energies

Article

Developing China's Electricity Financial Market: Strategic Design of Financial Derivatives for Risk Management and Market Stability

Hao Feng [1], Yidi Zhang [1], Zhou Lan [1], Kun Wang [1], Yizheng Wang [1], Sheng Chen [2] and Changsen Feng [2,*]

[1] Economic Research Institute of State Grid Zhejiang Electric Power Company, Hangzhou 310000, China; fhfpl@163.com.cn (H.F.); irisyidi@163.com.cn (Y.Z.); lanzhou_zju@163.com.cn (Z.L.); wk_cau@163.com.cn (K.W.); sgcc_wangyz@163.com.cn (Y.W.)
[2] College of Information Engineering, Zhejiang University of Technology, Hangzhou 310000, China; cs583905618@163.com
* Correspondence: fcs@zjut.edu.cn

Abstract: As China progresses with its electricity market reforms in pursuit of "carbon peak and carbon neutrality" objectives, the increasing integration of renewable energy sources introduces new risks and uncertainties, necessitating the development of an efficient electricity financial market. This paper outlines the fundamental principles of electricity financial derivatives, assesses their applicability to the Chinese market through an analysis of international experiences from the United States, Nordic countries, and Australia, and highlights critical issues for the construction of a robust market framework. It offers strategic recommendations regarding the structural and developmental aspects of China's electricity financial market and proposes derivative instruments tailored to China's market to improve liquidity and risk management mechanisms, thereby facilitating the renewable energy transition. The study demonstrates that these derivatives are instrumental in mitigating price volatility, managing transmission congestion, and supporting the shift to renewable energy. This provides a pragmatic approach for the reform and advancement of China's electricity financial market, aligning with global strategies and addressing the unique challenges of China's energy transition.

Keywords: electricity financial markets; risk management; electricity financial derivatives

Citation: Feng, H.; Zhang, Y.; Lan, Z.; Wang, K.; Wang, Y.; Chen, S.; Feng, C. Developing China's Electricity Financial Market: Strategic Design of Financial Derivatives for Risk Management and Market Stability. *Energies* **2024**, *17*, 5854. https://doi.org/10.3390/en17235854

Academic Editor: Jay Zarnikau

Received: 8 October 2024
Revised: 10 November 2024
Accepted: 13 November 2024
Published: 22 November 2024

1. Introduction

In 2015, China's State Council issued the "Several Opinions on Further Deepening the Reform of the Electricity System" [1]. This document laid the groundwork for a series of structural changes aimed at transforming China's electricity sector. Following its release, key electricity trading centers in Beijing and Guangzhou, along with 34 provincial trading centers, were established. These centers now operate with a fair degree of independence, handling transactions and facilitating a more decentralized electricity market [2]. Since then, the volume of electricity market transactions has grown steadily, accompanied by an increase in the number of market participants. The market is gradually evolving into a structure that features both medium- and long-term contracts alongside an increasingly active spot market. This dual approach provides market participants with flexibility, where long-term contracts offer stability, and the spot market reflects real-time fluctuations in supply and demand [3]. Such developments indicate substantial progress in constructing a market-oriented electricity system in China, moving it away from state-controlled pricing.

China's energy reform is also closely linked to its national "carbon peak and carbon neutrality" goals, which are viewed as strategic imperatives for the country's future [4]. These targets have intensified efforts within the energy sector to increase the share of renewable energy in the electricity mix [5]. In recent years, this shift towards cleaner energy has accelerated, with wind, solar, and hydropower all playing increasingly significant roles. However, the unpredictable nature of renewable energy, due to its dependency on weather and other external factors, has heightened the uncertainty faced by market participants [6]. This inherent variability has introduced substantial risks, especially in terms of price fluctuations. As the share of renewable energy grows, so does the volatility in electricity prices, creating a pressing need for tools that can help manage and mitigate these risks [7]. Without adequate mechanisms for risk transfer and avoidance, market participants may face financial instability, highlighting the importance of developing robust risk management solutions.

Due to the distinct characteristics of electricity compared to tangible commodities—specifically, its instantaneous production, difficulty in storage, and the inherent uncertainty in balancing supply and demand—the market price of electricity is highly uncertain and often unpredictable [8]. Unlike physical commodities that can be stockpiled or stored until needed, electricity must be consumed as soon as it is generated, which creates a unique set of challenges for market participants. This real-time nature of electricity production makes it difficult to predict and control prices, as the market is constantly influenced by fluctuations in demand, generation capacity, and even external factors like weather conditions or grid congestion [9]. In 2020, countries such as Germany, France, and Switzerland witnessed a record high number of hours with negative electricity prices. Ireland's negative pricing hours for the year were a staggering 310% of those in 2019. During these periods of negative pricing, power generators were compelled to pay consumers, sometimes at rates several times higher than normal electricity prices [10]. Consequently, price volatility becomes a prominent feature of electricity markets, which in turn heightens financial risks for participants.

Existing research has frequently centered on renewable energy technologies or specific aspects of electricity market mechanisms in isolation, underestimating the pivotal role and extensive influence of the electricity financial market in the broader scope of energy transition. Studies on renewable energy technologies often prioritize technological refinement and efficiency, overlooking the interplay with the electricity financial market and the potential of financial instruments to enhance the integration and advancement of renewable energy. This segmented approach is inadequate for tackling the complex challenges that the electricity market encounters during energy transition, including risks associated with price volatility and market stability.

To manage these risks, the development of electricity financial derivatives becomes essential. By drawing parallels with traditional financial derivatives—such as futures, options, and contracts for difference—which play a pivotal role in price discovery and risk management in other commodity markets [11], electricity financial derivatives offer similar benefits in the context of electricity. These instruments serve critical functions, including hedging against price volatility and enhancing the transparency of market pricing. Electricity financial derivatives enable market participants, such as power generation companies, electricity retailers, and large consumers, to lock in future prices, thus mitigating the financial risks posed by the fluctuating market. Furthermore, these derivatives can assist in price discovery by providing forward-looking price benchmarks, which reflect the market's expectations of future price movements. The document [1] in question advocates for the exploration and eventual development of electricity futures and over-the-counter derivatives when market conditions are conducive to their introduction. By offering market participants the ability to hedge against future price risks, these financial products will provide more stability and predictability in pricing, which is crucial for the effective functioning of both the electricity spot market and the broader electricity market. Such instruments can also attract a broader range of participants, including financial investors, who are not directly involved in electricity production or consumption but can provide liquidity to the market. The development of these financial tools is not just a complementary measure to the spot market but a necessary step in building an efficient and mature electricity market. Without the availability of derivatives like futures and options, market participants may find themselves vulnerable to unpredictable price swings, which can undermine investment confidence and hinder the smooth functioning of the electricity system. Thus, alongside the construction of the spot electricity market, the establishment of an efficient electricity financial market is imperative for providing the forward price benchmarks and risk management mechanisms needed to ensure long-term market stability.

The electricity market comprises both a spot market and a financial market. The spot market primarily deals with the physical delivery of electricity, characterized by the production, transmission, and sale of electrical power [12]. As a tool derived from the spot market to manage risk [8,13], the financial market introduces various financial derivatives, including electricity futures, options [7,14], contracts for difference [15], and transmission rights [16,17]. These instruments assist market participants in hedging against price volatility, encourage broad participation in the market, enhance the market's complexity, strengthen cooperation and competition within the electricity sector, foster innovation in electricity products, stabilize market prices, and promote the optimal allocation of resources [18–20].

At present, China's electricity financial market is still in its nascent stages. While previous studies have provided an overview of the electricity financial market, they have not delved into the applicability and feasibility of these international experiences within the context of China's unique national conditions. This implies that, although advanced international practices offer a reference for the reform of China's electricity market, they have not been effectively integrated with the specific realities of China. Considering the aforementioned circumstances, this study aims to address the price risks and changes in the spot market resulting from the penetration of renewable energy in China's electricity market reforms. By drawing on the experiences of established international markets, it evaluates their applicability to the Chinese context and identifies key issues that need to be resolved to build a robust electricity financial market, including risk management, market liquidity, and regulatory frameworks. Furthermore, the paper offers strategic recommendations for the structure and development pathway of China's electricity financial market, such as the integration of derivatives with the spot market and the introduction of innovative tools. It also designs tailored derivatives that meet the specific needs of the Chinese market to support the transition to renewable energy.

Further material is divided into several parts. Section 2 outlines the basic characteristics and functions of electricity financial derivatives. Section 3 reviews the operation of electricity financial markets in various countries. Section 4 summarizes the structural design of China's electricity financial market. Section 5 presents suggestions for the market's construction path. Discussions and conclusions are provided in Sections 6 and 7, respectively.

2. Electricity Financial Derivatives

Electricity financial derivatives play a pivotal role in modern electricity markets by offering market participants essential tools for managing price volatility and mitigating financial risks. As electricity prices fluctuate due to various factors, such as demand–supply imbalances, renewable energy variability, and grid constraints, these derivatives allow for better financial planning and risk mitigation. The key financial derivatives in the electricity market include futures, options, and contracts for difference (CFDs), each serving distinct purposes and offering tailored solutions for different market participants. These instruments provide flexibility in terms of contract length, settlement mechanisms, and hedging strategies, enabling market participants to navigate the inherent uncertainty of electricity pricing more effectively. In this section, we will explore the fundamental characteristics of electricity futures, power options, and CFDs, highlighting their significance in providing stability and predictability within an otherwise volatile market.

2.1. Electricity Forward Trading

Electricity forward trading is a contract in which the trading parties arrange to purchase or sell a certain quantity of electrical goods at an agreed price on a set date or within a certain period [8]. The contract terms and conditions are negotiated by the contracting parties. Electricity forward trading is a common over-the-counter traded commodity, and when the contract expires, it generally requires the settlement of the contract between the two parties.

2.2. Electricity Futures

Electricity futures refer to contracts for selling a certain quantity of electricity at a fixed price on a future date or time. The contracts are electricity financial derivatives with clear standards for trading units, delivery times, and the value of the underlying asset (see [21]).

Electricity futures contracts represent highly standardized derivatives based on traditional electricity forward contracts, exhibiting differences that are not absolute. This standardization allows electricity futures to be traded on exchanges, with the distinctions between the two types of contracts illustrated in Table 1.

Table 1. Differences between electricity forward contracts and electricity futures contracts.

	Electricity Forward Contract	**Electricity Futures Contract**
Participants	Electricity producers, operators and consumers	Hedgers, brokers, and speculators
Contract specifications	Not standardized. Negotiated between the two parties to the transaction	Standardized
Trading varieties	All Products	There are relative requirements
Cash deposit	Bilateral agreement	The bonding system is clear
Pricing methods	Bilateral agreement	On-market centralized bidding
Responsibility for performance	Stricter and will generally fulfill	Hedgeable unwinds
Trading risks	Credit risk	Price risk

Futures contracts play a significant role in the electricity market by assisting participants in managing price fluctuations through risk management, price discovery, and enhanced market liquidity. These contracts enable market participants to lock in future electricity prices, thereby reducing uncertainties and promoting transparent price formation. Additionally, the futures market offers a variety of investment opportunities, allowing investors to profit through arbitrage and speculation.

The electricity futures market provides market participants with flexible risk management tools through a diverse array of contract designs. These contracts can be classified based on their delivery timelines into day-ahead, seasonal, monthly, quarterly, and annual futures, thereby accommodating various hedging needs over different time spans [22]. Furthermore, electricity futures are categorized into two forms—cash-settled and physically settled—depending on the delivery mechanism. Additionally, based on the characteristics of the delivery periods, electricity futures are further segmented into baseload and peak load futures to reflect the specific attributes of supply and demand during different time intervals.

Compared to conventional commodity futures, the electricity futures market exhibits distinct features. Currently, the majority of electricity futures contracts globally utilize a cash settlement mechanism, with fewer contracts available for physical delivery. This phenomenon is primarily attributed to the unique nature of electricity as a non-storable commodity, which complicates and increases the risks associated with physical delivery. Moreover, physical delivery must consider the secure operation of the power grid and scheduling constraints, which can add uncertainty to contract fulfillment. In contrast, cash settlement simplifies the delivery process and reduces operational risks, enabling investors from non-electricity sectors to participate in the market without concerns regarding the practicalities of physical delivery.

2.3. Power Options

Options are versatile financial instruments that provide the holder with the right, but not the obligation, to buy or sell an underlying asset at a predetermined price on or before a specified future date [11]. These instruments are widely used across financial markets to hedge against price fluctuations and manage risk. In the context of the electricity market, power options offer participants the ability to trade electricity-related assets at specific times and prices, making them an essential tool for mitigating the inherent volatility of electricity prices. Electricity options can be classified based on several factors. One key distinction is the direction of the underlying asset. In this case, electricity options can either be call options, which give the holder the right to buy electricity-related assets, or put options, which grant the right to sell such assets. Another classification is based on the style of the option contract. European-style options can only be exercised at the expiration date, whereas American-style options allow the holder to exercise the contract at any point before or on the expiration date, offering greater flexibility in managing risk. Additionally, electricity options can be divided according to the type of underlying asset: electricity futures options and electricity spot options. Futures options pertain to storable electricity securities, allowing market participants to trade contracts that represent future deliveries of electricity. In contrast, spot options relate to non-storable electricity commodities, reflecting the real-time nature of electricity trading. Upon exercise, electricity option contracts convert into their corresponding electricity futures or spot contracts, ensuring the holder either receives or delivers electricity at the agreed-upon terms [14].

Beyond conventional options, certain operational directives in the electricity market can also function like options. For example, interruptible loads, which are a key component of demand-side management, can be seen as options (see [20,23]). In this scenario, consumers agree to reduce their electricity consumption during periods of high demand or grid stress in exchange for compensation, effectively treating the load reduction as an option for grid operators to alleviate pressure. Similarly, transmission rights in congestion management also resemble options, as they grant the holder the right to transmit electricity across constrained grid segments, helping to balance supply and demand across different regions. The flexibility provided by electricity options, whether in the form of traditional contracts or operational mechanisms like interruptible loads, plays a critical role in the efficient functioning of the electricity market. By offering a structured approach to managing price risk and operational uncertainty, these instruments enable market participants to respond proactively to the complexities and volatility inherent in the electricity sector. In Section 5, in response to the risks associated with renewable energy in China, this paper designs corresponding option products for use by China's power grid companies.

Power option trading and electricity futures trading exhibit two significant differences, as illustrated in Table 2.

Table 2. Differences between power option trading and electricity futures trading.

Difference	Content
No need for performance or closed out by hedging	Electricity forward contracts and futures contracts mandate the delivery of the underlying asset upon expiration; failure to fulfill this requirement may result in penalties. In contrast, electricity options grant purchasers the right, after paying a premium, to decide whether to exercise the contract, allowing them to make this determination based on prevailing market prices.
Asymmetric derivative asset	The returns from electricity futures trading are symmetric around zero, meaning their value can be either positive or negative. In contrast, the returns from electricity options are asymmetric, allowing for the potential of significant returns with relatively small investments.

2.4. Contract for Difference

A CFD is a medium- to long-term agreement established between two parties to mitigate spot market risks. Within this contract, the parties negotiate a contract price. If the electricity spot market price falls below the contract price, the buyer is still obligated to pay the price agreed upon with the seller. Conversely, if the electricity spot market price exceeds the contract price, the seller must refund the buyer for the amount exceeding the contract price [15]. The essence of electricity CFDs is to lock in the earnings of participants in the electricity spot market through a financial contract, thereby reducing the risks associated with significant price fluctuations in the spot market [24].

China's extensive geography is marked by considerable disparities in energy resource endowments and electricity demand among various regions. In regions abundant with renewable energy resources, electricity prices are notably susceptible to fluctuations in these resources [25]. CFDs can serve as a pivotal instrument in inter-regional electricity transactions, fostering the optimized allocation of electricity resources. For example, consumers in the economically vibrant eastern regions can mitigate price volatility by engaging in CFDs with power generation entities in the western regions, thereby also bolstering the utilization of renewable energy in those areas.

The comparison of the above electricity financial derivatives is shown in Table 3. This table presents the advantages, disadvantages, and application scopes of each product.

Table 3. The comparison of the electricity financial derivatives.

Types of Derivatives	Advantages	Disadvantages	Applicability
Electricity Forward Trading	Contract terms can be customized based on the specific needs of both parties to meet special trading requirements.	The risk of default is relatively high, and the lack of standardization results in poorer market liquidity.	Applicable to power generation companies and electricity users with long-term stable cooperative relationships, or market participants with clear expectations for specific power projects, to facilitate long-term matching of electricity supply and demand.
Electricity Futures	Strong price discovery function, effective hedging capabilities, and relatively good market liquidity.	A mature market environment is required; otherwise, it is susceptible to speculation, leading to abnormal price fluctuations.	Applicable to large power enterprises, electricity traders, and other entities that are sensitive to price risk and possess some market forecasting ability, and can be used for long-term electricity price risk management.
Power Options	High flexibility allows holders to choose to exercise or forgo their rights based on market conditions, effectively controlling risk.	There is a cost associated with the option premium, and market participants require a high level of expertise and experience to operate effectively.	Suitable for various market participants; for example, power grid companies in electricity-deficient provinces can engage in call option trading, while renewable energy companies in sending provinces can conduct put option trading, for risk hedging and price management in the short term or for specific periods.
Contract for Difference	Effectively isolates the risk of price fluctuations in the spot market and simplifies the trading process.	It relies on accurate price reference benchmarks; any issues with the benchmarks may lead to disputes in contract execution.	In an environment with significant price fluctuations in the electricity market, it is suitable for participants who wish to lock in price differences and reduce price risks.

3. Functioning of Electricity Financial Markets in Various Countries

Electricity financial markets across the globe have evolved to address the unique challenges posed by the electricity sector, particularly its price volatility and non-storability. Different countries and regions have developed distinct models for managing risk and enhancing market efficiency, often leveraging financial derivatives such as futures, options, and CFDs. These tools help market participants hedge against price fluctuations, stabilize revenues, and foster competitive market environments. This section explores the functioning of electricity financial markets in several key regions, including the United States, Nordic countries, Australia, Singapore, and China, highlighting the different approaches and instruments used to mitigate risks and improve market liquidity. By examining these international markets, we can draw valuable lessons for the development of an efficient electricity financial market in China.

3.1. U.S. Electricity Financial Markets

The PJM electricity financial market in the United States has introduced financial derivatives to meet the needs of its members and to mitigate price risks (see [21,26]). Financial products within this market include CFDs, virtual trading contracts, and Financial Transmission Rights (FTRs). The CFDs in the PJM market do not involve physical delivery; instead, they are settled through cash payments based on price differences. Virtual trading contracts allow participants to simulate actual electricity trades in the PJM market without the need for physical electricity delivery. FTRs serve as tools to hedge against the impact of transmission congestion on pricing. Holders of FTRs can utilize these rights to offset price differentials during periods of congestion on transmission lines. If inadequate transmission capacity in a certain region leads to increased electricity prices, participants holding FTRs for that region can generate income from these rights, thereby mitigating the cost increases associated with price hikes. The FTR market in PJM is well-developed, consisting of long-term, annual, and monthly auction markets, as well as a secondary market. The relationships and distinctions among the long-term, annual, and monthly auction markets are illustrated in Table 4.

Table 4. Differences among three auction markets.

Product Parameters	Long-Term FTR Auction	Annual FTR Auction	Monthly FTR Auction
Subject of Auction	FTR over three program years	FTR for the next program year	FTR for the next three program months
Auction Capacity Value	Assuming that the remaining transmission capacity after the FTR is equivalent to the value of the auction proceeds allocated in the previous year	Annual available transmission Capacity minus Approved Long-Term FTR Capacity	Remaining transmission capacity after removing long-term, annual FTR sales
Round	3 rounds	4 rounds	1 round
FTR Product Categories	Peak FTR, trough FTR, and 24 h FTR		

The FTR secondary market is not an auction market; it is exclusively used for trading Financial Transmission Rights (FTRs) that have already been transacted in the auction market.

The PJM market employs a collaborative model that separates the physical delivery market from the electricity financial market. By introducing Financial Transmission Rights and virtual trading contracts, this approach not only addresses the trading risks associated with regional grid congestion but also enhances market liquidity and competitiveness. Similarly, China's extensive power grid is confronted with a suite of challenges related to inadequate transmission capacity and congestion. These issues not only impede the efficient distribution of electricity but also pose a threat to the stability of power supply. To surmount these challenges, the introduction of FTRs emerges as an effective solution. FTRs can offer economic incentives for grid investment, attracting additional funding for the construction and enhancement of power infrastructure.

3.2. Nordic Electricity Finance Market

In the early stages of the Nordic electricity financial market, physical contracts were predominantly traded, requiring actual electricity delivery. However, due to operational constraints of the grid and the growing demand for market-driven transactions, pure physical delivery has increasingly failed to meet the developmental needs of the market. Consequently, a shift towards cash settlement has occurred, with the introduction of financial instruments such as futures contracts, contracts for difference, and options (see [24,27]).

Currently, the Nordic electricity financial market incorporates four types of futures and options contracts: monthly cash-settled base load futures, daily cash-settled base load futures, annual base load options, and quarterly base load options. These instruments ensure that market transactions are aligned with the actual operation of the electricity system. Generally, trading for Nordic electricity futures contracts concludes on the trading day prior to the spot delivery day for monthly, quarterly, or annual contracts. The trading timeframe for electricity options aligns with that of futures contracts, typically ending on the trading day before the delivery day. The timing of these transactions in relation to the spot market is illustrated in Figure 1.

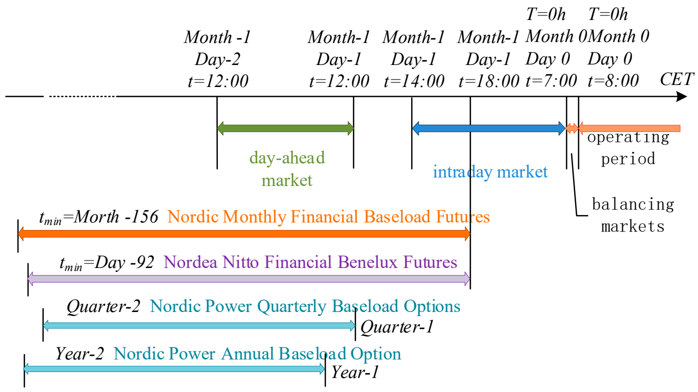

Figure 1. Timing of Nordic power futures options to spot markets. (Adapted from: [27]).

Nordic contracts for difference differ from traditional contracts, as they are designed for cross-regional and cross-national markets. Given the price disparities among countries, these contracts aim to mitigate the price risk arising from grid congestion, using the differential between regional prices and system prices as a reference for settlement.

The Nordic markets use an integrated electricity finance model, where the organization of trading in the electricity finance market and the organization of the electricity spot market are the same. The Nordic electricity market, as a regional consortium, has a solid price benchmark, a huge number of transactions, and economies of scale, which help to reduce transaction costs.

In the realm of electricity market systems, the Nordic electricity market encompasses spot markets, financial markets, and over-the-counter transactions. China's electricity market, similarly structured, is composed of spot and medium- to long-term markets. In terms of market models, China's current pilot programs adopt a centralized approach, with medium- to long-term markets settled in cash without physical delivery of electricity. This aligns with the Nordic financial market, where derivatives such as power futures and options are also cash-settled, mirroring China's model. Regarding the developmental trajectory, the Nordic electricity financial market was initiated following the establishment of their spot markets. China has already established multiple spot market pilots, with formal operations in Guangdong and Shanxi's provincial spot markets. The timeline of China's electricity market construction aligns with the Nordic region's financial market development phase. The Nordic electricity market shares similar developmental contexts with China's current electricity market, making the Nordic integrated model highly relevant and offering significant insights for China's market development.

3.3. Australian Electricity Finance Market

The primary financial derivatives in Australia's National Electricity Market (NEM) include electricity futures, electricity options, and CFDs [28,29]. Electricity futures are traded on the Australian Stock Exchange (ASX), while CFDs are executed as bilateral over-the-counter (OTC) transactions. Electricity options are available for both exchange trading and OTC trading. The exchange-traded electricity options are standard European options, whereas the OTC options tend to be more complex. The relationship between the Australian electricity market and the electricity financial market is illustrated in Figure 2.

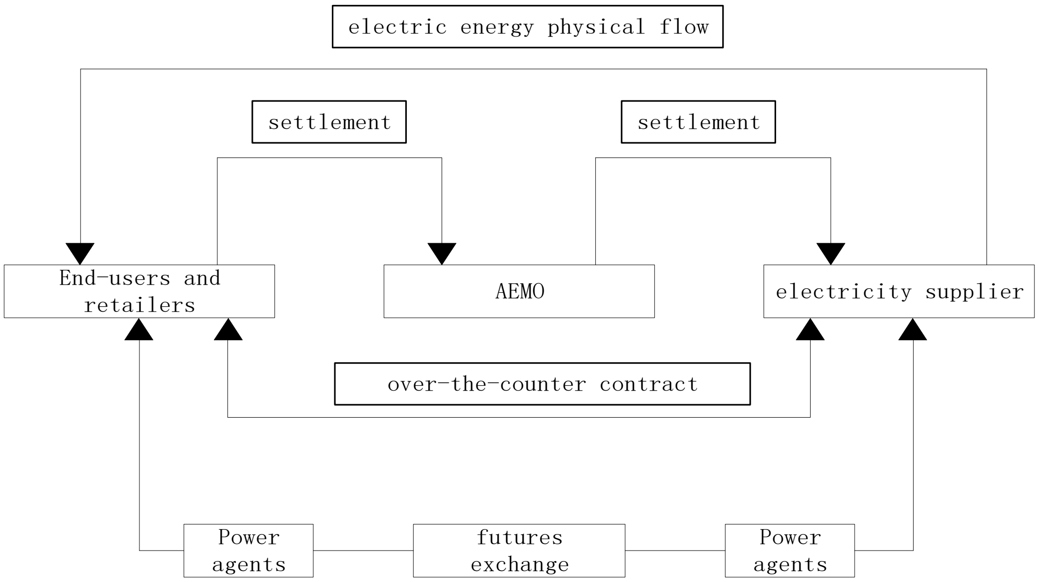

Figure 2. Relationship between the Australian electricity market and the electricity finance market. (Adapted from: [29]).

CFDs in Australia represent agreements between market participants that are used to hedge against price fluctuations relative to the reference node prices published by the Australian Energy Market Operator (AEMO). While CFDs dominate the OTC market, offering opportunities for price locking and risk management, their over-the-counter nature results in weaker liquidity and a lack of standardization. The changes in the share of CFDs within the Australian OTC electricity market are illustrated in Figure 3.

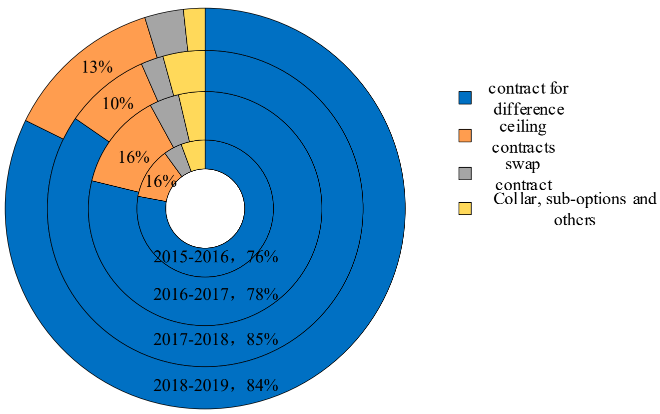

Figure 3. Changes in the share of CFDs in the Australian OTC electricity market.

Australia employs a collaborative electricity financial market model, where electricity futures and options are differentiated by state, and the operational environments are independent, exhibiting distinct regional characteristics.

At present, China has essentially established a market structure characterized by the separation of generation from transmission and distribution, with the pricing of electricity transmission and distribution subject to government approval and regulation. This aligns broadly with the reform direction in Australia, where the electricity industry in each state has largely achieved the separation of generation, transmission, distribution, and sales. However, there are still certain differences in the degree of market liberalization—since

2008, the Australian government has decided to open up all customer participation in electricity trading—and the depth of reform in each sector, with Australia having separated the distribution and retail sides. China can refer to Australia's market as it further reforms its electricity market.

3.4. Singapore Power Finance Market

In Singapore, the primary electricity financial derivatives are electricity futures and CFDs [30]. The electricity sector is characterized by high concentration and relatively stable load. In 2015, the Singapore Exchange (SGX) introduced electricity futures to mitigate price volatility in the spot market, allowing retailers without generation assets to enter the market and hedge against potential spot price risks through futures contracts. The electricity CFDs in Singapore are signed between the Energy Market Authority and generators, effectively functioning as government-sanctioned agreements aimed at limiting the market power of generators to enhance market efficiency.

Singapore's electricity financial market has attracted a diverse range of participants, including local and international players, such as generation companies, financial institutions, and traders, creating a competitive landscape. China could further relax market entry requirements to draw in more financial institutions and non-traditional power companies, enhancing market efficiency through increased competition. For instance, allowing more banks and investment firms to participate in trading electricity financial products could inject new vitality into the market.

3.5. China's Electricity Financial Market

During the 13th Five-Year Plan period, China made significant strides in its electricity market transactions. By the end of 2020, the national market-oriented trading volume surpassed 30,000 billion kWh, with a developing framework primarily based on medium- and long-term trading supplemented by a nascent spot market and initial auxiliary services. The liberalization of the retail market led to the emergence of active wholesale and retail markets.

As of October 2021, pilot settlements in eight spot markets, including Guangdong and Zhejiang, were underway, while the electricity financial market remained conceptual [31]. To mitigate price risks, particularly in a highly competitive environment, the introduction of suitable electricity financial derivatives is crucial for effective risk management. From a comprehensive perspective of the operational experiences and lessons of the electricity financial derivatives markets in the aforementioned typical countries and regions, the issues that need to be concerned when promoting the construction of China's electricity financial derivatives market are shown in Table 5.

Table 5. Key issues for promoting the construction of China's electricity financial derivatives market.

Issues	Experience Summary
The regional characteristics of electricity financial derivatives	The United State, Australia, and other countries and regions have all implemented regional divisions in their market construction. Currently, China's electricity spot market operates primarily at the provincial level. Consequently, when developing the electric power financial market, it may be advantageous to commence operations at the provincial level. This approach can effectively adapt to the existing market structure and establish a foundation for subsequent expansion and improvement.
The timing and sequence of building an electricity financial market	The establishment of a mature electricity spot market is a prerequisite for the operation of the electricity financial derivatives market. In most countries and regions, the electricity financial market is initiated only after several years of operation in the spot market. A well-functioning spot market is essential for facilitating electricity financial transactions. Currently, the ongoing construction of electricity markets in China can include preparations for the development of the electricity financial market, allowing for the timely introduction of electricity financial derivatives once the spot market has matured.

Table 5. *Cont.*

Issues	Experience Summary
Selection of delivery methods for electricity financial derivatives	Physical delivery is a common method of settlement for futures and other derivative contracts in many commodity markets. However, it is rarely used in the electricity financial derivatives market. Except for a few electricity futures with physical delivery on the EEX in select countries, the majority of electricity futures and options in other regions and countries are settled through cash settlement. Applying physical delivery to the electricity financial market can present several challenges, primarily in the difficulty of decomposing long-term contract volumes during actual physical execution and the difficulty of aligning with market clearing outcomes in centralized market designs. Therefore, when conditions are ripe for the introduction of electricity futures, active policy reforms should be advanced to ensure that electricity financial derivatives can be smoothly settled through cash settlement.

4. Structural Design for China's Electricity Financial Market

In the electricity financial derivatives market, in addition to the original participants from the electricity spot market—such as generation companies, retail electricity suppliers, electricity consumers, grid enterprises, and electricity trading institutions—financial trading institutions and investment entities or individuals without actual generation assets are also included. The interactions among various participants in both the electricity spot market and the electricity financial market are illustrated in Figure 4.

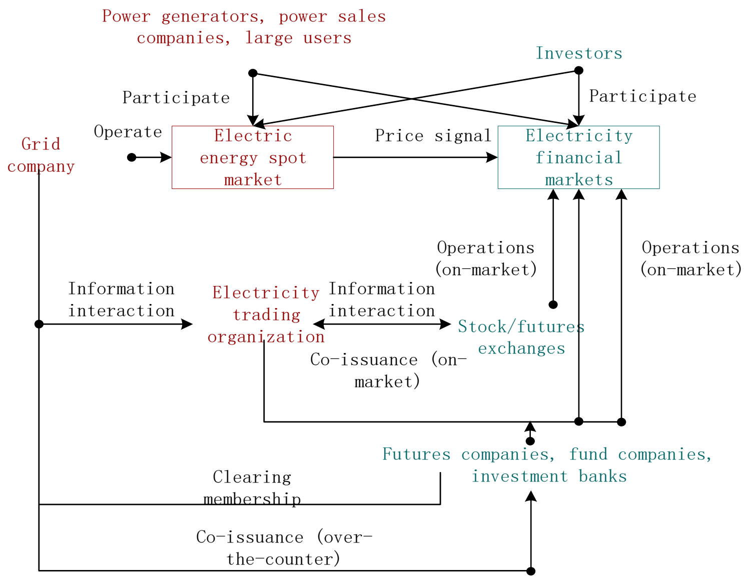

Figure 4. Interaction of power financial derivatives market players.

4.1. Forms of Transaction Organization

Based on the operational experiences of typical foreign markets, electricity financial transactions are primarily organized in two models: one where electricity financial contract trading and spot trading operate independently, and another where they are integrated into a single operational framework.

Considering the current state of transaction organization in China's electricity market, a partial integration of certain electricity financial products with the spot market could be adopted. For non-standard products such as medium- and long-term differential contracts, the existing model can continue to be led by electricity trading institutions. Their in-depth understanding of the market enables effective organization and management of transactions, playing a crucial role in fostering a positive industry atmosphere and guiding innovation in electricity financial derivatives. China's medium- and long-term electricity market is already relatively mature, with trading institutions possessing substantial organizational experience and a solid foundation for market operations.

For standardized products such as electricity futures and options, given the requirements and restrictions of relevant regulations (e.g., the Futures Trading Management Regulations), these products should be traded on futures exchanges approved by the national futures regulatory authority. Grid enterprises can collaborate with futures exchanges and electricity trading institutions to introduce a diverse range of electricity futures and options products. The organization of trading, market clearing, and settlement for these products will primarily be managed by the futures exchanges.

4.2. Forms of Settlement Organization

The settlement process plays a critical role in the functioning of electricity financial markets, ensuring the fulfillment of contractual obligations and facilitating smooth transactions. For non-standardized products such as medium- and long-term CFDs, or other financial derivatives that are closely tied to grid operations and necessitate physical delivery, the current settlement model is expected to remain in place. This model typically relies on grid enterprises to manage the settlement process, given their deep involvement in and understanding of the operational dynamics of the electricity system. These grid enterprises are best positioned to handle the complexities of physical delivery, especially for products that require precise coordination with grid operations, such as those involving the generation, transmission, or consumption of electricity. By centralizing settlement under the authority of grid enterprises, this model not only ensures smoother execution but also offers significant cost savings for market participants by reducing administrative burdens and streamlining the settlement process. The reliance on grid enterprises is particularly effective for market participants directly involved in the electricity supply chain, such as power generators, electricity retailers, and large end-users. For these entities, grid enterprises can provide a settlement mechanism that ensures the physical delivery of electricity, minimizes transaction costs, and improves overall settlement efficiency. Since these market participants are engaged in physical electricity trading, maintaining a close relationship with grid enterprises for settlement ensures that physical delivery constraints, such as grid capacity and transmission limitations, are fully accounted for in the process.

However, for standardized financial products, such as electricity futures and options, the settlement process must adapt to the more structured and regulated nature of these products. Unlike non-standardized products, which often require tailored settlement approaches, standardized products are typically traded on formal exchanges, where the settlement process is managed by the exchange itself. In this case, the futures exchange takes full responsibility for overseeing the settlement of trades, ensuring that all financial and contractual obligations are met. This centralized approach is essential for maintaining the integrity of the market, providing transparency, and ensuring that standardized contracts are executed efficiently and reliably. Grid enterprises, while traditionally focused on physical delivery, can play an extended role in the settlement of standardized products by becoming settlement members of futures exchanges. In this capacity, grid enterprises would offer comprehensive settlement services that cover both the physical spot market and financial derivatives such as futures and options. By integrating these roles, grid enterprises can provide a one-stop settlement solution for market participants, particularly those involved in both the physical and financial aspects of electricity trading. This would enable power generators, electricity retailers, and end-users to manage their contracts more effectively, whether they are trading physical electricity or financial instruments.

This hybrid settlement approach—where grid enterprises handle non-standardized product settlements and futures exchanges manage standardized product settlements—offers a balanced and efficient system for participants in the electricity financial market. It ensures that all market participants, regardless of their focus on physical delivery or financial speculation, can rely on specialized, well-structured settlement processes that meet their specific needs. In doing so, this model is expected to improve overall settlement efficiency, enhance participant experience, and reduce risks associated with mismanagement or settlement failures, ultimately contributing to a more robust and reliable electricity financial market.

4.3. Forms of Regulatory Organization

The electricity financial market is inherently complex, as it merges the principles of commodity trading with financial derivatives, creating a unique environment that demands specialized regulatory oversight. The nature of electricity as a commodity, with its non-storability and real-time delivery requirements, presents challenges distinct from traditional financial markets. As such, the regulatory framework governing electricity financial markets must not only align with general financial market standards but also account for the specific operational characteristics of electricity products, such as their volatility, supply–demand dynamics, and reliance on grid infrastructure. To ensure market stability and protect participants, standardized exchange-traded electricity financial derivatives, including electricity futures and options, fall under the jurisdiction of the China Securities Regulatory Commission (CSRC). The CSRC is responsible for regulating the broader financial markets in China, ensuring that financial derivatives adhere to transparent trading practices, risk management protocols, and investor protections. The CSRC's role is critical in maintaining the integrity of the electricity futures and options markets, as these standardized products are widely traded on exchanges and attract a broad range of participants, including speculators, institutional investors, and companies directly involved in the electricity sector. The regulation of these products by the CSRC ensures that trading is conducted in a manner that minimizes systemic risks, such as market manipulation or excessive speculation, while providing clear rules on margin requirements, settlement procedures, and disclosure obligations. In China, the evolution of the electricity financial derivatives market is subject to various risks, including price volatility, escalating credit risk, impediments to liquidity, stringent legal compliance, and heightened operational risks. Among the numerous risks, price risk is the core risk that deserves the most attention. To mitigate these challenges, China's futures exchanges may implement several risk management systems to prevent and control the aforementioned risks.

1. Margin system: Margin is the capital that traders are required to deposit when engaging in futures trading, ensuring their ability to fulfill contractual obligations. By adjusting margin requirements, futures exchanges can effectively manage market risk. During periods of high volatility or increased risk, raising margin requirements compels traders to allocate more funds, thereby reducing excessive speculative behavior and minimizing the risk of defaults.
2. Price ceiling and floor system: The price limit system establishes boundaries on the price fluctuations of futures contracts within a single trading day. This mechanism helps maintain market order, preventing drastic declines or explosive increases in prices, while providing traders with sufficient time to reassess market risks.
3. Position limit system: The position limit system refers to the restrictions imposed by futures exchanges on the number of contracts that members and clients can hold. By capping the position size, this system helps to disperse market risk and prevents excessive concentration of market power among a small number of participants.
4. Mandatory liquidation system: When a trader's margin falls below the required level and they fail to replenish it within the specified time frame, or if they violate other exchange regulations, the exchange will initiate a forced liquidation of their positions. This timely action helps mitigate credit risk associated with insufficient margins, ensuring the safety of funds and the integrity of market transactions.

However, the regulation of non-standardized products, such as FTRs and CFDs, requires a different approach due to their close ties to the physical electricity market and grid operations. Unlike standardized products, which are highly structured and traded on exchanges, non-standardized financial derivatives are often tailored to specific market conditions or regional requirements. These products may involve bilateral agreements between market participants and are typically less liquid than their standardized counterparts.

For example, FTRs are used to manage the financial risks associated with transmission congestion on the grid, and CFDs help lock in price differences between spot and contract prices. Given their strong connection to physical electricity flows and their role in grid management, the oversight of these non-standardized products is better suited to the National Energy Administration (NEA), which already governs medium- and long-term trading within the electricity market. The NEA, as the primary regulatory body for China's energy sector, has the expertise to oversee products that require close coordination with grid operations and physical electricity delivery. Its involvement ensures that these financial products do not undermine grid stability or interfere with the secure operation of the electricity market. The NEA's regulatory framework for medium- and long-term electricity trading can be applied to oversee non-standardized financial derivatives, ensuring that these products align with the broader objectives of grid reliability, price stability, and risk management. The NEA's regulatory oversight includes monitoring contract terms, settlement mechanisms, and the interaction between financial contracts and physical electricity markets to mitigate potential risks that could arise from poorly coordinated or speculative trading.

5. Suggestions for the Construction Path of China's Electric Financial Market

In order to facilitate the development of China's electric power financial market, it is essential to devise a well-defined roadmap. By leveraging insights from successful international experiences and integrating them with the specific characteristics of the domestic market, we can investigate potential market structures and reformulate products that align with the needs of our country. This approach aims to enhance the efficiency and stability of the market, while also fostering the growth of power financial derivatives in a sustainable manner.

5.1. The Construction Path of China's Electricity Financial Market System

The initial phase of developing the electricity financial market is marked by the commencement of the electricity spot market. During this stage, electricity financial derivatives primarily serve to ensure the secure and stable operation of the spot market, addressing the hedging needs of market participants and aiding in the refinement of the spot market's regulatory framework.

The mid-stage of electricity financial market development in China is characterized by several years of stable operation of the electricity spot market, during which the market's scale and price volatility have met the basic requirements set by the Securities Regulatory Commission for the establishment of futures contracts, with the contracts for difference market functioning smoothly.

By 2030, the electricity spot market in China will have been in operation for over a decade, effectively fulfilling the requirements for further development of the electricity financial market. Coinciding with the "carbon peak" target in 2030, the country is vigorously promoting the development of renewable energy. Due to their clean and renewable characteristics, renewable energy sources play a significant role in energy conservation and emission reduction. However, technical limitations in wind and solar power generation systems, such as the inability to regulate voltage and frequency, may pose challenges to grid stability. Additionally, the instability of wind speed and sunlight results in fluctuations in the output power of renewable energy, potentially impacting price stability in the electricity market.

At the same time, government policy adjustments in the energy sector, including carbon taxes, subsidy policies, and emission standards, directly affect the costs of electricity production and pricing. The uncertainty surrounding these policies complicates companies' ability to predict future electricity price trends, which may lead to increased prices after 2030, subsequently raising electricity costs for consumers.

This also makes it possible for electricity market players to face three aspects of price risk in the future electricity spot market, as shown in Table 6.

Table 6. Possible price risks faced by electricity market players.

Risks	Elements
Energy price risk	In the electricity market, power generators, electricity sales companies, and consumers face price risks due to fluctuations in fuel costs or changes in the overall supply and demand dynamics.
Blocking price risk	A blockage in the transmission network in the electricity market results in an additional purchase price that the selling company or customer has to pay in the spot market compared to what they would have had to pay in the absence of the network blockage.
Day-ahead–real-time two-tier market price risk	In the spot market, discrepancies between the day-ahead market and the real-time market regarding supply and demand conditions and boundary constraints can lead to price deviations. As a result, the quantities of contracts marked in the real-time market and the day-ahead market become exposed to price risks associated with the real-time market.

Therefore, considering the price risks from the aforementioned three aspects, the mid-term development of China's electricity financial market system should primarily focus on a combination of standardized on-exchange financial derivatives, represented by electricity futures and options, and differentiated financial derivatives, such as contracts for differences. In the medium to long term, CFDs are primarily utilized to mitigate both energy price risks and congestion price risks within the electricity market. Electricity futures and options are predominantly employed to address energy price risks. Furthermore, the introduction of FTRs, in conjunction with a centralized market model, should be contemplated as a strategic tool for managing congestion price risks. The implementation of virtual bidding as a spread-risk management instrument can effectively cover potential market risks, thereby enhancing the stability and efficiency of the electricity market's operation.

A key indicator of the long-term development of China's electricity financial market will be the mature operation of electricity futures, alongside the enhancement of relevant laws and regulations governing electricity commodities and the clarification of over-the-counter trading standards. And the construction path of China's electricity financial market system is shown in Figure 5.

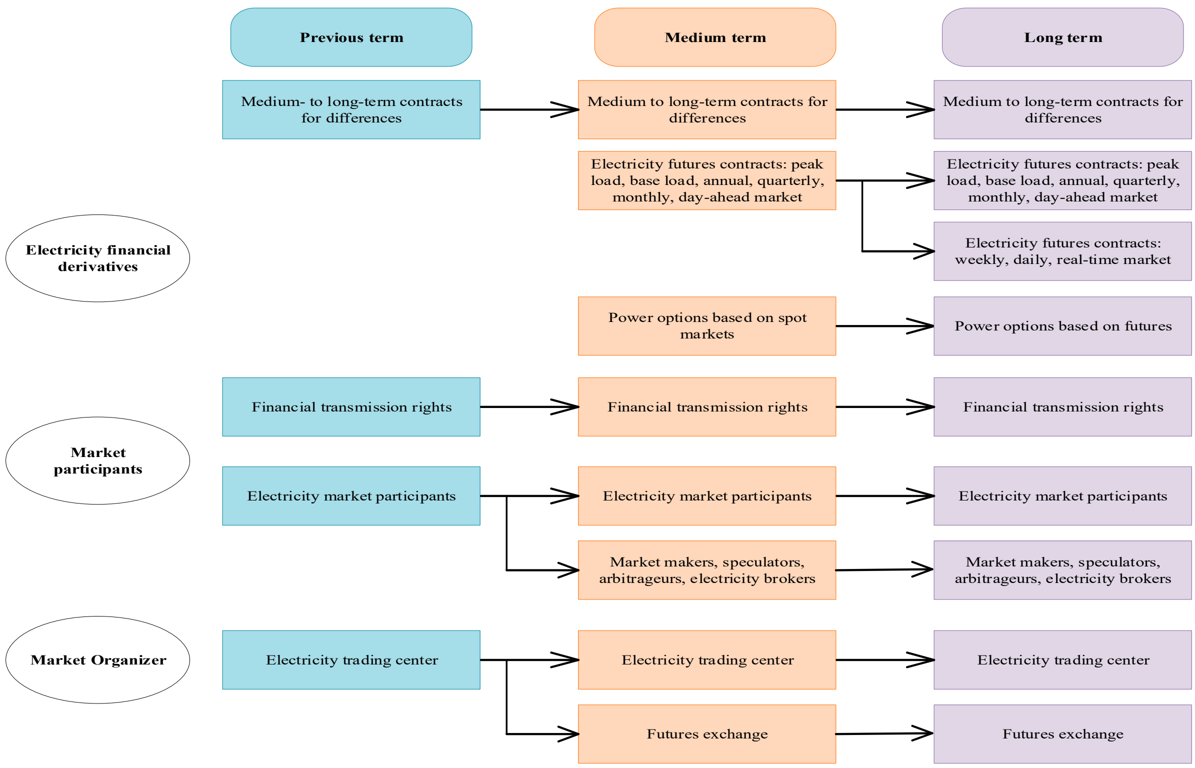

Figure 5. The construction path of China's electricity financial market system.

In this phase, the over-the-counter trading market should transition from an intermediary system to a market-making system, with market makers responsible for the operation and management of the market, providing bid and ask price information. Market makers will maintain market liquidity through continuous buying and selling. Furthermore, standardized and diverse market operation modes for electricity futures and options should be implemented, facilitating the establishment of a complementary electricity market system that integrates both the electricity spot market and the electricity financial market.

5.2. CFDs and Power Generation Rights Trading

Currently, certain trading varieties in the electricity market have already shown signs of financial derivatives. In the existing spot market pilot programs, a centralized clearing model based on full electricity volume is typically used. Medium- to long-term contracts do not require physical execution; instead, they are settled based on a price difference with the spot market at a unified settlement point, making these contracts akin to financial derivatives in nature.

In the context of the accelerating pace of power reform, the development direction of medium- and long-term CFDs is as follows:

(1) The trading periods are more flexible. To accommodate a new power system led by renewable energy, medium- to long-term contracts could be designed with annual or longer terms. These contracts would address the recovery needs of renewable investments and support the green energy demands of consumers.

(2) The benchmark prices are more flexible. Market participants could choose various reference prices, such as spot prices at different nodes, regional average prices, or overall market averages. Additionally, benchmarks could be derived from the energy price differential relative to node prices, drawing inspiration from European electricity markets.

(3) The contract prices are more flexible. Contract prices could be categorized into fixed and variable pricing. In the market's early stages, fixed-price contracts could help mitigate price volatility risks. As market fluctuations intensify, variable pricing contracts could be introduced, linking them to spot market prices for a defined range of movement, thereby achieving the goal of "shared risks and shared benefits".

To respond to national energy conservation and emission reduction initiatives, the introduction of power generation rights trading (on a monthly, weekly, or daily basis) is proposed during the initial stages of market construction. This trading mechanism facilitates financial transactions that allow power generation companies to substitute contractual electricity production through market mechanisms. Typically, the annual initial power generation rights or shares for various generation units are determined in the primary market, followed by transfers or purchases in the secondary market through centralized matchmaking or bilateral/multilateral negotiations. This process enables electricity substitution between different power generation companies, allowing efficient and environmentally friendly generation units to replace less efficient, high-pollution thermal power plants. Consequently, energy utilization efficiency is enhanced, and environmental pollution is reduced. This mechanism is regarded as a valuable financial derivative that encourages the development of the electricity market.

5.3. Options Trading

Once the electricity futures market matures, the development of on-market electricity options products can be pursued. This paper proposes two concepts for electricity options products tailored to the specific conditions of our country: intra-provincial options and interruptible load options.

1. The balance of electricity supply and demand in each province is significantly influenced by natural factors such as temperature and precipitation, as well as economic uncertainties. Compared to the relatively small price cap in the intra-provincial spot market and the typical settlement volume of less than 10%, the transaction volume in

the inter-provincial spot market exhibits greater uncertainty, accompanied by larger price fluctuations. This scenario presents participants in the inter-provincial spot market with considerably higher cost risks. Electricity option trading, with its inherent insurance mechanism, is particularly suitable as a complementary trading product for the current inter-provincial electricity futures market, providing a risk management mechanism for participants exposed to price volatility, especially extremely high prices. Option trading can be conducted on existing electricity trading platforms.

Currently, inter-provincial spot market transactions are organized through the State Grid Control Center and its regional and provincial control center platforms, with settlement occurring at the Beijing Power Trading Center and its regional branches, as well as provincial trading institutions. The electricity control centers and trading institutions share foundational information such as market participant registrations. Initially, two trading varieties for inter-provincial electricity options may be established. The first is inter-provincial monthly electricity spot options trading, primarily suitable for electricity grid companies in provinces facing shortages to engage in call option trading. The second is seasonal midday spot options trading, mainly applicable for renewable energy enterprises in exporting provinces to conduct put option trading. Considering the characteristics of electricity supply and demand balance, both options will adopt an American-style format, allowing buyers to exercise their options at any time prior to the expiration date.

2. The liberalization of the electricity market's sales side provides channels for demand-side resources to participate actively in electricity markets. Virtual Power Plants (VPPs), as virtual entities utilizing advanced information and communication technology along with control frameworks, facilitate interaction with demand-side resources, allowing these resources to participate freely in electricity market transactions.

The essence of interruptible loads lies in granting system dispatchers the right to interrupt a portion of the load under specific circumstances to alleviate grid pressure. However, in a market environment, load reductions should be voluntary on the part of users, who can sell their right to interrupt loads at an appropriate price to dispatchers, with the proceeds compensating for losses incurred due to load shedding. This can be viewed as a barrier option. The dispatch center pays the corresponding premium to gain the authority to reduce user loads; when load levels are tight, the dispatcher can interrupt the user's load, and when levels are stable, the dispatcher refrains from interruption, thereby incurring only the loss of the premium paid.

The market-based pricing of options on interruptible loads is a crucial aspect that enables their effective participation in the market. The remaining elements of the contract formulation are largely consistent with those found in most electricity option contracts. The pricing methodology is consistent with that presented in reference [8]. Specifically, the tariff modeling for interruptible loads is first carried out by means of BS modeling. Then, the Monte Carlo simulation is applied to this tariff model to obtain the tariffs of the interruptible load option expiration date for specific samples. Subsequently, the option value of this sample is calculated. By repeating the above operations of modeling and obtaining values through simulation multiple times, the option values of multiple samples are obtained. Finally, the average of these sample option values is taken as the final option price, thus realizing the effective evaluation of the option price of interruptible loads.

At present, in some of the electricity spot market pilots, the generation side employs nodal tariffs while the customer side utilizes a uniform settlement point price (i.e., the weighted average price of the nodal tariffs). Consequently, customers are not currently exposed to the risk of blocking, and the issue of blocking surplus allocation in the market does not arise. As the market reform progresses, the customer side will also adopt the nodal tariff mechanism, which will result in the emergence of two key issues: blocking price risk and blocked surplus distribution. In this context, the introduction of financial transmission rights can serve as a blocking risk management tool for market participants, addressing the aforementioned issues and facilitating the distribution of blocked surpluses in the spot market.

Options trading offers multiple specific benefits for participants in China's electricity market. In terms of risk management, it effectively addresses the price volatility risks in inter-provincial spot markets. Its flexible exercise strategies can adapt to the changes influenced by natural and economic factors. For instance, monthly inter-provincial electricity spot options are well-suited for grid companies to manage shortages, while seasonal midday spot options benefit renewable energy enterprises. Additionally, leveraging existing trading platforms can help reduce costs.

Regarding market trading and costs, options provide demand-side resources with additional revenue streams. For example, interruptible load options allow users to sell their interruption rights for compensation. Furthermore, by diversifying trading products, options enhance market activity and efficiency, supporting the advancement of electricity market reforms and addressing the challenges associated with implementing node pricing mechanisms on the customer side.

6. Discussion

This paper breaks new ground by shifting the research focus from the traditional, isolated analysis of renewable energy technologies and specific electricity market mechanisms to the development of electricity financial markets. It underscores the critical role of financial derivatives in addressing the challenges faced by electricity markets during the energy transition. Unlike studies confined to a single country's context, this paper draws on experiences from a diverse array of nations, including the United States, Nordic countries, and Australia. It critically assesses their applicability to the Chinese market, identifying several issues that need to be addressed for China's electricity market, such as the regional characteristics of electricity financial derivatives.

The paper presents a methodology for constructing an electricity financial market tailored to China's unique national conditions, outlining the organizational structures required for the development of China's electricity market, including settlement, trading, and risk management within the financial framework. Furthermore, while many studies broadly discuss electricity financial derivatives, this paper specifically proposes derivative schemes designed to meet the needs of the Chinese market. It benchmarks the development of electricity financial derivatives along a timeline, proposing short-, medium-, and long-term products that are adapted to the market's evolution. The introduction of inter-regional options and interruptible load options aims to mitigate the price volatility risks associated with renewable energy in China. This problem-oriented research philosophy provides concrete and actionable solutions for advancing China's electricity financial market.

For policymakers, this paper offers a comprehensive framework and strategic direction for constructing an electricity financial market, serving as a reference for informed decision-making. It highlights the importance of an efficient electricity financial market in mitigating renewable energy risks and facilitating the energy transition, encouraging policymakers to guide market participants in using financial instruments for effective risk management to ensure the success of the energy transition.

7. Conclusions

Serving the real economy is the fundamental goal of financial development in China. Therefore, when constructing the electricity financial market system, priority should be given to risk management needs, emphasizing the hedging function of electricity financial derivatives rather than speculative activities. Within this framework, and considering the current state of electricity reforms, future development trends, and market management requirements, this paper presents construction ideas for China's electricity financial market, focusing on market structure and development pathways. Additionally, it explores the design of electricity financial derivatives tailored to China's unique circumstances.

Designing and operating an electricity financial market is indeed a challenging endeavor. This paper's research and analysis on key issues in the development of China's electricity financial derivatives market, along with proposed solutions, are based on the summarization and theoretical extrapolation of international experiences. However, further in-depth exploration is required, particularly regarding the integration of these derivatives with the spot market. Further research should be devoted to the study of the following questions: the pricing mechanisms of electricity financial market products based on the spot market, the synchronization of electricity financial product timing with the physical delivery cycles of the electricity market, and the coordination of fund flows and settlement procedures of electricity financial products with the actual settlement and delivery processes of the electricity market.

Author Contributions: Conceptualization, H.F. and Y.Z.; methodology, Z.L.; formal analysis, Y.W.; investigation, S.C.; writing—original draft preparation, H.F.; writing—review and editing, Y.Z. and H.F.; supervision, K.W.; project administration, C.F. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: The data presented in this study are available on request from the corresponding author due to project requirements.

Conflicts of Interest: Authors Hao Feng, Yidi Zhang, Zhou Lan, Kun Wang and Yizheng Wang were employed by the company Economic Research Institute of State Grid Zhejiang Electric Power Company. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

References

1. Fa, Z. Opinions of the Central Committee of the Communist Party of China and the State Council on Further Deepening the Reform of the Electric Power System. *Wind. Energy Ind.* **2015**, *4*, 19–23.
2. Xiao, Q.; Yu, Y.; Jing, Z. Discussion on the objectives, structure, and key issues in the construction of the electricity market in China. *Glob. Energy Interconnect.* **2020**, *3*, 508–517.
3. Schiro, D.A.; Zheng, T.; Zhao, F.; Litvinov, E. Convex hull pricing in electricity markets:formulation, analysis, and implementation challenges. *IEEE Trans. Power Syst.* **2016**, *31*, 4068–4075. [CrossRef]
4. Xi, J. Statement by H.E. Xi Jinping President of the People's Republic of China At the General Debate of the 75th Session of the United Nations General Assembly. *Peace* **2020**, *3*, 5–7.
5. Wang, C.; Lei, X.; Liu, L.; Li, Z. Design of Short-term Renewable Energy Integration Mechanism in the Electricity Market Transition Period. *J. Glob. Energy Interconnect.* **2018**, *1*, 565–573.
6. Zhang, Z.; Li, R.; Li, F. A novel peer-to-peer local electricity market for joint trading of energy and uncertainty. *IEEE Trans. Smart Grid* **2020**, *11*, 1205–1215. [CrossRef]
7. He, M.; Wang, J. Experience of Foreign Electricity Futures Market Development and Its Implications for China. *Price Theory Pract.* **2017**, *12*, 22.
8. Zhang, X.; Wang, X. Power Finance Market Overview. *Autom. Electr. Power Syst.* **2005**, *20*, 5–13+23.
9. Yao, L.; Zhang, L.; Zou, B.; Gu, S.S. Electricity Price Prediction for Electricity Market with High Proportion of Wind Power. *Autom. Electr. Power Syst.* **2020**, *44*, 49–55.
10. Guo, X. Reflections on the Issue of Negative Electricity Prices in Europe's Energy Transition. *China Power Enterp. Manag.* **2023**, *25*, 48–55.
11. Hull, J.C. *Options, Futures, and Other Derivatives*, 10th ed.; Pearson Education Inc.: New York, NY, USA, 2018.
12. Zou, P.; Chen, Q.; Xia, Q.; He, C.; Ge, R. Logical Analysis of Foreign Electricity Spot Market Construction and Implications and Suggestions for China. *Autom. Electr. Power Syst.* **2014**, *38*, 18–27.
13. Dai, Z. Finance Market Overview. *Electron. Test* **2016**, *22*, 151–152.
14. Zhou, X.W. Electricity Option Market Construction and Option Pricing Modeling Research. Master's Thesis, Southeast University, Nanjing, China, 2018.
15. Xiao, Q.; Yang, Z.; Yang, Y.; Ji, T.; Jing, C. Foreign Electricity CFD Models and Their Implications. *Guangdong Electr. Power* **2020**, *33*, 27–34.
16. Xiao, Q.; Yang, Z.; Zeng, P.; Ji, T.; Chen, H. Reconstructing the Medium- and Long-Term Market for Electricity in the Southern Region: (II) An Overview of the Practical Experiences of Foreign Financial Transmission Rights Markets and Their Implications. *Guangdong Electr. Power* **2020**, *33*, 7–16.
17. Zeng, P.; Sun, Y.; Ji, T.; Jing, C.; Chen, Z. A Study of Revenue Adequacy Issues in the Financial Transmission Rights Market and Its Implications for China. *Power Syst. Technol.* **2021**, *45*, 3367–3380.
18. Huang, R. Research on Microstructure Theory and Realization Path of Electricity Financial Markets. Master's Thesis, North China Electric Power University (Beijing), Beijing, China, 2010.

19. Xun, J. *Research on Key Issues of Electricity Financial Derivatives Market Development*; North China Electric Power University (Beijing): Beijing, China, 2020.
20. Zhou, X.W.; Li, Y.; Chen, X.; Liao, Y.; Liu, J.Y. Development of the European Electricity Financial Derivatives Market and its Integration with Demand Side Management. *Power Demand Side Manag.* **2018**, *20*, 60–64.
21. He, Y.; Su, F.; Xia, X. PJM Power Futures Trading Experience and Implications for China's Power Futures Market Construction. *Guangdong Electr. Power* **2021**, *34*, 37–42.
22. Lu, Z.; Huang, W. Global Electricity Futures Market Overview and Contract Features Analysis. *Secur. Futures China* **2018**, *05*, 23–27.
23. Hua, Y.S.; Yan, Z.; Huang, T.; Huang, H.L.; Yang, L.B.; Liu, F.B. Research Transmission Right in East China Electricity Market. *Power Syst. Technol.* **2009**, *33*, 72–77.
24. He, C.; Yang, L.; Li, X.; Zhou, H. A study of CFDs in the Nordic electricity finance market. *Price Theory Pract.* **2008**, *4*, 53–54.
25. Gao, F.L. *Research of Financial Transaction Mode Selection in Power Market of ZJ Province*; Zhejiang University: Hangzhou, China, 2017.
26. LI, D.; Han, F. Financial Transaction Models in U.S. Electricity Markets. *Power Syst. Technol.* **2008**, *10*, 16–21.
27. Bai, Y.; Xu, Z.; Ji, T.; Jing, C.; Zhong, J. Implications of the Nordic Electricity Derivatives Market for China's Medium- and Long-Term Market Construction for Electricity. *South. Power Syst. Technol.* **2024**, *18*, 1–11.
28. Leng, Y.; Gu, W. Operating Mechanism ofAustralian Electric Financial Derivatives Market andIts lmplications for Electricity Market Construction in China. *Electr. Power* **2021**, *54*, 36–43+61.
29. Fei, Y.Z. *Construction and Effectiveness of Wlectric Power Fancial Market*; North China Electric Power University (Beijing): Beijing, China, 2020.
30. Wang, X.; Hong, Z.; Pang, J.; Wang, J. The Formation and Development of Singapore's Electricity Futures Market. *Zhejiang Electr. Power* **2019**, *38*, 22–26.
31. Chen, Q.X.; Fang, X.C.; Guo, H.Y.; Wang, X.Y.; Yang, Z.L.; Cao, R.Z.; Xia, Q. Progress and Key lssues for Construction of Electricity Spot Market. *Autom. Electr. Power Syst.* **2021**, *45*, 3–15.