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An Appraisal on China's Feed-In Tariff Policies for PV and Wind Power: Implementation Effects and Optimization

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Abstract: AbstractsChina's FIT policies for PV and wind power are leading policies to promote the low-carbon transformation of the power system. We design composite models based on real options and the cost–benefit analysis, using the Evaluation Model of Implementation Effects and the Optimization Model for Policy Design to evaluate the design and implementation effects of FIT policies for PV and wind power. The results of the Evaluation Model of Implementation Effects are the following: (1) The economic and environmental competitiveness of developing PV and wind power projects under the parity policy raised significantly (2.524 to 3.136 times increase). (2) The last two-phase FIT policies fail to encourage power generation enterprises to carry out R&D activities, and supporting policies can be considered to offer incentives for R&D activities in upstream industries of power generation. (3) The substitution effect of green certificates on government subsidies is limited, and new market compensation mechanisms such as CCER can be introduced nationwide. The results of the Optimization Model for Policy Design are the following: (1) There is still space for a 10.306% to 22.981% reduction in feed-in tariffs during the parity policy. (2) Due to the risk of the mismatch in the cost attribute and uneven investment across regions, the parity policy is not suitable for long-term implementation, so the feed-in tariffs for PV and wind power should progressively be disconnected from feed-in tariffs for thermal power.

Keywords: feed-in tariff policies; photovoltaic power; wind power; real options; dynamic recursive

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1. Introduction

1.1. Research Background

The feed-in tariff policies for PV and wind power have been placed at the core of China's policy framework for the development of renewable energy, and price signals released through FIT policies incessantly support the sustainable growth of the green power market by stabilizing the expected return for power-generating projects. Since the FIT policies for PV and wind power directly affect the investment in incremental projects and the R&D activities of PV and wind power generation enterprises, and indirectly influence the business activities in associated supply chains, the design and implementation effects of FIT policies for PV and wind power have extensive research significance.

China's FIT policies for PV and wind power have undergone a metamorphosis from the benchmark price to the guiding price and finally reached price parity. Before 2019, PV and wind power industries were in their growing phases. Under the benchmark price policy, PV and wind power projects received preferential treatment in feed-in tariffs and strong support from government subsidies. As a result, the installed capacity of PV and wind power delivered spectacular growth within a decade. By July 2019, the NDRC (National Development and Reform Commission) and NEA (National Energy Administration) proclaimed that feed-in tariffs for stock projects of PV and wind power changed from benchmark price to guiding price [1,2]. By August 2021, feed-in tariffs for PV and wind power had essentially fulfilled the requirements for the elimination of subsidies and parity with the feed-in tariff of thermal power (NDRC and NEA, 2019) [3]. Hence, the NDRC stopped funding incremental projects and instituted the parity policy, adjusting feed-in tariffs to the same level as the feed-in tariff of thermal power, and they subsequently announced that the parity policy will continue in 2022.

So far, academia usually separately discusses the problems related to PV and wind power FIT policies such as the price verification [4], the design of the price formation mechanism [5], the adjustment of subsidy sources [6,7], and the impacts of policy changes on project investment and the advancement in power generation technology [8]. However, for the following three reasons, we believe that it would be more reasonable to combine the FIT policies of PV and wind power as the research object.

(1) The targets of the adjustment of feed-in tariffs of PV and wind power are consistent: both are reducing feed-in tariffs until they are equal to or less than the feed-in tariff of thermal power [9,10].

(2) The evolution patterns of the price formation mechanisms of FIT policies for PV and wind power are consistent, which have both experienced the transition from the benchmark price to the guiding price, and finally turned to price parity at the same time.

(3) Generation costs of PV and wind power have highly similar compositions, and the development maturity of the two power generation technologies is also relatively similar, which satisfies the feasibility of a merger discussion.

Based on the above considerations, we design appraisal models to find out and discuss the problems faced by PV and wind power FIT policies in the process of implementation and optimization.

1.2. Literature Review

Scholars widely hold a point of view that when PV and wind power industries achieve "grid parity", i.e., the generation costs of PV and wind power drop to levels comparable to that of thermal power, the era of the parity reform for PV and wind power will be expected to come [11]. However, the research priorities are vastly different when it comes to assessing the implementation effects of the development policies for PV and wind power.

1.2.1. Evaluative Dimensions

The existing literature emphasized the measurement of the economic and environmental contribution of development policies and tabled ideas and suggestions for future optimization. Boqiang Lin (2014) claimed that to promote the long-term development of wind power generation technology and carbon emissions reduction in the power generation sector, China should set higher feed-in tariffs for wind power during the period of the benchmark price policy [12]. Zhang et al. (2020) attempted to measure the unsubsidized unit profits (UUPs) of PV projects in 335 Chinese cities under the government-regulated and market-oriented mechanisms of FIT policy to determine which mechanism has greater economic and environmental performances throughout the whole nation and when the grid parity for PV power projects can be achieved [9]. To promote technological advancement and the reduction in generation costs of renewable energy, Rong Wang [13] and Karneye et al. (2017) suggested that a relatively stable policy environment and mechanisms may be conducive to the further growth of investment in PV power and minimize the cost of electricity to society [14]. In general, the existing literature focused on measuring and comparing the contribution of different development policies for renewable energy in promoting grid parity and the growth in installed and generating capacity. However, few studied the following two topics, which were closely related to the objectives of policy implementation. Firstly, we will verify whether the substitution effect of the market-oriented compensation mechanisms (e.g., green certificates and carbon emissions rights) on government subsidies has been improved. Secondly, we will examine how the level and pricing mechanism of the feed-in tariffs affect the R&D activities, maintenance and renovation of fixed assets in the power generation enterprises.

1.2.2. Research Methods

Scholars mostly applied qualitative or quantitative analysis methods to evaluate the implementation effects of development policies for renewable energy. Among the qualitative analysis studies, Schuman et al. (2010) compared China's policy framework for renewable energy to those of the EU and the US, and they put forward proposals such as introducing a preferential scheduling policy for market-oriented transactions [15]. Sahu et al. (2018) presented an overview of development policies for China's wind power industry and then pointed out the bottlenecks that restricted the development of this industry [16]. However, applying qualitative analysis methods exclusively would weaken the comparability of the contribution of different policies, and the conclusions would be somewhat subjective. So complementing with quantitative analysis methods can effectively compensate for these limitations.

Among quantitative analysis studies, Maroušek et al. (2014) applied the NPV approach to determine whether the EU's renewable energy subsidies can raise the return on investment in power-generating projects [17]. Kai Chang (2015) put forward an estimating technique based on cost–benefit analysis which is used to value the economic benefits generated by renewable energy subsidies [18]. Biondi et al. (2015) and Qing et al. (2016) treated the decisions of investing in renewable energy projects as problems of executing call options [19,20], and they tested the effectiveness of development policies by constructing a real options model. In general, when dealing with dynamic uncertainties, a single quantitative evaluation technique tends to underestimate the contribution of policies in part because of overlooking the fact that objects of policy implementation are entitled to decide to "exercise the option" or "defer exercising the option" according to expected returns. To address these inadequacies, it would be imperative to develop composite methods that incorporate various quantitative analysis techniques.

1.3. Research Gap and Contributions

In light of the aforementioned considerations, we design policy appraisal models that are widely applicable to FIT policies for renewable energy. For the state, these models are referential in the evaluation of implementation effects and the optimization of policy design. For power generation enterprises and their upstream supply chains, these models also help form investment decisions on incremental projects and R&D activities. The following three contributions are made by this research.

Firstly, to deal with dynamic uncertainties in the evaluation of policy implementation effects and fill the gap in existing research, we utilize a composite method based on real options and the cost–benefit analysis to examine whether the FIT policies can effectively encourage power generation enterprises to invest in R&D activities.

Secondly, to examine whether the levels of feed-in tariffs are optimal and help form policy optimization ideas, we apply the dynamic recursion solution to test whether the feed-in tariffs of PV and wind have reached the level that maximizes the implementation effects; then, we estimate the floating range of feed-in tariffs in the future according to the optimal feed-in tariffs under multi-scenario and multi-objective frameworks.

Thirdly, to fill the gap in the existing research on the topic of examining the substitution effect of market compensation mechanisms for government subsidies, we measure and analyze the substitution effect of green certificates on government subsidies, and we table suggestions for increasing the diversity of the market compensation mechanism and improving the transmission efficiency of the environmental value of PV and wind power.

2. Materials and Methods

In this section, based on the policy documents and the results of the literature review, we first screen out the key factors that affect the implementation effects of FIT policies and their influence scope. Then, according to the main assumptions and evaluation objectives, the design of assessment elements and the specification of the appraisal models are completed step by step.

2.1. The Influencing Factors

Based on the policy documents issued by the NDRC and NEA, and the achievements outlined in the existing literature, we screen out the following eight factors which primarily influence the implementation effects of FIT policies in economic and environmental terms, and these are shown in Table 1.

Table 1. Critical factors influencing the implementation effect of FIT policies for PV and wind power.

Influencing Factors	Screening Basis of Influencing Factors	Influencing Range
Feed-in tariffs for PV and wind power	As core contents of FIT policies, the level of feed-in tariffs and the price formation mechanism will directly affect the investment and operation activities of PV and wind power enterprises [2,3], thus affecting the economic benefits generated by FIT policies.	Economic contribution generated by FIT policies
The price formation mechanism of feed-in tariffs		
The generation cost of PV and wind power	As the basis for the update and adjustment of FIT policies, the declining trend in the generation cost of PV and wind power provides the space for the reduction in feed-in tariffs and the opportunity for the price formation mechanism to carry out the de-subsidized reform.	
The generation cost of thermal power	Thermal power is the main guaranteed power supplied in China at present. The difference between the generation cost of thermal power and the generation cost of PV and wind power will affect the design of the price formation mechanism of FIT policies and the verification of feed-in tariffs, thus indirectly affecting the benefits generated by FIT policies in economic terms.	
R&D investment in PV and wind power generation enterprises	The smooth conversion of R&D investment will help PV and wind power enterprises reduce the generation cost [21], thereby creating room for reduction in feed-in tariffs and influencing the economic contribution of FIT policies.	
Power generating demand for PV and wind power	Generating demand for PV and wind power will influence power producers' investment decisions, generation costs, carbon emission reduction costs, as well as the level and price formation mechanism of the feed-in tariff, and other factors that affect the economic and environmental contribution of FIT policies.	Economic and environmental contribution generated by FIT policies
Costs of carbon reduction in the power sector	The development of PV and wind power generation technologies will help reduce the overall expense of carbon emission reduction in the power industry and increase the benefits of FIT policies in terms of environmental protection.	Environmental contribution generated by FIT policies
Subsidies for PV and wind power generation	Subsidies for PV and wind power generation are important carriers to reflect the environmental value of PV and wind power [22]. As core elements of the FIT policy, the source and intensity of subsidies for PV and wind power will influence the environmental contribution of the FIT policy [23,24].	

2.2. Assumptions

The appraisal on the implementation effects of FIT policies is based on the following four assumptions in Table 2.

2.3. Assessment Elements and the Structure of the Appraisal Models

According to the selected influencing factors and their influence scope in Table 1, influencing factors are grouped into two kinds of assessment elements of *Net Economic Benefits* and *Net Environmental Benefits*, and we regard the value of *Net Comprehensive Benefits* as the sum of these two main elements. The allocation of each influencing factor is shown in Table 3.

Table 2. Assumptions and basis.

Assumptions	**Basis**	
Target policies	The guiding price policy and the parity policy.	
Implementation periods	Guiding price policy (July 2019–July 2021)	The *Notice on Improving the Feed-in tariff Policy for Wind Power* and the *Notice on Issues Related to Improving the Feed-in Tariff Mechanism for Photovoltaic Power Generation* both have been implemented since 1 July 2019.
	Parity policy (August 2021–August 2023)	The *Notice on Matters Related to China's Feed-in Tariff Policy For New Energy in 2021* has been implemented since 1 August 2021, and a follow-up document on the continued implementation of the parity policy was issued in April 2022. Considering the guiding price policy and the parity policy are both for transitional adjustments, we assume that the implementation period of the parity policy will last 2 years, the same as the guiding price policy.
The object of policy implementation	Assume centralized PV and onshore wind power projects as the object of policy implementation.	
Pricing formation mechanism	To emphatically examine the macro-regulatory effects of the FIT policies, we assume the government-regulated FIT as the only price formation mechanism in the following discussion.	

Table 3. Assessment elements of the appraisal models on the implementation effects of the FIT policies.

Factors Influencing the Implementation Effects of FIT Policies for PV and Wind Power	**Assessment Elements of the Appraisal Models**	
Feed-in tariffs for PV and wind power The price formation mechanism of feed-in tariffs The generation cost of PV and wind power The generation cost of thermal power R&D investment in PV and wind power generation enterprises	*Net Economic Benefits*	*Net Comprehensive Benefits* = *Net Economic Benefits* + *Net Environmental Benefits*
Power-generating demand for PV and wind power	*Net Economic Benefits* and *Net Environmental Benefits*	
Costs of carbon reduction in the power sector Subsidies for PV and wind power generation	*Net Environmental Benefits*	

To enable the appraisal model to play a role in the process of policy design, implementation and optimization, we believe that a systematic model for policy evaluation needs to achieve the following two goals: Firstly, evaluate whether the implementation effect of the existing policy has been improved compared with the previous one. Secondly, evaluate whether the existing policy is suitable for continued implementation in the future and put forward ideas for optimizing policy design.

Accordingly, we design the Evaluation Model of Implementation Effects and the Optimization Model for Policy Design, respectively, to meet the above two types of evaluation requirements. To fill the research gap in this field, we also add other evaluation objectives in the following two models, as presented in Table 4.

2.4. Specification of the Appraisal Models

As the allocation of influencing factors shown in Table 3, the Evaluation Model of Implementation Effects consists of two main elements: *Net Economic Benefits* and *Net Environmental Benefits*, regarding the value of *Net Comprehensive Benefits* as the sum of these two main elements.

2.4.1. Evaluation Model of Implementation Effects

Net Economic Benefits

Net Economic Benefits is to measure the overall economic contribution of FIT policies. It can determine whether the price signals released by FIT policies can present positive effects in economic terms. If the results of *Net Economic Benefits* are positive, that means the target policy has a competitive advantage to encourage the development of PV and wind power projects in economic terms.

Table 4. The structure and critical evaluation objectives of the appraisal models.

The Structure and the Critical Objectives of Appraisal Models	Evaluation Objectives	
Evaluation Model of Implementation Effects: to evaluate whether the implementation effect of the current policy has been improved compared with the previous policy	1	Identify which FIT policy is more conducive to promoting the development of PV and wind power [25], according to the results of *Net Comprehensive Benefits*.
	2	Compared with traditional thermal power generation, test whether PV and wind power projects have greater economic competitiveness under the support of the last two-phase FIT policies.
	3	Analyze the impact of the last two-phase FIT policies on the R&D activities of PV and wind power generation enterprises.
	4	Assess the substitution effect of the market compensation mechanisms on the government subsidy during the last two-phase FIT policies.
	5	Assess the curbing effect of carbon dioxide emissions brought by the last two-phase FIT policies.
Optimization Model for Policy Design: to evaluate whether the existing policy is suitable for continued implementation in the future and put forward ideas for optimizing policy design.	1	By calculating the optimal feed-in tariffs under a multi-scenario and multi-objective framework, test whether the existing feed-in tariff has reached the level of maximizing implementation effects, and estimate the room for the price reduction in the future.
	2	Analyze whether the existing pricing mechanism is suitable for long-term implementation and put forward corresponding suggestions for policy optimization.

The function of *Net Economic Benefits* can be divided into three parts; the variables and parameters are presented in Table 5. The composition and formulas are shown in Tables 6 and 7.

Table 5. Variables and parameters in *Net Economic Benefits*.

Variables	Meanings
$V_{ec}(k,i,r)$	Net economic benefits of FIT policies for PV and wind power at No.k period: after r times of R&D investment and i times escalation in the generation cost of thermal power (billion CNY)
$p_{wp}(k)$	Weighted average feed-in tariff of PV and wind power at No.k period (CNY/kWh, value-added tax included)
$C_{wp}(k,r)$	Weighted average costs of PV and wind power at No.k period: after r times of R&D investment (CNY/kWh)
$C_t(k,i)$	The generation cost of thermal power generation at No.k period: after i times escalation in costs (CNY/kWh)
$G_{wp}(k)$	Generating capacity of PV and wind power at No.k period (kWh)
$I_{w/p}(k)$	Cumulative installed capacity of PV/wind power at No.k period (kw)
$-R$	R&D investment (billion CNY)
Parameters	**Meanings**
α	Discount rate
f	Probability of the escalation in the generation cost of thermal power
k	Number of the implementation period of FIT policies (years)
r	Cumulative number of R&D investments (times)
i	Cumulative number of the escalation in thermal power costs (times)
T	Total implementation periods of FIT policies (years)
p_{wp}^{g}	Weighted average feed-in tariff of PV and wind power during the guiding price policy (CNY/kWh, value-added tax included)
p_{wp}^{p}	Weighted average feed-in tariff of PV and wind power during the parity policy (CNY/kWh, value-added tax included)

Table 6. The composition of *Net Economic Benefits*.

$V_{ec}(k,i,r)$	Meanings
Economic Earnings	*Economic Earnings*, i.e., the comparative returns contributed by the development of PV and wind power industries compared to that of the thermal power industry. In particular, when $C_t(k,i)$ values are higher than $C_{wp}(k,r)$, the substitution effect of PV and wind power projects on thermal power projects will bring positive economic benefits to China. In contrast, when $C_t(k,i)$ values are no more than $C_{wp}(k,r)$, the increase in the generating capacity of PV and wind power will raise the overall expenses of power consumption, bringing negative economic benefits for the country and weakening the economic attractiveness of PV and wind power projects.
Economic Costs	*Economic Costs* of FIT policies can be measured by the economic profit earned by the power generation projects under the guidance of FIT policies. For power generation enterprises, the economic profit depends on the difference between the revenue and the costs regulated and influenced by FIT policies. From another point of view, the economic profit earned by power generation enterprises can be understood as the costs paid by the state to obtain a stable electricity supply by introducing the FIT policies. Therefore, we defined economic profit for PV and wind power projects as the *Economic Costs* of FIT policies.
The PV of Future Net Economic Benefits	*The Present Value of Future Net Economic Benefits* will be expressed as the cumulative discounted value of the *Net Economic Benefits* over the remaining implementation period.

Table 7. The composition of the function of *Net Economic Benefits*.

$V_{ec}(k,i,r)$	Corresponding Formulas
Economic Earnings	$(C_t(k,i) - C_{wp}(k,r))G_{wp}(k)$
Economic Costs	$-(p_{wp}(k) - C_{wp}(0,0))G_{wp}(k)$
The PV of Future Net Economic Benefits	$\alpha\{fV_{ec}(k+1,i+1,r+1) + (1-f)V_{ec}(k+1,i,r+1)\}$

As Formula (1), we can solve the Net Economic Benefits $V_{ec}(k,i,r)$.

$$\begin{gathered} V_{ec}(k,i,r) = (C_t(k,i) - C_{wp}(k,r))G_{wp}(k) - (p_{wp}(k) - C_{wp}(0,0))G_{wp}(k) \\ +\alpha\{fV_{ec}(k+1,i+1,r+1) + (1-f)V_{ec}(k+1,i,r+1)\} \end{gathered} \tag{1}$$

Considering that the investment in R&D is an expenditure that is not necessarily incurred and the power producers are entitled to choose whether and when to invest, we draw on the idea of real options and assume that the market of PV and wind power needs to make the decision of "invest in R&D" or "not invest in R&D" at the beginning of every implementation period. If the market chooses to "invest in R&D" at No. k period, a cost reduction can be realized in the No. $k+1$ period. Meanwhile, the expenditure of investment R can also be saved if the market collectively chooses "not to invest in R&D". Generally, the decision depends on which option can result in greater *Net Economic Benefits*. Accordingly, Formula (1) can be optimized into Formula (2).

$$V_{ec}(k,i,r) = \max\left\{\begin{gathered} -R + (C_t(k,i) - C_{wp}(k,r))G_{wp}(k) - (p_{wp}(k) - C_{wp}(0,0))G_{wp}(k) \\ +\alpha\{fV_{ec}(k+1,i+1,r+1) + (1-f)V_{ec}(k+1,i,r+1)\}, \\ (C_t(k,i) - C_{wp}(k,r))G_{wp}(k) - (p_{wp}(k) - C_{wp}(0,0))G_{wp}(k) \\ +\alpha\{fV_{ec}(k+1,i+1,r) + (1-f)V_{ec}(k+1,i,r)\} \end{gathered}\right\} \tag{2}$$

Since Formula (2) includes 4 dynamic parameters ($C_t(k,i)$, $C_{wp}(k,r)$, $G_{wp}(k)$ and $p_{wp}(k)$) which cannot be directly calibrated by inputting historical data, it is necessary to set corresponding functions to simulate the changes in the above parameters.

(1) Generation Cost of thermal power generation $C_t(k,i)$

Considering that the fluctuation in the coal cost is inevitably transferred to the generation cost of thermal power, therefore, it is necessary to take the risk that arises from price fluctuation in the coal cost into account when measuring $C_t(k,i)$. In a market where coal prices continue to rise for a long period, provincial and municipal governments will subsidize the losses of thermal power plants in addition to benchmark feed-in tariffs. According to this, we use the mechanism of "benchmark feed-in tariffs + FIT subsidies" to measure $C_t(k,i)$, and it can be solved by using Formula (3).

$$C_t(k,i) = \sum_{k=0} (p_{k,x} + E_{k,x})\omega_{k,x} \tag{3}$$

where $p_{k,x}$ represents the benchmark feed-in tariffs for thermal power exercised by region x at the No. k period. $E_{k,x}$ represents the sum of subsidies for desulfurization, denitration, and dust removal, which are exercised by region x at the No. k period. In addition, $\omega_{k,x}$ are proportions of thermal power generation in region x at the No. k period.

In addition, the path of change in the generation cost of thermal power at the No. $k+1$ period can be expressed as Formula (4).

$$\begin{cases} C_t(k+1,i+1) = u \cdot C_t(k,i), & \text{the probability of an increase is } f \\ C_t(k+1,i) = d \cdot C_t(k,i), & \text{the probability of } a \text{ decrease is } (1-f) \end{cases}$$
$$\text{——} > \ C_t(k,i) = C_t(0,0) \cdot u^i d^{k-i} \tag{4}$$

where u is the rate of increase in the generation cost of thermal power, d is the rate of decrease in the generation cost of thermal power, and f is the probability of an increase in the generation cost of thermal power.

(2) Weighted average costs of PV and wind power $C_{wp}(k,r)$

According to research on the drivers of cost reduction in PV and wind power projects made by GWEC and CPIA [26,27], we assume that there are two main drivers of cost reduction: firstly, the technological progress brought by the investment in R&D, and secondly, the scale effect brought by the development of PV and wind power industries. According to the learning curve theory, it can be manifested as a continuous decline in costs along with the accumulation of production experience [28], and we assume that the rate of cost reduction caused by the scale effect can be quantified in the form of the growth rate in installed capacity. According to Formula (5), we can solve $C_{wp}(k,r)$.

$$C_{wp}(k,r) = \left(C_{wp}(0,0) - \frac{(C_{wp}(0,0) - C') \times r}{T} \right) \times (1-\delta_l)^{\log_2 \frac{I_{wp}(k)}{I_{wp}(0)}} \tag{5}$$

where C' is the lowest generation cost of PV and wind power, $\frac{(C_{wp}(0,0)-C') \times r}{T}$ represents the cost reduction driven by the technological progress brought by the R&D investment, δ_l is the learning rate, and $(1-\delta_l)^{\log_2 \frac{I_{wp}(k)}{I_{wp}(0)}}$ is the rate of cost reduction caused by the increase in installed capacity.

(3) Generating capacity of PV and wind power $G_{wp}(k)$

We use the conservative, neutral and positive planning of generating capacity of PV and wind power in 2025, 2030, and 2060 as the basic data made by the NEA, CEC, and CPIA, and we set conservative, neutral and positive scenarios correspondingly to forecast the generating capacity of PV and wind power in the rest period of the parity policy.

(4) Weighted average FIT for PV and wind power $p_{wp}(k)$

This paper solves the weighted average FIT for PV and wind power $p_{wp}(k)$ by applying the method of one-time and two-timed weighted averages to follow the requirements of the pricing mechanisms regulated by FIT policies.

Specifically, p_{wp}^g can be solved according to the proportions of generating capacity of PV and wind power and the guiding prices given in policy documents. To determine p_{wp}^p, two-time treatments of weighted average need to be performed in sequence. The first-time treatment is carried out according to the proportion of the installed capacity of incremental and stock projects to reflect the requirement that incremental projects should exercise the parity prices and stock projects should exercise the guiding prices. The second-time treatment should be processed according to the proportions of generating capacity of PV and wind power. Formula (6) is applied to solving p_{wp}^p during the parity policy.

$$p^b_{wp}(k) = \left\{ \frac{p^g_w(k)\cdot I_w(k-1) + p^b_w(k)\cdot(I_w(k) - I_w(k-1))}{I_w(k)} G_w(k) + \frac{p^g_p(k)\cdot I_p(k-1) + p^b_p(k)\cdot(I_p(k) - I_p(k-1))}{I_p(k)} G_p(k) \right\} \div G_{wp}(k) \quad (6)$$

Net Environmental Benefits

As the allocation of influencing factors, the function of *Net Environmental Benefits* is divided into three parts, and the variables are presented in Table 8. The composition and formulas are shown in Tables 9 and 10.

Table 8. Variables of the Net Environmental Benefits.

Variables	Meanings
$V_{en}(k)$	Net environmental benefits of the FIT policies for PV and wind power at No. k period (CNY)
$V(k,i,r)$	Net comprehensive benefits of the FIT policies for PV and wind power at No. k period: after r times of R&D investment and i times escalation in the generation cost of thermal power (CNY)
$\overline{p_{TGC}}(k)$	The weighted average price of green certificates at No. k period (CNY/sheet)
$w_{TGC}(k)$	The volume of green certificate traded (sum of subsidized and non-subsidized TGC) at No. k period (sheets)
$A(k)$	Costs of CO_2 emission reduction per ton of standard coal consumption at No. k period (CNY/tonne)
$\mu_S(k)$	CO_2 emission factor per ton of standard coal consumption at period No. k period (tonnes/standard coal)
$\theta_s(k)$	Standard coal consumption per unit of thermal power generation at period No. k period(g standard coal/kWh)

Table 9. The composition of *Net Environmental Benefits*.

$V_{en}(k)$	Meanings
Benefits of Emission Reduction	Under the positive incentive of the FIT policies, the development of PV and wind power industries can save a large amount of emission reduction costs for the state, especially the costs of CO_2 emission reduction. Hence, the overall savings in the costs of CO_2 emission reduction due to the FIT policies can be used to evaluate the *Benefits of Emission Reduction* in FIT policies.
Benefits for State Subsidies	The parity reform removed the state subsidy for incremental projects and permitted the issuance of unsubsidized green certificates. For now, PV and wind power generation enterprises are allowed to receive reasonable compensation through the sale of traded green certificates and CCER (Chinese Certified Emission Reduction, not yet restarted nationwide). Hence, we only use the total revenue of tradable green certificates to measure the savings in the expenditure of state subsidy due to the introduction of market-orientated compensation mechanisms.
The PV of Future Net Environmental Benefits	*The Present Value of Future Net Environmental Benefits* will be expressed as the cumulative discounted value of the *Net Environmental Benefits* of the policy over the remaining implementation period.

Table 10. The composition of the function of *Net Environmental Benefits*.

$V_{en}(k)$	Corresponding Formulas
Benefits of Emission Reduction	$A(k)\cdot\mu_S(k)\cdot\theta_s(k)\cdot G_{wp}(k)$
Benefits for State Subsidies	$\overline{p_{TGC}}(k)\cdot w_{TGC}(k)$
The PV of Future Net Environmental Benefits	$\alpha\cdot V_{en}(k+1)$

According to Formula (7), we can solve the *Net Environmental Benefits* $V_{en}(k,i,r)$.

$$V_{en}(k) = A(k)\cdot\mu_S(k)\cdot\theta_s(k)\cdot G_{wp}(k) + \overline{p_{TGC}}(k)\cdot w_{TGC}(k) + \alpha\cdot V_{en}(k+1) \quad (7)$$

Since Formula (7) includes 2 dynamic parameters ($\overline{p_{TGC}}(k)$ and $w_{TGC}(k)$) which cannot be directly calibrated by inputting historical data, it is necessary to further set corresponding functions to simulate the changes in the above dynamic parameters.

(1) Weighted average price of green certificates $\overline{p_{TGC}}(k)$

To correct the unreasonableness of using the method of simple arithmetic average, we adopt the weighted average price of subsidized and non-subsidized green certificates as the average sales price, and we quantify the stability of the price, as shown in Formula (8).

$$\begin{aligned} \overline{p_{TGC}}(k) &= \frac{\sum p_{TGC}(d)\cdot w_{TGC}(d)}{\sum w_{TGC}(d)} \\ Y &= \frac{w_{TGC}^{v}}{\sum w_{TGC}}, Y \in [0, 100\%] \end{aligned} \tag{8}$$

where $\overline{p_{TGC}}$ is the weighted average price of the green certificate during the period of FIT policies. $p_{TGC}(d)$ and w_d represent the prices of green certificates and the trading volume at the price in date d. In addition, Y is the stability of the transaction price during the implementation period, w_{TGC}^{v} is the volume of transactions within the range of price fluctuation $\overline{p_{TGC}}(k)(1 \mp v)$.

(2) Volume of trading green certificate $w_{TGC}(k)$

We complete the prediction of the volume of green certificates transaction during the later period of the parity policy (August 2022 to August 2023) by measuring the average growth rate of the sales volume during the early period of the parity policy (August 2021 to July 2022).

Net Comprehensive Benefits

According to Formula (9), the *Net Comprehensive Benefits* $V(k,i,r)$ can be solved.

$$\begin{aligned} V(k,i,r) \quad &= \max\left\{ \begin{array}{c} -R + \left(C_t(k,i) - C_{wp}(k,r)\right)G_{wp}(k) - \left(p_{wp}(k) - C_{wp}(0,0)\right)G_{wp}(k) \\ +\alpha\{f\cdot V_{ec}(k+1,i+1,r+1) + (1-f)\cdot V_{ec}(k+1,i,r+1)\}, \\ \left(C_t(k,i) - C_{wp}(k,r)\right)G_{wp}(k) - \left(p_{wp}(k) - C_{wp}(0,0)\right)G_{wp}(k) \\ +\alpha\{f\cdot V_{ec}(k+1,i+1,r) + (1-f)\cdot V_{ec}(k+1,i,r)\} \end{array} \right\} \\ &+A(k)\cdot\mu_S(k)\cdot\theta_s(k)\cdot G_{wp}(k) + \overline{p_{TGC}}(k)\cdot w_{TGC}(k) + \alpha\cdot V_{en}(k+1) \end{aligned} \tag{9}$$

Before applying the method of dynamic recursion to solve *Net Comprehensive Benefits*, it is necessary to set a boundary condition with an economic implication that *Net Comprehensive Benefits* are no longer considered once the FIT policy is suspended, as illustrated in Formula (10).

$$V(T+n,i,r) \equiv 0(n>0) \tag{10}$$

Subsequently, we can solve backward recursively for the *Net Comprehensive Benefits* at any point in time and then process the *Net Comprehensive Benefits* over the entire period of the policy implementation.

2.4.2. Optimization Model for Policy Design

Based on the Evaluation Model of Implementation Effects, we only need to add formulas to simulate the trend of Net Comprehensive Benefits under different levels of feed-in tariff, and the structure of the Optimization Model for Policy Design can be completed.

Two new formulas are added to reflect the impact of changes in the level of feed-in tariff on the cost and generating capacity of PV and wind power. In particular, the effect of the investment attractiveness of feed-in tariff at different levels on the weighted average costs $C_{wp}(k,i;p_{wp})$ and total generating capacity of PV and wind power $G_{wp}(k,i;p_{wp})$ can be measured by Formulas (11) and (12). Since dynamic changes in C_{wp} and G_{wp} will be transmitted to $V(k,i,r)$, we can obtain the optimal weighted average feed-in tariffs that maximize the *Net Comprehensive Benefits* of parity policy by applying a dynamic recursion solution.

$$C_{wp}(k,i;p_{wp}) = C(k,r)\left\{p_{wp}(T)\cdot exp\left(\partial \times \left(p_{wp}(0) - p_{wp}(T)\right)^2\right)\right\} \tag{11}$$

$$G_{wp}(k,i;p_{wp}) = G(k,r)\cdot exp\left(-\partial \times \left(p_{wp}(0) - p_{wp}(T)\right)^2\right) \tag{12}$$

where $exp(\partial \times \left(p_{wp}(0) - p_{wp}(T)\right)^2$ is used to measure the investment attractiveness of feed-in tariffs at different levels. The larger the dynamic factor ∂, the more significant the effect of the reduction in feed-in tariff on curbing the growth rate of generating capacity and the rate of cost decline.

2.5. Data Description of the Appraisal Models

Considering that some original data need to be pre-processed and calibrated before putting into existing formulas, the sources of data, the calibration basis, and the results will be covered in this section.

2.5.1. Evaluation Model of Implementation Effects

Net Economic Benefits

(1) The generation cost of thermal power generation $C_t(k,i)$

According to data on the Bohairim Steamcoal Price Index obtained from the WIND database, the rate of increase in the generation cost of thermal power u, the rate of decrease in the generation cost of thermal power d, and the probability of an increase in the generation cost of thermal power f can be calibrated, as shown in Table 11.

Table 11. Values and sources of calibration of parameters in the *Net Economic Benefits*.

Parameters	Meanings	Values	Sources and Assumptions
T	Total implementation periods of FIT policies (years)	2	Assuming the implementation period of the parity policy will execute 2 years, the same as the guiding price policy.
ρ	Risk-free interest rate	0.021	The benchmark interest rate for 2-year deposits was set by the People's Bank of China in 2021.
α	Discount rate	0.979	$\alpha = e^{-\rho}$
σ	Annual volatility of the generation cost of thermal power	0.151	Based on monthly data on Bohairim Steamcoal Price Index from 2018 to 2022, obtained from the WIND Data.
u	Rate of increase in the generation cost of thermal power	0.112	$u = \left(e^{\alpha\sqrt{\frac{T}{n}}} - 1\right) \cdot coal\ index$, *coal index* is the proportion of coal price in the generation cost of thermal power which is calibrated based on real-time data of thermal power plants in a group company in China.
d	Rate of decrease in the generation cost of thermal power	0.861	$d = e^{-\alpha\sqrt{\frac{T}{n}}}$
f	Probability of the escalation in thermal power costs	0.999	$f = \frac{e^{\alpha} - d}{u - d}$
R	Annual investment in R&D (CNY billion)	18.019	Based on the public data on the R&D investment of 133 listed companies in PV and wind power generation.
δ_l	Learning rate for the costs of PV and wind power	0.019	Based on data published by IRENA in 2021.

Formula (4) can be recursed back and forth by inputting historical data at a point within the period of policy implementation, so we collect the data on feed-in tariffs of thermal power $p_{k,x}$ and the generating capacity of 32 regions from *the Annual Report of China's Electricity Industry 2021*, as shown in Figures 1 and 2. After calculating the proportion of generating capacity $\omega_{k,x}$ of every region, $C_t(k,i)$ can be solved.

(2) Weighted average costs of PV and wind power $C_{wp}(k,r)$

Since Formula (5) can also be recursed back and forth by inputting historical data at a point, we collect historical data including the costs of PV and wind power in 2021, the annualized rate of cost decline of PV and wind power (IRENA, 2021), and the installed capacity of PV and wind power (NBS, 2019–2021). Subsequently, the learning rate δ_l can be calibrated reversely from the rate of cost reduction driven by the scale effect $(1-\delta_l)^{\log_2 \frac{I_{wp}(k)}{I_{wp}(0)}}$, as presented in Table 11.

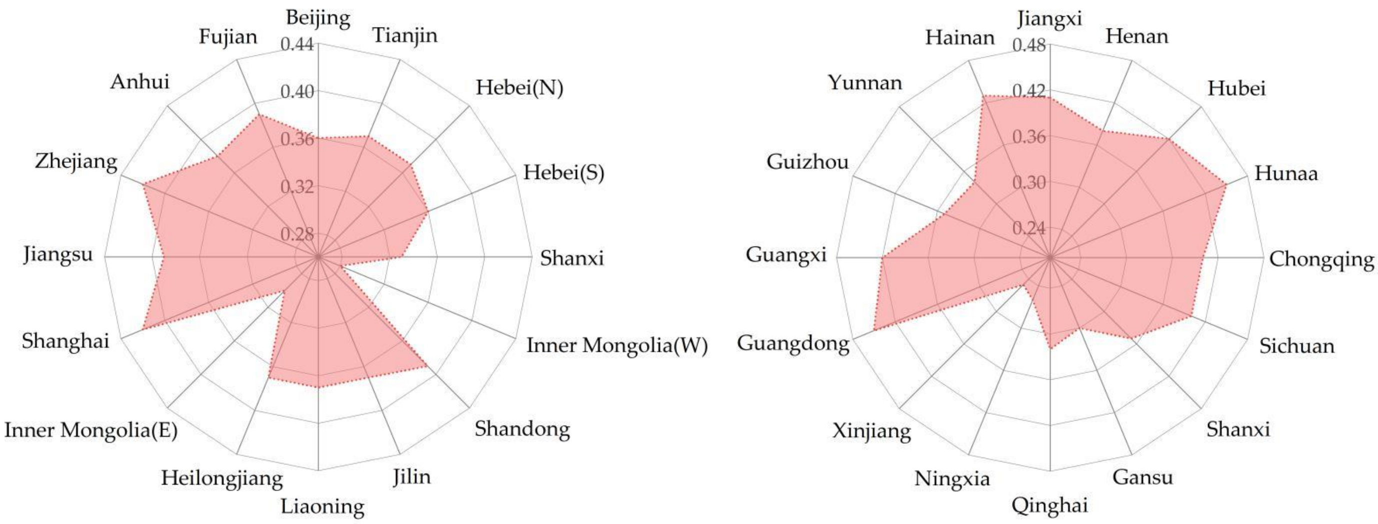

Figure 1. China's benchmark feed-in tariffs for thermal power by region, 2021 (CNY/kWh, desulfurization, denitration, and dust removal subsidies, and value-added tax included).

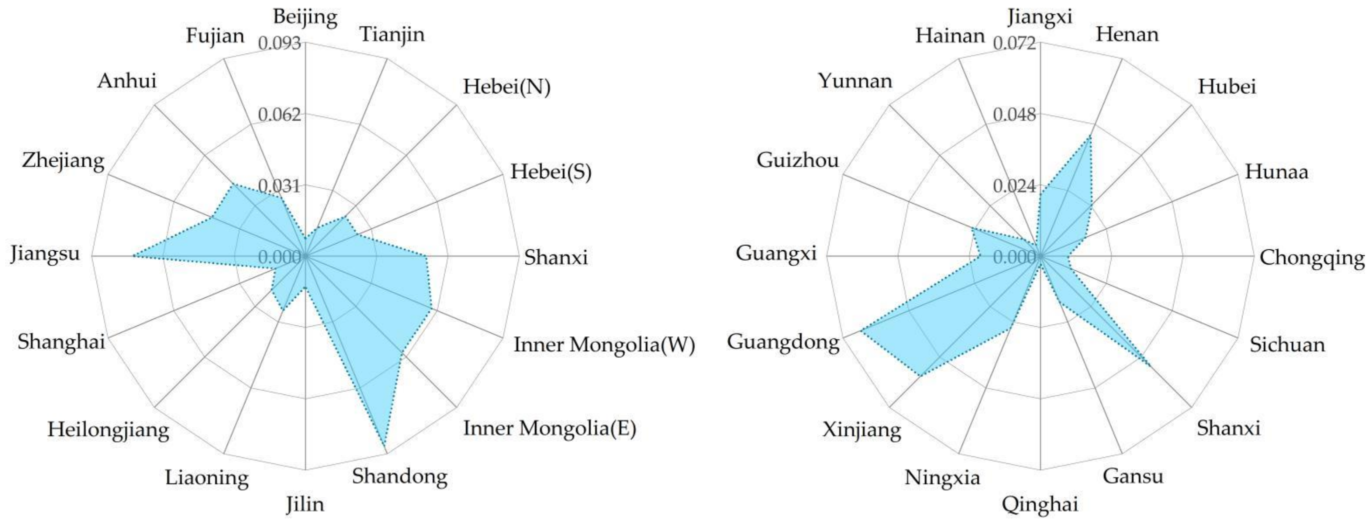

Figure 2. The proportion of generating capacity of thermal power by region, 2021 (%).

(3) Generating capacity of PV and wind power $G_{wp}(k)$

Historical data on generating capacity from 2019 to 2021 is available in NBS Data, and the data for 2022–2023 have not yet been published. Therefore, we combine the conservative, neutral, and positive planning of generating capacity of PV and wind power in 2025, 2030, and 2060 as the basic data (as shown in Figure 3), which was made by the NEA, CEC, and CPIA, setting conservative, neutral, and positive scenarios correspondingly to forecast the generating capacity in 2022 and 2023, and the results are presented in Table 12. It assumes that the generating capacity will rise linearly between 2020 and 2025.

Table 12. The prediction of generating capacity of PV and wind power.

Generating Capacity of PV and Wind Power (GWh)	2022	2023
Conservative scenario	949,676.80	1,060,715.20
Neutral scenario	1,149,078.00	1,229,405.00
Positive scenario	1,236,374.40	1,490,761.60

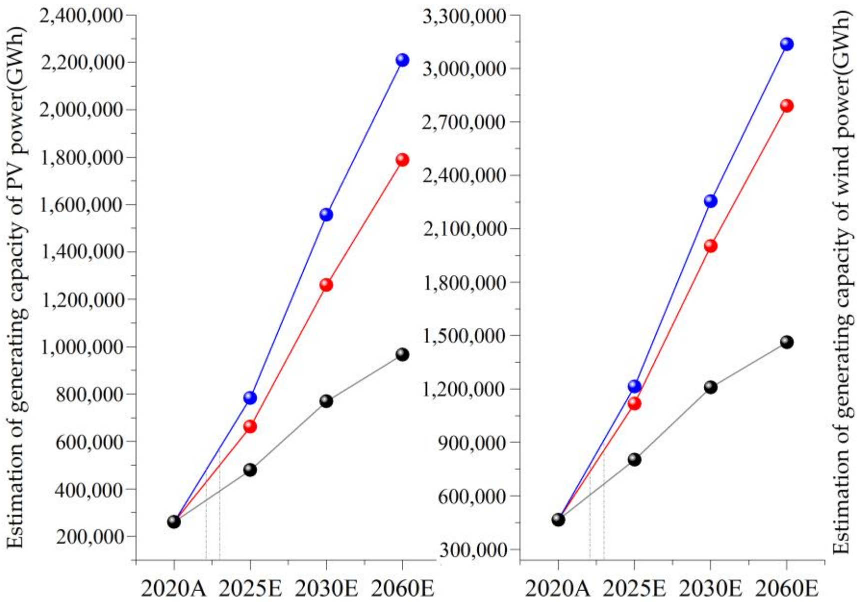

Figure 3. The conservative (black), neutral (red), and positive (blue) planning of generating capacity of PV and wind power in 2025, 2030 and 2060.

(4) Weighted average FIT for PV and wind power $p_{wp}(k)$

To solve the weighted average feed-in tariff, we obtain historical data on the installed capacity from the NBS Database and obtain data on the feed-in tariffs from the policy documents issued by the NDRC and NEA.

Net Environmental Benefits

(1) Weighted average price of green certificates $\overline{p_{TGC}}(k)$

The historical data on the transaction price of green certificates from July 2019 to July 2022 are available from the database of China's Green Certificate Subscription Platform, but the data during the remaining period of the parity policy have not yet occurred, so we reasonably predict that the weighted average price of green certificates from August 2022 to August 2023 will gradually converge to the guiding price of unsubsidized green certificate (CNY 50/sheet) set by the transaction platform, as shown in Figure 4; the reason is that the price of the unsubsidized green certificates is much lower than that of the subsidized green certificates.

(2) Volume of trading green certificate $w_{TGC}(k)$

We assume that the trading volume from August 2022 to August 2023 will grow at the average growth rate of transaction volume during the first year of the parity policy.

Values and sources of other parameters in the function of *Net Environmental Benefits* are presented in Table 13.

Table 13. Values and sources of parameters in the *Net Environmental Benefits*.

Parameters	Meaning	Values	Source
A	Costs of CO_2 emission reduction per ton of standard coal consumption in 2021 (CNY/tonne)	180.00	BCG Research [29]
μ_S	CO_2 emission factor per ton of standard coal consumption in 2021 (tonnes/standard coal)	2.60	China Carbon Emissions Trading Network
θ_s	Standard coal consumption per kilowatt hour of thermal power generation at period in 2021 (g standard coal/kWh)	330.00	

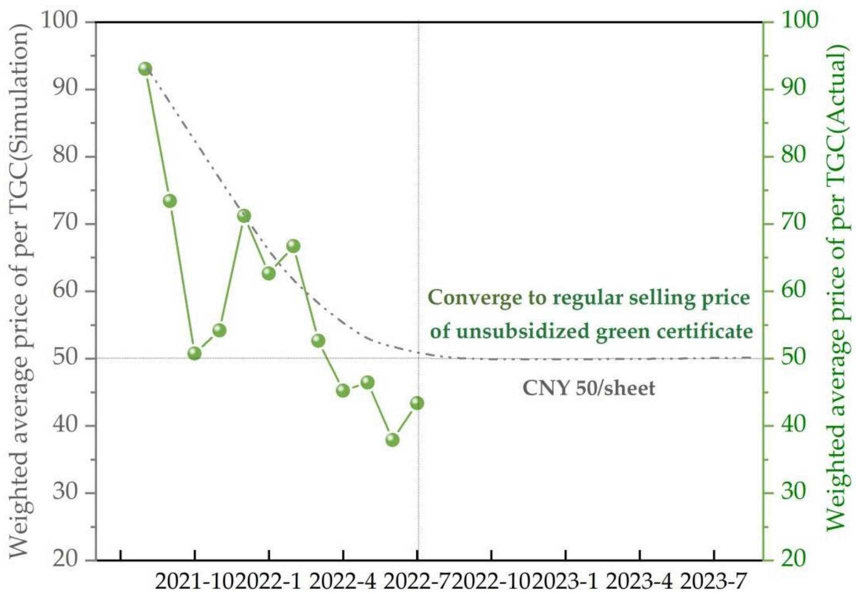

Figure 4. Simulation of the weighted average price of green certificates from August 2022 to August 2023 (CNY per sheet, value-added tax excluded). Note: no regulation has been promulgated to levy value-added tax on green certificates so far.

2.5.2. Optimization Model for Policy Design

To use the Optimization Model for Policy Design, we need to calibrate the value of the parameter ∂. Before that, we assume that the minimum value of the feed-in tariff for PV and wind power (starting point for the range of price fluctuation in the dynamic simulation) equals the generating cost of hydropower (as shown in Formula (13)), for the reasons that PV, wind, and hydro-power have similar cost structures, and the power-generating technology of hydropower has been developed and is relatively mature.

$$\lim C(k, i; p_{wp}) = C_h \tag{13}$$

where C_h is the generating cost of hydropower; after integrating Formulas (11)–(13), the value of the parameter ∂ can be calibrated to 6.5.

3. Results and Discussion

3.1. Evaluation Model of Implementation Effects

After applying the static price simulation of the guiding price policy and the parity policy, the results of *Net Economic Benefits, Net Environmental Benefits,* and *Net Comprehensive Benefits* of the last two-phase FIT policies can be solved and demonstrated in Table 14.

Table 14. Net Economic Benefits, Net Environmental Benefits and Net Comprehensive Benefits (CNY billion, value-added tax included).

		Guiding Price Policy						*Parity Policy*	
		Year 1	**Year 2**	**Year 1**	**Year 2**	**Year 1**	**Year 2**	**Year 1**	**Year 2**
				Conservative		Neutral		Positive	
V_{ec}	*Economic Earnings*	43.259	89.483	144.327	288.274	163.365	324.359	170.573	366.991
	Economic Costs	−4.250	−2.927	−10.051	−30.229	−11.429	−34.421	−12.032	−38.784
	Invest in R&D?	*No*	*No*	*No*	*No*	*No*	*No*	*No*	*No*
V_{en}	*Benefits of Emission Reduction*	31.706	41.477	50.575	78.033	57.511	88.855	60.547	100.115
	Benefits for State Subsidies	0.001	0.001	0.002	0.008	0.002	0.008	0.002	0.008
V		203.558		513.862		580.276		638.406	
Rate of change (%)		-		152.440%		185.067%		213.624%	

According to the evaluation objectives presented in Table 15, we provide the following discussion of the results of the Evaluation Model of Implementation Effects point by point.

Table 15. The evaluation objectives and main conclusions of the Evaluation Model of Implementation Effects.

Appraisal Model		Evaluation Objectives	Main Conclusions
Evaluation Model of Implementation Effects	1	Identify which FIT policy is more conducive to promoting the development of PV and wind power, according to the results of *Net Comprehensive Benefits*.	The parity policy is more conducive to promoting the development of PV and wind power compared to the guiding price policy.
	2	Compared with traditional thermal power generation, testing whether PV and wind power projects have greater economic competitiveness under the support of the last two-phase FIT policies.	Under the support of the last two-phase FIT policies, PV and wind power projects have greater economic competitiveness.
	3	Analyze the impact of the last two-phase FIT policies on the R&D activities of PV and wind power generation enterprises.	The last two-phase FIT policies have not been effective in encouraging R&D investment in the market of PV and wind power generation.
	4	Assess the substitution effect of the market compensation mechanisms on the government subsidy during the last two-phase FIT policies.	The market compensation mechanism of green certificates has a limited substitution effect on government subsidies during the last two-phase FIT policies, which makes it difficult to relieve the pressure of government subsidies.
	5	Assess the curbing effect of carbon dioxide emissions brought by the last two-phase FIT policies.	Compared to the guiding price policy, the effect of the parity policy to suppress carbon dioxide emissions proved better.

(1) Which FIT policy is more conducive to promoting the development of PV and wind power?

Under the parity policy, developing PV and wind power projects are more competitive than they would be under the guiding policy; the growth trend is shown in Figures 5 and 6. According to results under the conservative, neutral, and positive scenarios, the *Net Comprehensive Benefits* of the parity policy are 2.524, 2.851, and 3.136 times more than those of the guiding price policy, as illustrated in Table 14, so the parity policy is more conducive to promoting the development of PV and wind power compared to the guiding price policy.

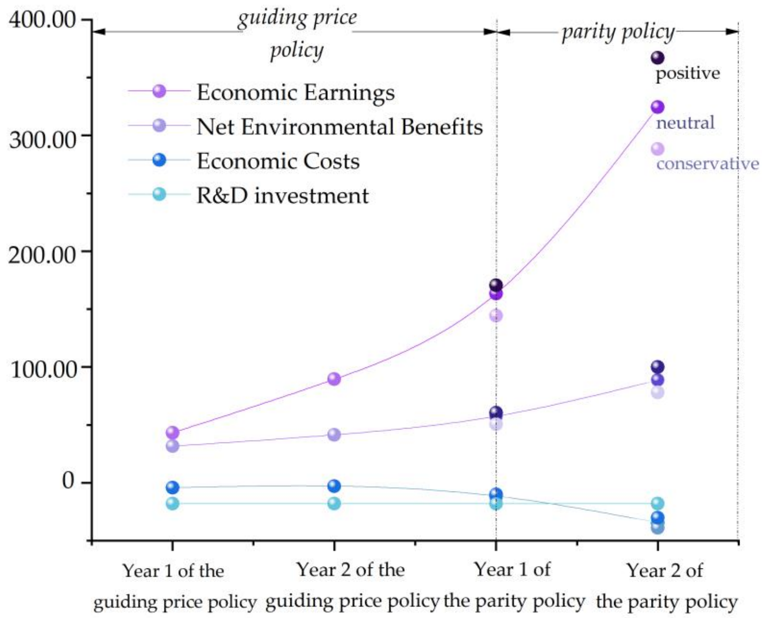

Figure 5. Main components of the *Net Comprehensive Benefits* (CNY billion, value-added tax included).

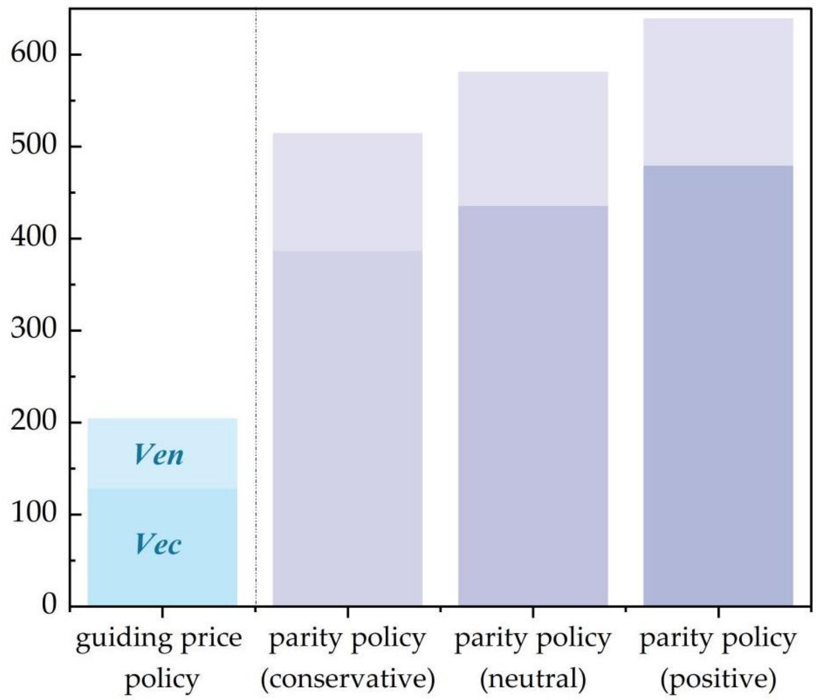

Figure 6. Results of Net Economic Benefits and Net Environmental Benefits (CNY billion, value-added tax included).

(2) Development potential compared to thermal power

Compared to the development of thermal power projects, the development of PV and wind power projects has a higher level of economic competitiveness and cost-saving potential under the support of the guiding price policy and the parity policy. As shown in Table 14, there are all positive results quantified in *Economic Earnings* during the implementation period of both FIT policies.

During the period of the parity policy, triple impacts from the long-term increase in the coal price, the progressive decline in the generating costs [30], and rapid expansion in the generating capacity of PV and wind power result in a 3.138 to 3.898 times increase in *Economic Earnings* compared to those of the guiding price policy. It means that the relative economic advantages of developing PV and wind power projects are stronger during the parity policy period.

(3) The impact on the R&D activities of PV and wind power enterprises

As demonstrated in Table 14, the last two-phase FIT policies fail to effectively encourage the power generation market as a whole to invest in research and development, indicating that the decision to invest in R&D cannot result in greater *Net Economic Benefits*.

(4) The substitution effect of green certificates on government subsidy

As the trend is shown in Figure 7, although there is a drop in the weighted average price of green certificates during the parity policy period, the trading volume of green certificates increased significantly, and *Benefits for State Subsidies* increased by 31.738–417.970% after the introduction of the parity policy. However, *Benefits for State Subsidies* account for less than 0.01% of the *Net Environmental Benefits* during the period of both FIT policies, indicating that the contribution of this market-subsidized instrument is not significant.

In summary, the substitution effect of the green certificate on the government subsidy is limited, so other market compensation mechanisms can be introduced in the later stage.

(5) The curbing effect of carbon dioxide emissions

During the period of the parity policy, the influence of factors such as the growth in the generating capacity of PV and wind power and the decrease in carbon dioxide emission reduction cost result in a 1.715 to 2.098 times increase in *Benefits of Emission Reduction* compared to those of the guiding price policy. It can be seen from this that compared to the guiding price policy, the curbing effect of carbon dioxide emissions during the period of the parity policy is better.

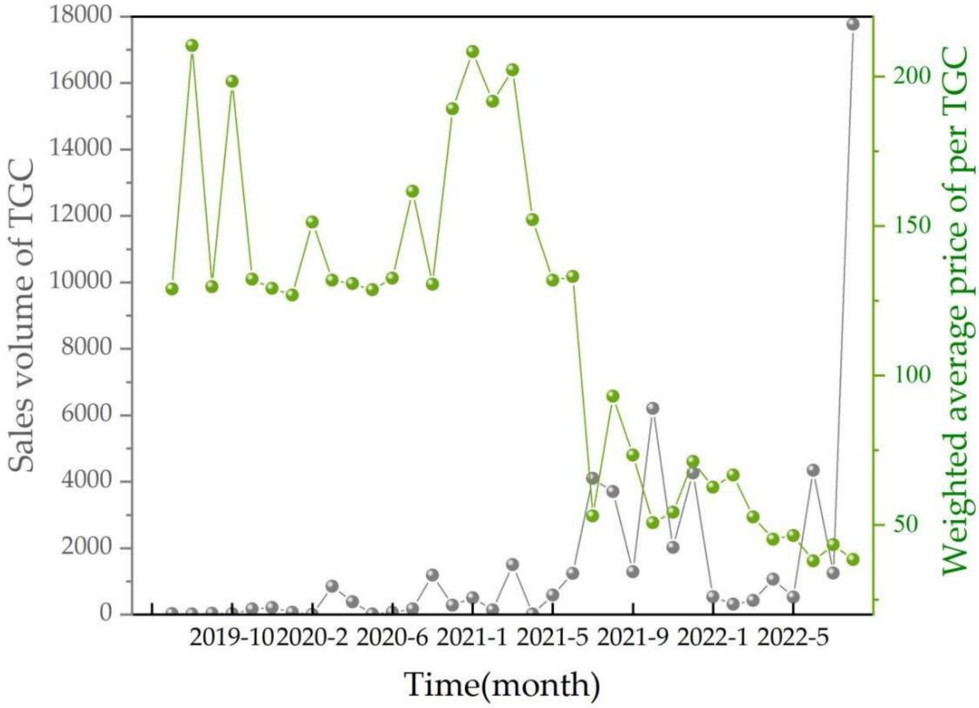

Figure 7. Volumes (sheets) and weighted average prices of traded green certificates (CNY/sheet, value-added tax excluded), 2019–2022.

3.2. Optimization Model for Policy Design

To ensure the robustness of the conclusions obtained, we conduct a sensitivity analysis for the parameter ∂. As the results presented in Table 16 show, when ∂ floats up or down by 20%, the fluctuation of the optimal weighted average feed-in tariff is no more than 6%, meaning the impact of calibration deviation is negligible, and the main conclusions drawn from the Optimization Model for Policy Design have not altered.

Table 16. Sensitivity analysis for the parameter ∂.

∂	$p_{optimal}$	*Sliding Scale*	V_{ec}	*Sliding Scale*	V_{en}	*Sliding Scale*	V	*Sliding Scale*
5.20	0.304	−5.69%	472.57	0.55%	182.03	5.06%	654.61	1.76%
5.85	0.313	−2.90%	470.57	0.12%	177.44	2.41%	648.01	0.74%
6.50	0.322	-	469.99	-	173.27	-	643.26	-
7.15	0.340	5.48%	473.76	0.80%	166.19	−4.08%	639.95	−0.51%
7.80	0.340	5.48%	471.55	0.33%	165.88	−4.27%	637.43	−0.91%

According to the evaluation objectives presented in Table 17, we make the following analysis based on the results of the Optimization Model for Policy Design point by point.

(1) Optimal test of feed-in tariffs and the estimation of the room for the price reduction

As shown in Table S1 and Figures 8 and 9, to maximize the *Net Comprehensive Benefits*, the optimal weighted average feed-in tariffs (CNY 0.322–0.323/kWh) are lower than those (CNY 0.358–0.359/kWh) to maximize *Net Economic Benefits*. It can indicate that the measure to remove government subsidies does not hinder the reduction in the feed-in tariff in the future but helps to speed up the realization of the grid parity.

Table 17. The evaluation objectives and main conclusions of the Optimization Model for Policy Design.

Appraisal Model		Evaluation Objectives	Main Conclusions
Optimization Model for Policy Design	1	By calculating the optimal feed-in tariffs under a multi-scenario and multi-objective framework, test whether the existing feed-in tariff has reached the level of maximizing implementation effects, and estimate the room for the price reduction in the future.	The existing weighted average feed-in tariff exercised by the parity policy is higher than the optimal weighted average feed-in tariffs that maximize the implementation effects, and there is still space for price reduction.
	2	Analyze whether the existing pricing mechanism is suitable for long-term implementation and put forward corresponding suggestions for policy optimization.	The existing pricing mechanism is not suitable for long-term implementation.

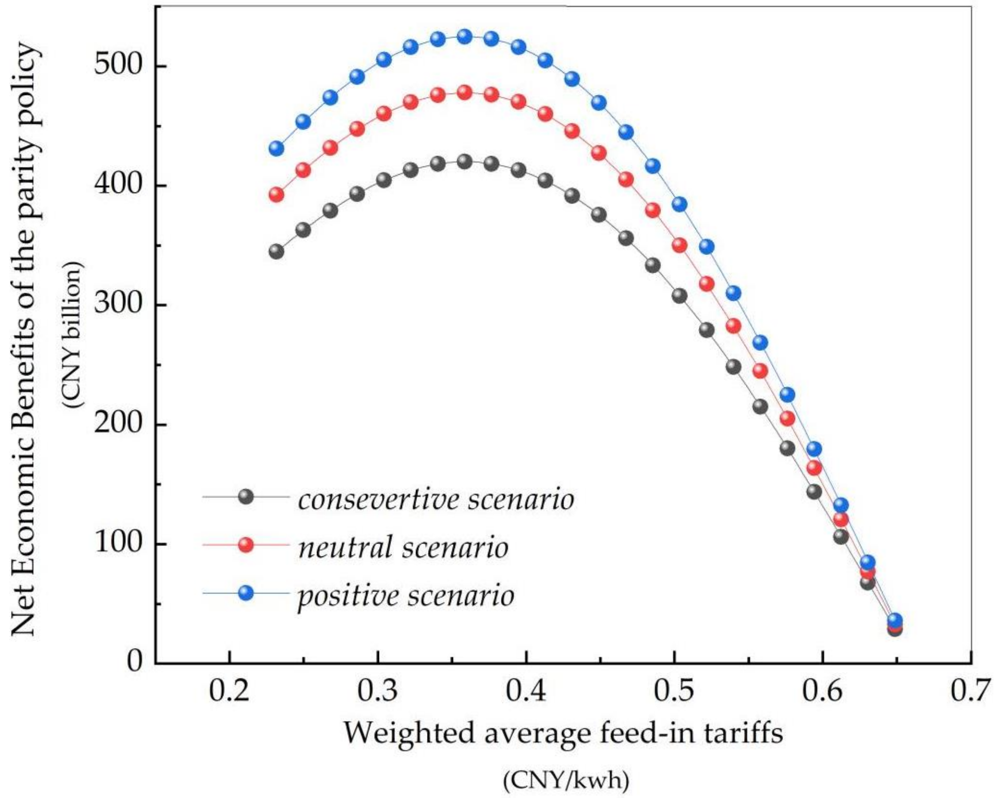

Figure 8. *Net Economic Benefits at different level of feed-in-tariff (CNY billion, value-added tax included).*

The existing weighted average feed-in tariff (CNY 0.396/kWh) exercised by the parity policy is higher than the optimal weighted average feed-in tariffs (CNY 0.322–0.359/kWh). We can deduce that there is still room for the feed-in tariff to decrease along with the accumulation of scale effect and technological advancement. As illustrated in Table 18, there is still space for a 10.306% to 22.981% reduction in the existing feed-in tariffs.

Table 18. The optimal weighted average feed-in tariffs and room for price reduction.

	The Optimal Weighted Average Feed-In Tariffs (CNY/kWh, Value-Added Tax Included)			
	Maximizing *Net Economic Benefits*	Room for Reduction	Maximizing *Net Comprehensive Benefits*	Room for Reduction
Conservative scenario	0.358	−10.615%	0.322	−22.981%
Neutral scenario	0.359	−10.306%	0.322	−22.981%
Positive scenario	0.359	−10.306%	0.323	−22.601%

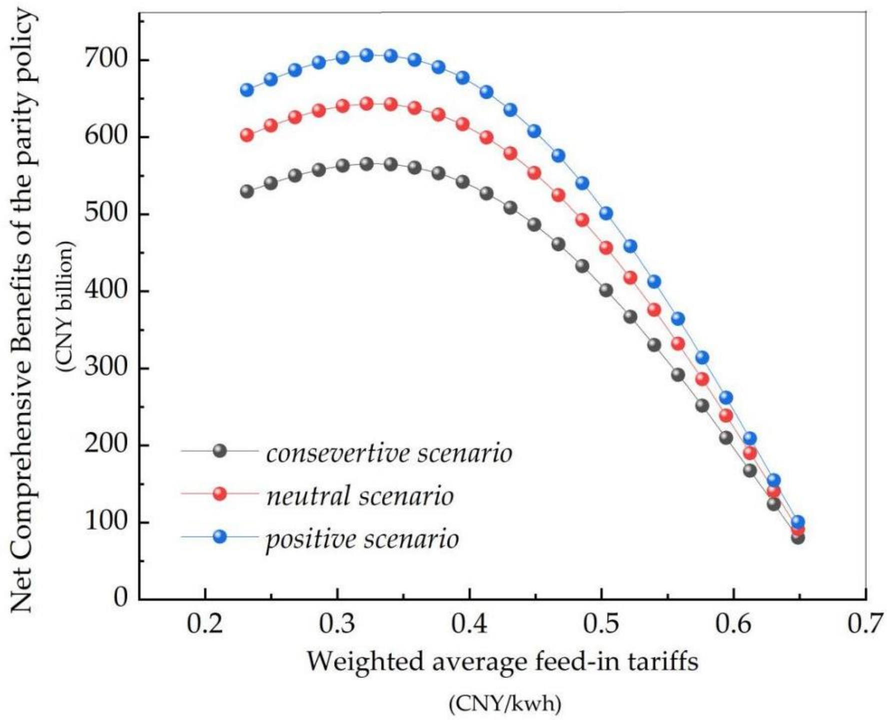

Figure 9. *Net Comprehensive Benefits* at different level of feed-in-tariff (CNY billion, value-added tax included).

(2) Discussion on the pricing mechanism

As shown in Figures 10 and 11, the parity policy lowers the level of feed-in tariffs for incremental projects of PV and wind power, and it is consistent with the downward trend of feed-in tariffs. However, if the parity policy is to remain as a long-term policy, there are still two potential risks that need to be ruled out.

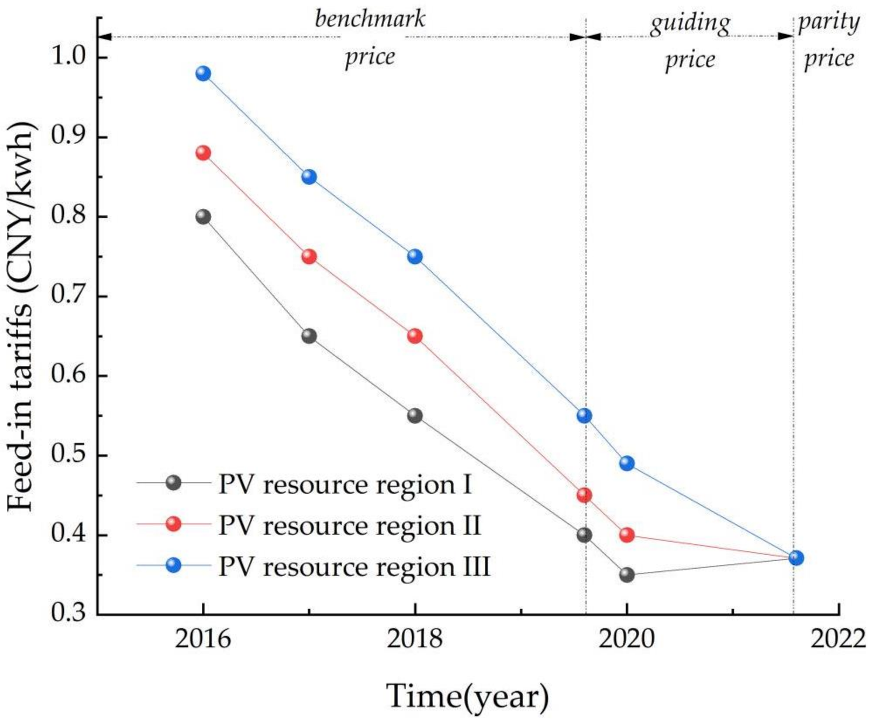

Figure 10. Feed-in tariffs for PV power 2016–2022, value-added tax included.

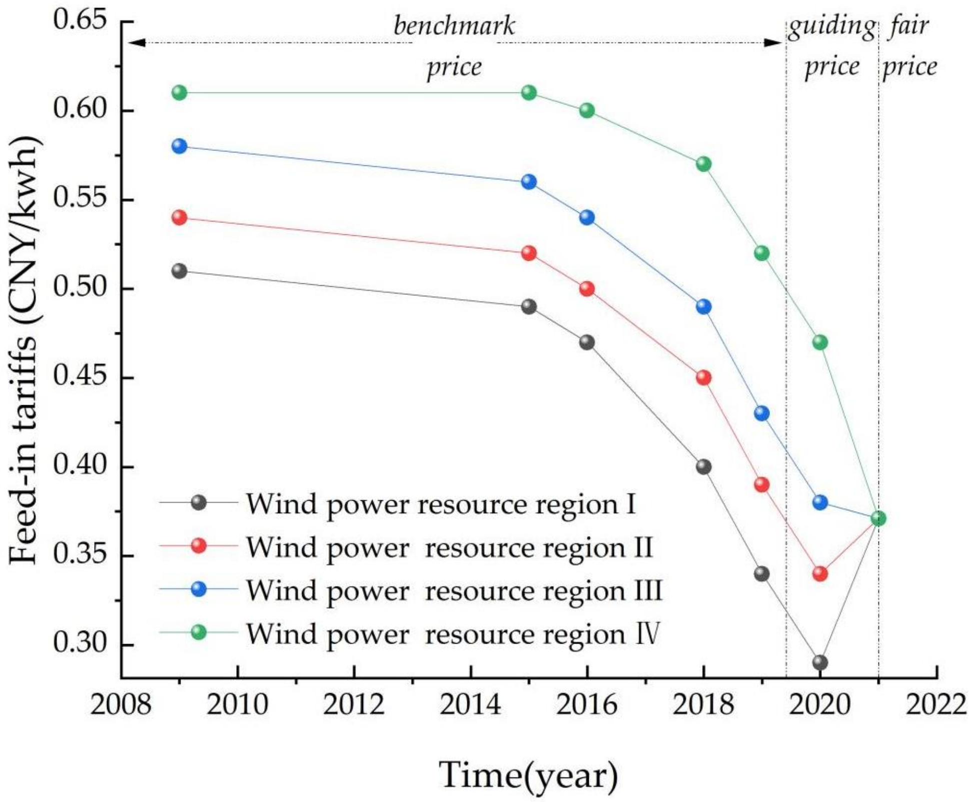

Figure 11. Feed-in tariffs for wind power 2016–2022, value-added tax included.

(2.1) Mismatch in the cost attributes

Setting the feed-in tariffs of PV and wind power at the same level as thermal power does not reflect the cost attributes of PV and wind power. The initial investment cost of PV and wind power projects still has a large downward space [31], but the feed-in tariff for thermal power generation cannot accurately and timely reflect the change in the generation cost of PV and wind power, so it is not conducive to maximizing the implementation effects of the FIT policies. So, the price verification standard of parity with feed-in tariffs of thermal power needs to be adjusted after the parity policy ends.

(2.2) Uneven investment across regions

There shows a risk of uneven investment in PV and wind power projects because of the wide disparity in feed-in tariffs for thermal power across regions. Since there is no discernible difference in the initial investment costs of PV and wind power projects across regions, implementing the parity policy in the long run would widen the profit gap between incremental projects in different regions, which is not favorable to the healthy and balanced development of the PV and wind power industries [32,33]. Therefore, the existing pricing mechanism is not suitable for long-term implementation.

4. Suggestions

According to conclusions drawn by the Evaluation Model of Implementation Effects, we can know that in economic and environmental terms, the parity policy is more conducive to the development of PV and wind power industries than the guiding price policy. However, according to conclusions drawn by the Evaluation Model of Implementation Effects, the parity policy is only suitable to be implemented as a transitional policy. Therefore, we put forward the following four recommendations for the later optimization of the FIT policies for PV and wind power.

(1) Gradual decouple

Since the parity policy is not suitable for long-term implementation, the feed-in tariffs for PV and wind power should progressively be disconnected from feed-in tariffs for thermal power. The policy-makers can turn to follow the mechanism of "benchmark FIT + range for fluctuation", upgrading the benchmark FIT and the floating range separately, and consider the discrepancy in energy quality of different regions as well as any other variations related to the sustainable supply of electricity.

(2) Dynamic regulation

Considering that the generation cost of PV and wind power generation will be gradually reduced driven by multiple factors, various regions should also dynamically adjust the level of feed-in tariffs for incremental PV and wind projects by changes in the cost of initial investment to reflect the general trend of the costs reduction in feed-in tariffs in due course and ensure that a reasonable return on the investment for PV and wind power projects can be realized.

(3) Incentives for R&D investment

Since the last two-phase FIT policies fail to effectively encourage the power generation market as a whole to invest in R&D, policymakers can consider formulating supporting policies to offer incentives for R&D activities in upstream industries of power generation [34,35] to reduce the cost of the initial construction for PV and wind power projects.

(4) Restart CCER

Since the compensation effect of the green certificate is limited, other market compensation mechanisms can be introduced in the later stage. Among the market compensation mechanisms currently being piloted, CCER is expected to relieve the pressure of government subsidies by channeling the environmental value of PV and wind power to the market [36]. Therefore, policymakers can consider restarting CCER nationwide along with the green certificate to enhance the substitution effects of market-oriented compensation mechanisms for government subsidies [37].

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su15065137/s1, Table S1: *Net Economic Benefits* and *Net Comprehensive* Benefits (CNY billion) at different level of feed-in tariff.

Author Contributions: X.S.: funding acquisition, conceptualization, writing—original draft, review and editing; Y.H.: conceptualization, writing—original draft, methodology, formal analysis, data curation; Y.Z.: validation, investigation, data curation; W.Z.: validation, resources, data curation; Z.G.: resources, data curation. All authors have read and agreed to the published version of the manuscript.

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