Research Gap

Existing literature relevant to this study spans three areas: electricity market design, the market value of variable renewables, and renewable energy investment risk. Medium- and long-term contracts can reduce part of the price exposure faced by market participants, while day-ahead, real-time and balancing markets reveal supply, imbalance and system conditions at shorter timescales (Cretì and Fontini 2019). Joskow (2022) further points out that, under conditions of deep decarbonisation, stable arrangements supporting long-term investment can coexist with short-term market competition, with each fulfilling distinct functions such as investment support, dispatch, balancing and price discovery.

For wind and solar power, market value is not determined solely by annual generation or the average electricity price. Hirth (2013) shows that the market value of variable renewables depends on the alignment between generation profiles and market prices; when similar resources generate simultaneously, the additional supply can depress prices during those hours. Hirth *et al.* (2015) further show that variability gives rise to profile, balancing and grid-related integration costs, which become increasingly important as renewable penetration rises.

Investment research focuses on how these uncertainties enter project evaluation. Egli (2020) documents changes in renewable energy investment risk and its underlying drivers, while Salm (2018) shows that investors may value the same risks differently and reflect them through risk premiums, financing costs and required returns. Relevant studies in China have focused on electricity market reform, the effectiveness of provincial-level implementation, and investment in

renewable energy. Guo *et al.* (2020) discussed the development of China's electricity market reform and provincial-level pilot schemes since 2015; Li *et al.* (2025) assessed the economic impact of provincial-level electricity sector reform using Jiangsu as a case study; whilst Zhang *et al.* (2025) found that the impact of the transition to market-oriented policies on investment in renewable energy varies by region and technology.

These studies provide an important foundation for understanding China's electricity market reform and renewable energy investment. However, less attention has been paid to how national pricing reforms are translated through provincial market design into the prices, contracts and settlement exposures faced by individual projects, and how these factors affect value capture, cash flows and corporate decision-making. Provincial differences in market implementation make this issue particularly relevant in China. From a market-participant perspective, this paper links national institutions, provincial markets and corporate decision-making, focusing on how price signals affect project investment, settlement and asset operations.

1.3. Research Questions and Methodological Approaches

This paper addresses how national renewable energy pricing reform is transmitted through provincial electricity markets into project-level price, contract and settlement exposure, and how these signals reshape investment evaluation, revenue structures and asset operations. The study adopts a qualitative case-study design centred on China's market-oriented reform of renewable energy pricing. Shanxi, Shandong and Guangdong are used as illustrative provincial cases, supplemented by descriptive market-data analysis. The three provinces differ in renewable energy participation, price formation, contract arrangements and settlement rules. They are used to illustrate how a common national reform is implemented across different provincial markets, rather than to provide statistically representative national evidence.

Sources include national and provincial policy documents, electricity market rules, official statistics, market transaction data and anonymised project settlement materials. The market-participant perspective reflects the author's industry experience, while the analysis itself is based on documentary and market evidence.

The analysis uses 15-minute day-ahead and real-time prices from Shanxi, Shandong and Guangdong between 1 January and 30 June 2026 to examine price distributions, low and negative prices, intraday patterns and day-ahead–real-time deviations. For Shanxi and Shandong, where technology-specific generation data can be matched consistently, wind and solar capture-price proxies are also calculated. These data describe provincial price exposure; they are not used to estimate a national average or identify the causal effect of Document No. 136.

2. Renewable Energy Pricing Mechanisms and Price Signal Formation in China

2.1. From Fixed Support to Market-based Pricing

In the early stages of China's renewable energy development, the sector relied primarily on benchmark feed-in tariffs, guaranteed off-take arrangements and subsidy support. A resource-zone benchmark feed-in tariff was introduced for onshore wind in 2009, while the photovoltaic benchmark tariff framework was established between 2011 and 2013 (National Development and Reform Commission 2009, 2011, 2013). Under this framework, project revenue was relatively predictable and investment evaluation focused mainly on resource conditions, utilisation hours and costs.

From around 2019, renewable energy pricing began shifting from benchmark feed-in tariffs towards guidance prices, competitive allocation and grid parity. Grid-parity projects reduced their reliance on central subsidies, while project acquisition and pricing became more closely linked to bidding and cost competitiveness. From 2021, newly registered centralised PV, commercial and industrial distributed PV, and newly approved onshore wind projects were in principle no longer eligible for central subsidies, and their on-grid prices could be determined through market

transactions (National Development and Reform Commission and National Energy Administration 2019a; National Development and Reform Commission 2019b, 2019c, 2021).

Between 2019 and 2024, renewable energy projects were still not broadly exposed to short-term market prices. Competitive bidding increasingly affected project acquisition, while the benchmark price for coal-fired power continued to provide an important reference for revenue formation. Time-of-use prices, nodal prices and day-ahead–real-time deviations had not yet become standard inputs in project valuation. This period marked a transition from administratively supported pricing towards broader market exposure.

Table 1. Evolution of renewable energy pricing mechanisms and price signals in China.

Stage	Period	Dominant Pricing and Revenue Mechanisms	Revenue Characteristics	Key Considerations for Enterprises
Fixed Tariffs and Subsidy-driven Development	2009–2018	Resource-zone or project-specific feed-in tariffs, guaranteed purchase arrangements, and subsidy support	Unit revenues were relatively predictable, with income mainly determined by tariff levels and generation volumes	Resource conditions, utilisation hours, construction costs, financing costs, and subsidy payments
Transition through Guidance Prices, Competitive Allocation and Grid Parity	2019–2024	Guidance price caps, competitive project allocation, subsidy-free grid-parity projects, and partial market trading	Dependence on subsidies declined, while bidding prices and cost competitiveness increasingly affected project acquisition and revenue potential	Whether competitive bids could support profitability over the project life cycle while securing project development rights
Coexistence of Market Trading and Mechanism-based Settlement	2025–present	Market-based electricity prices, the renewable energy sustainable development price settlement mechanism, differentiation between existing and new projects, and provincial implementation rules	Part of project revenue is stabilised through mechanism-based settlement, while the remaining revenue is exposed to contracts, spot-market prices, and other market arrangements	Mechanism coverage, contract profiles, generation timing, nodal prices, residual market exposure, and risk-management capability

Source: Author's compilation based on policy documents issued by the National Development and Reform Commission and the National Energy Administration

2.2. The 2025 Reform and Provincial Implementation

China's electricity market operates under a national reform framework but is implemented largely at provincial level. National policy sets the overall direction for market construction and renewable energy pricing reform, while provinces specify medium- and long-term trading rules, spot-market arrangements, renewable energy participation models and settlement mechanisms. Regional price differentiation is not new, as benchmark feed-in tariffs already varied across provinces and resource zones. Market-based pricing, however, extends this differentiation within provincial markets. Projects in the same province may realise different prices and settlement outcomes because of their location, generation profile, contract position, mechanism coverage and other settlement adjustments. A provincial average price therefore does not necessarily represent the revenue actually realised by an individual project.

Document No. 136 requires renewable generation, in principle, to participate in the electricity market and uses 1 June 2025 as the cut-off date between existing and new projects. It also establishes

the renewable energy sustainable development price-settlement mechanism. Electricity covered by the mechanism continues to participate in market trading, with the difference between the mechanism price and the provincial market reference price settled separately (National Development and Reform Commission and National Energy Administration 2025). For developers, relevant revenue variables now include the mechanism price, coverage ratio, implementation period and remaining exposure to market prices.

Table 2. Illustrative provincial implementation of China's renewable energy pricing reform.

Dimension	Shanxi	Shandong	Guangdong
Mechanism arrangement	Existing centralised grid-parity projects retain transitional arrangements; new wind and solar projects compete separately	Existing projects follow provincial transitional arrangements; new projects enter competitive mechanism allocation	The 2025 auction covered distributed PV; mechanism price: RMB 0.360/kWh; term: 12 years
Market price exposure	Technology-specific real-time prices affect the mechanism reference price and revenue outside mechanism coverage	All renewable generation participates in the real-time market and is settled at 15-minute nodal prices	Price-taking projects are settled at real-time nodal prices
Medium- and long-term contracts	Mechanism-covered volume reduces the electricity available for independent medium- and long-term contracting	Mechanism volume is covered by mechanism contracts; other contracts specify delivery profiles and settlement reference points	Participation mode affects access to medium- and long-term trading; mechanism coverage reduces residual tradable volume
Green power and GECs	Mechanism-covered electricity cannot receive duplicate GEC revenue	Green power and GEC treatment follows provincial rules and interacts with mechanism coverage	Green power and GEC settlement volumes exclude mechanism-covered electricity

Source: Author's compilation based on provincial implementation schemes, market rules and Guangdong's 2025 auction results.

In Guangdong, the 2025 mechanism auction covered 11,588 distributed-PV projects with a combined capacity of 5,240 MW and 4.43 billion kWh of mechanism-covered electricity (Guangdong Power Exchange Center 2025a). Coverage ratios vary across projects, so the degree of revenue stabilisation depends on the volume covered by the mechanism.

2.3. Price Signals in China's Provincial Electricity Markets

To examine provincial price exposure, the analysis compares 15-minute day-ahead and real-time prices in Shanxi, Shandong and Guangdong from 1 January to 30 June 2026. Each series contains 17,376 observations across 181 days. Because pricing and settlement conventions differ across the three markets, the comparison focuses on price distributions, low and negative price frequency, real-time volatility and day-ahead–real-time deviations. Absolute price levels are not treated as directly comparable project settlement prices.

Table 3. Spot price characteristics in Shanxi, Shandong and Guangdong, January–June 2026.

Province	Day-ahead Mean Price (RMB/MWh)	Real-time Mean Price (RMB/MWh)	Real-time Price Standard Deviation (RMB/MWh)	Share of Negative Real-time Prices	Share of Real-time Prices Below RMB 50/MWh	Day-ahead–Real-time MAE (RMB/MWh)
Shanxi	236.4	240	225.3	0.00%	28.60%	50.7
Shandong	293.5	293.9	231.5	21.50%	23.60%	85.1
Guangdong	389.4	407.4	252.3	3.00%	4.90%	106.9

Note: MAE denotes the mean absolute error between day-ahead and real-time prices. Low-price periods are defined as real-time prices below RMB 50/MWh.

Source: Author's calculations based on provincial market data.

Table 3 shows three distinct forms of price risk: persistent low prices in Shanxi, frequent negative prices in Shandong, and greater real-time volatility and day-ahead–real-time deviations in Guangdong. A higher provincial average price therefore does not necessarily imply lower project risk. These differences reflect multiple factors, including generation mix, weather, load, inter-regional exchanges, grid constraints and provincial rules, and are not interpreted as causal effects of Document No. 136.

3. How Market Reform Reshapes Renewable Energy Investment, Revenue and Risk Exposure

3.1. Investment Decisions: From Resource Assessment to Market Value Assessment

During the 15th Five-Year Plan period, China's renewable energy policy continues to support capacity growth while placing greater emphasis on system integration, reliable output and market participation. The plans also call for improved market and pricing mechanisms (National Development and Reform Commission and National Energy Administration 2026a, 2026b).

Wind and solar output varies across multiple timescales, while forecast errors differ by season, time of day and forecast horizon (Zhu 2019, pp. 302-307). Because the timing of variable renewable generation cannot be adjusted freely in response to market prices, its market value depends on how the generation profile aligns with prices over the same periods. Even projects with similar annual utilisation hours may realise materially different market revenues if their generation output is concentrated in low-price and high-price periods, respectively. Resource conditions determine how much electricity a project can generate, while market conditions determine how much value that electricity can realise.

Under fixed feed-in tariffs, revenue per MWh was relatively predictable in project valuation. Enterprises typically assessed project NPV and IRR based on expected generation, resource conditions, construction and operating costs, and financing terms. Resource endowment, utilisation hours and cost control remained central to project valuation.

Market reform does not change the basic financial logic of NPV and IRR. What changes are the revenue assumptions used in the model. Once renewable electricity enters the market, project revenue is no longer based on a single fixed price applied to all generation. It is shaped by medium- and long-term contract prices, spot prices, the share of electricity covered by the mechanism, the reference price used for mechanism settlement, and actual generation profiles. For new projects in particular, mechanism prices and mechanism-covered volumes are increasingly determined through competitive processes. Investors therefore need to assess project cost competitiveness, the extent of revenue stabilisation and the remaining market exposure. Project valuation needs to move from "annual generation and an assumed price" towards "time-profiled output and corresponding prices",

while incorporating contract allocation, mechanism settlement, deviations and related market costs into the assessment of project cash flow.

This makes capture price relevant to project valuation. Hirth (2013) defines market value as the output-weighted wholesale price and the value factor as its ratio to the time-weighted average market price. Following this logic, this paper calculates provincial technology-level capture-price proxies using real-time prices and actual generation.

Table 4. Wind and solar capture price proxies in Shanxi and Shandong.

Province	Average Real-time Market Price (RMB/MWh)	Wind Capture Price (RMB/MWh)	Wind Capture Rate	Solar Capture Price (RMB/MWh)	Solar Capture Rate
Shanxi	240	224	93.30%	89.7	37.40%
Shandong	293.9	296.1	100.80%	112.6	38.30%

Note: Data cover 1 January–30 June 2026.

Source: Author's calculations based on provincial real-time market prices and technology-specific generation data.

Table 4 shows substantially lower capture rates for solar than for wind in both provinces. This is consistent with Hirth's (2013) finding that concentrated generation can depress prices during the hours in which it occurs. These indicators represent provincial technology-level price exposure rather than project-level settlement revenue, which also depends on nodal prices, contracts, mechanism coverage and operating conditions.

3.2. Revenue Logic: From a Single On-grid Tariff to a Constrained Revenue Portfolio

China's market-oriented renewable energy reform has increased the complexity of project revenue and changed how that revenue is formed and settled. Under fixed feed-in tariffs, revenue per MWh was largely determined by policy-set prices. Under market-based pricing, project cash flow may include market electricity revenue, mechanism-based difference settlements, environmental attribute value, other eligible market revenues and legacy policy revenue, while also being affected by deviations, market charges and other settlement adjustments. Renewable energy projects therefore face a revenue portfolio shaped by institutional rules, contracts and project status, rather than simply a larger number of revenue streams.

The anonymised project settlement materials reviewed in this paper also show that renewable energy settlement may involve medium- and long-term contracts, day-ahead and real-time markets, mechanism-based difference settlements, ancillary services, and adjustments for deviations, congestion, operational assessments and retrospective reconciliations. Final project cash flow cannot be estimated simply by multiplying actual electricity delivered to the grid by an average market price. It reflects the net result of market revenues after mechanism settlements and other adjustments.

These revenue streams cannot simply be added together. The provincial rules examined in this paper apply different deduction and linkage arrangements between mechanism-covered electricity and medium- and long-term trading, green power and GEC entitlements, in order to avoid double counting the same electricity volume or environmental attribute. A higher mechanism coverage ratio can stabilise a greater share of revenue, but it also changes how much of the remaining electricity is exposed to market prices and the scope for other transactions. For enterprises, the practical question is which revenues can be realised together, which are subject to entitlement constraints, and how much revenue under different combinations remains directly affected by market price fluctuations.

A project's policy vintage also affects its cash-flow structure. Within the same province, subsidised projects, competitively allocated projects, grid-parity projects, and existing and new projects under the 2025 reform may be subject to different forms of price support, mechanism coverage and project obligations. Projects facing the same market prices can therefore still have different net cash-flow

structures. Revenue analysis should first identify the project's policy vintage and then assess mechanism coverage, contract configuration and the extent to which revenue remains affected by market prices.

Technology-specific capture value also affects market electricity revenue. Institutional and contractual arrangements determine which revenues a project can receive, while the alignment between its actual generation profile and market prices affects how much value can be realised from market electricity sales. Table 5 summarises the main revenue and settlement components.

Table 5. Revenue and settlement components of renewable energy projects under market-based pricing.

Component	Formation and Role	Main Constraints
Market electricity revenue	Medium- and long-term contracts and day-ahead/real-time market settlement; provides core market revenue	Affected by generation timing, nodal prices, contract profiles and actual output
Mechanism-based difference settlement	Difference between the mechanism price and the provincial market reference price; stabilises revenue for mechanism-covered electricity	Depends on mechanism coverage, price, duration and provincial reference-price rules
Legacy policy and project-specific revenue	Historical subsidies, competitive allocation arrangements and other project-specific agreements; provides additional revenue for some existing assets	Depends strongly on project vintage; some projects may face repayment or revenue-sharing obligations
Green environmental value	Green power trading and Green Electricity Certificates (GECs); adds environmental value	May be subject to deductions or exclusivity with mechanism-covered electricity and other environmental attributes
Ancillary services and other market revenue	Peak regulation, frequency regulation and other eligible markets; provides supplementary revenue	Not available to all projects and may involve related cost allocations
Market settlement adjustments	Imbalance, congestion, market operation charges, excess-revenue recovery, operational assessments and retrospective adjustments; converts gross revenue into final net settlement revenue	Depends on provincial rules and operating conditions; may increase or reduce final cash flow

Source: Author's compilation based on national and provincial policy documents, electricity market rules and anonymised project settlement materials.

These revenue arrangements do not eliminate market risk. Contract prices, market prices and settlement rules can still affect final project cash flow through different channels.

3.3. Key Risks under Market-based Pricing

Projects first face price, volume and deviation risks. Provincial average prices do not fully capture project-level exposure because generation timing and nodal prices affect the value ultimately realised. At the same time, deviations between actual output, contracted volumes and market bids can affect cash flow across medium- and long-term, day-ahead and real-time markets (Cretì and Fontini 2019; Zhu 2019, pp. 302-307).

Projects also face nodal, contractual and institutional risks. Medium- and long-term contracts can stabilise part of project prices or revenues, but they do not fully remove locational price differences. Chen *et al.* (2023) show that congestion risk in generation-side medium- and long-term contracts depends on spot-settlement arrangements and the relationship between nodal prices and contract reference prices. Contract prices may therefore still differ from the prices ultimately reflected in project settlement. Mechanism coverage, reference prices, and the linkage rules governing medium-

and long-term trading, green power and GECs also affect how much project revenue is relatively stable and how much remains directly exposed to market prices.

These risks are not independent. Mechanism settlements and medium- and long-term contracts can cushion part of the revenue impact of falling spot prices. At the same time, a high average market price does not necessarily imply low risk: low capture value, forecast deviations or nodal price differences can still lead to substantial cash-flow volatility. These market, operational and institutional uncertainties ultimately affect both the level and predictability of future cash flows, and are reflected in project valuation and investors' required returns (Bhattacharyya 2019, pp. 161-166; Egli 2020; Salm 2018).

4. Commercial Implications and Corporate Responses

4.1. Asset Operations: From Generation Management towards Value Management

For renewable energy enterprises, as market prices begin to directly affect project cash flow, the objectives of asset operations also need to expand. Generation volume and equipment availability remain fundamental, but project management can no longer focus only on "generating more electricity". Enterprises also need to consider when electricity is produced, through which contracts and market arrangements its value is realised, and how production conditions and trading decisions jointly affect final cash flow. Asset performance assessment therefore needs to look beyond generation volume, equipment availability and O&M costs to include capture prices relative to market benchmarks, curtailment losses, deviation and assessment costs, contract coverage, and the reasons why actual revenue differs from budget. Renewable energy asset operations are therefore extending from production-indicator management towards a common revenue perspective, with performance ultimately assessed by the revenue per MWh and net cash flow actually realised by the project.

Value management for renewable energy assets needs to cover the full process of investment, construction, production, trading and settlement. Trading is not the starting point of project value creation. The amount of electricity and the risks that can be managed through trading are already constrained by project development, grid-connection conditions, equipment status, maintenance, curtailment and forecasting quality. If problems arising from project design or operation have already caused unrecoverable generation losses or output deviations that are difficult to adjust before trading decisions are made, the scope for trading to recover value is usually limited. Even when average market prices are relatively high, persistent curtailment, equipment failures or forecasting errors can still leave actual cash flow well below investment expectations. Trading capability cannot substitute for asset quality; it can only be effective when production, data and organisational coordination are able to support market participation. The main risks faced by a project also change over its life cycle, with construction and operation potentially involving different sources of risk (Ding *et al.* 2021). Project evaluation should therefore not stop at a one-off pre-investment assessment, but should extend to continuous revenue management after commissioning.

4.2. Corporate Responses in Investment, Trading, and Risk Management

On the investment side, IRR under a single base-case scenario is no longer sufficient to describe the full risk–return profile of a project. Zhang *et al.* (2022) show that different policy scenarios can change the investment value, risk level and portfolio choice of different generation technologies. In addition to traditional NPV and IRR analysis, enterprises need to use sensitivity analysis and stress scenarios to test how changes in market prices, capture value, mechanism coverage, contract structures and costs affect project cash flow. The required return of a project should also reflect its own risk characteristics, rather than relying mechanically on a uniform cost of capital or hurdle rate (Bhattacharyya 2019, pp. 161-166). Price, contract and operational risks vary across provinces and

technologies. National renewable energy enterprises therefore cannot apply exactly the same market and revenue assumptions to every project.

On the operations and trading side, risk management should not focus only on expected returns. Xiao *et al.* (2023) use VaR, CVaR and loss probability to measure tail risk in stochastic trading for a wind-storage system. Their study shows that market participants with different risk preferences may adopt different trading strategies. For renewable energy enterprises, the allocation of electricity between medium- and long-term contracts and the spot market needs to consider both expected returns and the downside risk that the enterprise can bear. Market-based operations also place greater demands on multi-timescale forecasting and production–trading coordination. Pinson (2013) points out that the value of wind power forecasting depends not only on forecast accuracy, but also on whether it can support specific trading and operational decisions at the relevant timescale. Production–trading coordination has at least three dimensions. Information coordination ensures that production conditions are reflected in market decisions in time. Strategy coordination allows changes in production conditions to be translated into contract or bid adjustments within the trading window. Revenue coordination uses final project cash flow as a common measure of operating performance, rather than relying on separate indicators for production and trading teams.

Production information has clear time value. If information on maintenance, equipment failures, curtailment or output changes reaches decision-makers before the trading window closes, enterprises may still reduce part of the risk through contract or market adjustments. If the same information becomes available only after the window has closed, the physical change is more likely to result in deviations and settlement losses. From a management perspective, this coordination should continue through project evaluation, operational trading and post-settlement review. Before investment, price, contract and operational risks should be identified and included in revenue assumptions. During operation, trading decisions should be adjusted according to forecasts, actual output and equipment conditions. After settlement, actual cash flow should be compared with the budget. Differences can then be attributed to generation volume, equipment availability, curtailment, capture price, contract allocation, forecast errors, trading execution, mechanism settlement and other market charges. Revenue attribution should establish a traceable link between production conditions, market conditions, strategy choices and final outcomes. The results can then feed into the next cycle of investment and operational decisions.

Digital capabilities should support this operating cycle. *The Renewable Energy Development Plan for the 15th Five-Year Plan Period* calls for improvements in power forecasting, market operations and trading capabilities, and for the use of artificial intelligence to improve market decision-making efficiency. Digitalisation needs to be built on stable coordination processes and clear responsibilities. On this basis, production and market data can support power forecasting, electricity price analysis, strategy optimisation, deviation monitoring and revenue attribution. AI can improve information processing and decision-making efficiency, but it cannot replace an understanding of market rules, risk control or operational governance.

4.3. Project Selection and Business Models under Regional Differences

Renewable energy projects face clear regional differences in market risk. Project screening should therefore consider not only resource conditions and construction costs, but also how well resource conditions match the market environment and contract structure. Based on a study of 29 Chinese provinces and municipalities, Dong and Shi (2019) show that regional absorption capacity and wind curtailment can affect wind project performance. Under market-based conditions, project evaluation can be further understood as an assessment of the fit between resources, markets and contracts.

Existing and new projects differ in mechanism prices, mechanism-covered volumes and implementation arrangements. The share of relatively stable revenue therefore also differs. Document No. 136 uses 1 June 2025 as the cut-off date between the two groups. When evaluating existing assets and new investments, enterprises need to consider policy vintage, mechanism

coverage and contract structure separately. Stronger market price signals increase the potential value of flexibility resources and long-term contracts. The temporal variability, uncertainty and network constraints of variable renewable energy increase the system's need for flexibility (Hirth *et al.* 2015). Storage can shift the timing at which part of the electricity enters the market. Long-term PPAs can stabilise part of project revenue. Virtual power plants and aggregation models provide a route for distributed resources to participate in the market. Long-term contracts can also coexist with competitive markets that provide short-term price discovery (Joskow 2022).

Combining storage, PPAs and virtual power plants does not necessarily increase project returns. The value of storage depends on price spreads, efficiency, cycling frequency, equipment costs and market rules. The value of a PPA depends on contract price, duration and risk allocation. The data in this paper only show that price volatility and differences in time-specific value increase the potential value of flexibility and contract management. They do not demonstrate that storage, PPAs or virtual power plants generate positive incremental returns for every project.

5. Price Signal Transmission and the Hybrid Transition of China's Renewable Energy Market

5.1. Framework for Price Signal Transmission

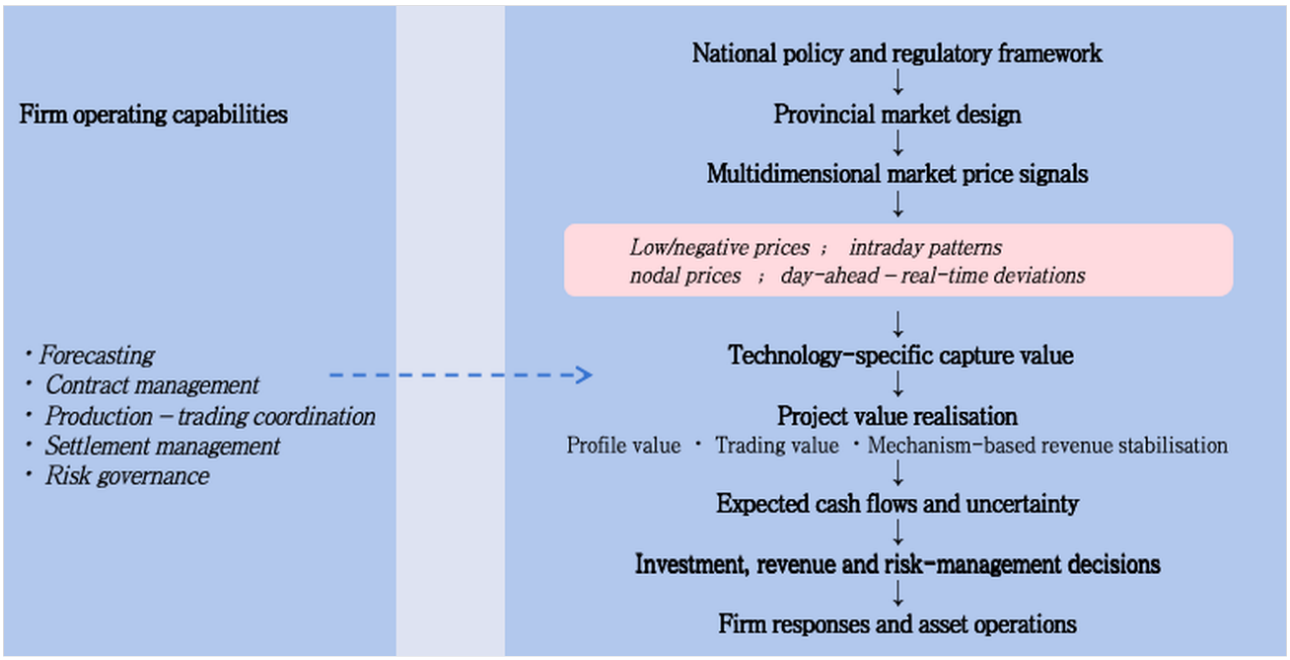

Figure 1. Price-signal transmission framework for renewable energy investment and operations in China (Source: Author's conceptual framework).

This paper proposes the price-signal transmission framework shown in Figure 1. National renewable energy pricing reforms are first translated through provincial market design into specific price, contract and settlement arrangements. These arrangements then generate market signals related to time of day, location, low or negative prices, and day-ahead–real-time deviations. For wind and solar power, these price signals need to be considered together with actual generation profiles to determine technology-specific capture value. A uniform national reform therefore does not directly produce uniform project revenue outcomes. Provincial market design and technology-specific generation characteristics are important links through which institutional change is transmitted to project value.

At the project level, technology-specific capture value reflects the basic price exposure created by the relationship between generation profiles and market prices. Final cash flow, however, is also

affected by profile value, trading value and institutional arrangements that stabilise part of project revenue. In this paper, trading value refers to the value created or retained through contract allocation and market participation when enterprises manage price and volume risks. Institutional revenue stabilisation refers to arrangements such as the renewable energy sustainable development price-settlement mechanism, which can reduce fluctuations in part of project revenue. Enterprise capabilities in forecasting, contract management, production–trading coordination, settlement management and risk governance further affect whether these potential sources of value are ultimately reflected in actual cash flow. The framework therefore focuses on how price signals pass through market design, project characteristics and enterprise capabilities before affecting investment and operational decisions.

5.2. The Hybrid Transition of China's Renewable Energy Market

China's current renewable energy market reform has expanded the scope of market-based price formation, but has not eliminated revenue stabilisation arrangements. Spot and medium- and long-term markets now play a greater role in price discovery and contract allocation, while the renewable energy sustainable development price-settlement mechanism buffers revenue fluctuations for part of the electricity generated. As renewable energy costs declined, China's renewable energy pricing had already begun to shift from fixed support towards competitive price formation (Zhao *et al.* 2022). The 2025 reform further increases the influence of market pricing on project revenue, while project cash flows remain shaped by market prices, contracts and mechanism arrangements. This paper characterises this institutional arrangement as a hybrid transition in which market-based price discovery coexists with revenue stabilisation mechanisms. The provincial cases show that this hybrid transition takes different forms under a common national framework, leaving projects with different combinations of market and institutional risk. From a governance perspective, this also reflects a shift in the boundary between government and market roles. The government is gradually moving from directly setting renewable energy on-grid prices towards setting market rules and revenue stabilisation mechanisms, while the market plays a greater role in price discovery and resource allocation.

5.3. Policy and International Implications

As market exposure for renewable energy increases, policy attention should extend beyond average price levels to the clarity of price signals and revenue rules. The design of high-share renewable electricity markets simultaneously involves short-term price formation, market integration, contractual arrangements, and flexibility resources (Newbery *et al.* 2018). For investors, regulatory continuity, medium- and long-term market liquidity, and transparency of spot and settlement data all affect whether price signals can inform long-term investment decisions. At the same time, clear boundaries regarding rights and deductions need to be established among mechanism-covered electricity, medium- and long-term contracts, green power, and green certificates, so that investors can identify which revenues are stable, which can be combined, and which remain subject to market risk.

National market integration does not require provincial market designs to be identical. Pollitt and Anaya (2016), in their comparison of Germany, the UK, and New York State, show that under the common goal of increasing renewable energy shares, different electricity systems may adopt different reform paths based on their existing structures and system conditions. The provincial variation in China similarly suggests that a unified national market calls for coordination of basic trading rules, information standards, and inter-provincial trading mechanisms, rather than requiring provinces to produce identical price and risk structures.

From an international perspective, the Chinese experience relates to a question that is not unique to China: how to strengthen market price signals while maintaining the bankability of capital-intensive low-carbon investments. The UK's Electricity Market Reform also places competitive

markets alongside long-term arrangements for low-carbon investment (Grubb and Newbery 2018), echoing Joskow's (2022) analysis that short-term markets and long-term investment mechanisms can coexist. The specific institutional designs in China are different, but the experience suggests that for economies still in the process of building electricity markets, marketisation does not necessarily require the one-off elimination of all revenue stabilisation mechanisms. The key lies in whether stabilisation arrangements can establish clear and predictable boundaries with market price signals.

This paper has three main limitations. First, the market data cover only the first half of 2026, and the rules and price definitions across the three provincial markets are not fully consistent. The results are intended to identify price exposure rather than long-term trends or strict cross-provincial comparisons. Second, the capture prices are proxy indicators at the provincial technology-type level, and the descriptive design of this paper cannot identify the causal impact of Document No. 136. Third, due to the lack of project-level cost, financing, contract, and operational data, this paper cannot directly test the project-level profitability of business models such as storage, PPAs, or virtual power plants. Future research could incorporate longer time series and project-level cash flow data to further examine the relationships among price signals, capture values, and investment behaviour.

6. Conclusion

The analysis shows that China's renewable energy marketisation involves more than a change in on-grid pricing. Project value increasingly needs to be realised through the market. National-level price reforms are translated through provincial market rules into different time-of-day prices, contractual arrangements, mechanism coverage and settlement outcomes. As a result, resource conditions and installed capacity still determine the physical foundation of a project, but they can no longer explain its economic performance on their own. The alignment of generation profiles with market prices, contract allocation and project exposure to market prices now jointly determine the actual value that renewable energy assets can realise.

This shift extends the economic evaluation of renewable energy projects from pre-investment estimation to the entire operating cycle. Investment decisions need to more fully account for price and revenue uncertainties. Revenue management needs to identify the constraints among different market and mechanism arrangements. Operations management needs to integrate production status, forecasting, trading, and settlement into a unified cash-flow perspective. For renewable energy enterprises, competitive advantage no longer stems solely from project acquisition, resource conditions, and construction costs; it increasingly depends on the ability to continuously identify and manage value erosion and revenue opportunities for assets in the market. The prerequisite for price signals to truly take effect is that enterprises can translate them into investment, contracting, production, and trading decisions.

From a broader market-design perspective, the Chinese case suggests that renewable energy marketisation does not necessarily mean that all projects are fully exposed to short-term market prices. As the price-discovery function strengthens, some revenue stabilisation arrangements still serve the function of managing long-term investment risks, and the specific allocation of risks is further influenced by provincial market designs. This institutional combination indicates that the key to renewable energy market reform is not a simple choice between marketisation and revenue stabilisation, but rather enabling price signals to enter investment and operational decisions while maintaining the predictability needed for long-term capital formation.

Declarations

Author contributions. Qianya Duan: Conceptualization, Methodology, Investigation, Formal analysis, Data curation, Writing (original draft), Writing (review and editing), Visualization, Validation, Project administration.

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