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Research on Multi-value Market Realization Mechanism of Green Hydrogen, Ammonia and Alcohol

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Abstract. This study explores the collaborative mechanism of electricity, green certificate, and carbon markets to address the value realization challenges of renewable hydrogen and green ammonia/alcohol production. By systematically reviewing the development status of China's electricity-green certificate-carbon market system, this paper demonstrates the feasibility of green hydrogen, ammonia, and alcohol participating in multiple markets, analyzes core trading rules, and proposes feasible pathways and cost allocation mechanisms. Results indicate that grid-connected renewable hydrogen projects are highly compatible with electricity market rules in terms of energy value, flexibility value, and capacity reliability. The CCER methodology for renewable hydrogen released in December 2025 provides a methodological foundation for carbon market participation. The green certificate market can facilitate approximately 2%-5% of hydrogen production cost recovery. These findings provide theoretical support and practical guidance for constructing a multi-value market system for hydrogen, ammonia, and alcohol, contributing to energy transition and the achievement of "dual carbon" goals.

Keywords: green hydrogen; ammonia; alcohol; value realization mechanism; electricity-green certificate-carbon market synergy; CCER.

1. Introduction

In the context of global climate change mitigation and deep energy system transformation, China's energy structure transition has entered a critical phase. The large-scale development and efficient utilization of renewable energy has become the core pathway to address resource and environmental constraints and build a clean, low-carbon energy system[1]. By 2025, China's total installed capacity of wind and solar power accounted for 47% of all power generation capacity, historically surpassing thermal power to become the largest power source in the country[2].The collaborative development of electricity markets, green certificate markets, and carbon markets has established a multi-market framework for renewable energy value realization. Renewable hydrogen production, as a critical link connecting renewable energy consumption with end-use decarbonization, has attracted significant attention for its value transformation potential across multiple markets.

Currently, China's electricity-green certificate-carbon market construction has achieved preliminary success. The electricity marketization reform has deepened continuously, with national market-based trading volume reaching 6.64 trillion kWh in 2025, accounting for 64% of total societal electricity consumption [3]. The green certificate trading mechanism has been continuously improved, with trading volume increasing by 1.2 times year-on-year to 930 million certificates[4]. The national carbon market has operated steadily, with carbon quota trading volume reaching 235 million tons and turnover of 14.63 billion yuan in 2025 [5]. However, the collaborative mechanism among these three markets still needs optimization, particularly regarding cross-market trading rule coordination and value transmission pathways.

Meanwhile, renewable hydrogen production faces challenges including high costs, unclear market access thresholds, and limited value return channels. Current green hydrogen production costs are approximately 22-30 yuan/kg, while gray hydrogen costs only 10-12 yuan/kg, representing a significant economic gap[6]. How to leverage the synergistic effects of electricity, green certificate, and carbon markets to construct a scientific multi-value realization mechanism for hydrogen, ammonia, and alcohol is of significant theoretical and practical importance for activating the diversified value of the industrial chain and accelerating the achievement of "dual carbon" goals..

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2. Status of Electricity-Green Certificate-Carbon Markets

2.1 Electricity Market

China's electricity energy market adopts a "medium/long-term + spot" architecture. Medium and long-term trading serves as the "ballast stone," undertaking risk hedging and expectation stabilization functions, accounting for approximately 80% of trading volume. The spot market acts as the "weather vane," reflecting real-time supply-demand relationships and temporal-spatial value of electricity commodities. By the end of 2025, electricity spot market coverage was basically achieved nationwide, with 25 spot market operation regions covering 30 provinces and regions.

The ancillary services market follows the principle of "those who provide benefit, those who benefit bear the cost." The 2025 "Basic Rules for Electricity Ancillary Services Market" established a unified market framework, allowing new entities such as energy storage, virtual power plants, and load aggregators to participate. In 2024, national electricity ancillary services market costs reached 40.25 billion yuan, with peak regulation services accounting for 82%[3]. Regarding capacity compensation mechanisms, the January 2026 "Notice on Improving Generation-side Capacity Pricing Mechanism" unified coal power capacity pricing to no less than 50% (corresponding to 165 yuan/kW/year) [7].

2.2 Green Certificate Market

China's green certificate trading adopts a primarily "voluntary subscription" model, with certificates issued by the National Renewable Energy Information Management Center. Green certificates cover wind power (including distributed and offshore wind), solar power (including distributed PV and solar thermal), conventional hydropower, biomass power generation, and other renewable energy projects.

In 2025, a total of 2.947 billion green certificates were issued nationwide, of which 1.893 billion were tradable. Green certificate trading volume increased by 1.2 times year-on-year to 930 million certificates. As of December 2025, cumulative issuance reached 7.902 billion certificates, with cumulative trading volume of 1.483 billion[4]. In May 2025, RE100 unconditionally recognized Chinese green certificates, marking China's formal entry into the international green power mechanism landscape.

2.3 Carbon Market

The national carbon emission trading market launched on July 16, 2021, initially covering 2,162 power generation sector key emission units, representing approximately 4.5 billion tons of CO2 emissions. In March 2025, the Ministry of Ecology and Environment released the "Work Plan for Expanding National Carbon Emission Trading Market Coverage to Steel, Cement, and Aluminum Smelting Industries," achieving the first expansion. The current coverage extends to over 3,000 key emission units across four industries, covering approximately 8 billion tons of CO2 emissions, accounting for more than 60% of national emissions[5].

The national voluntary greenhouse gas emission reduction trading market launched on January 22, 2024, with Certified Emission Reductions (CCER) as trading products. On December 26, 2025, the Ministry of Ecology and Environment and National Energy Administration jointly released the "CCER Project Methodology for Renewable Energy Electrolytic Hydrogen Production (CCER-01-004-V01)," clarifying project boundaries, crediting periods, and emission reduction accounting methods for renewable hydrogen projects, filling a gap in China's voluntary emission reduction methodology for the renewable hydrogen sector[8].

2.4 Synergy Characteristics of the Three Markets

The three markets serve as core market-based instruments for promoting low-carbon energy transformation and achieving "dual carbon" goals, with highly aligned fundamental objectives. The electricity market functions as the foundational platform for energy resource allocation, guiding

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optimized resource allocation through price signals. The green certificate market serves as an environmental rights quantification tool, incentivizing renewable energy investment through environmental premiums. The carbon market establishes hard constraints on carbon emissions through quota allocation and carbon pricing mechanisms.

In terms of market trading synergy, the three markets exhibit overlapping market participants, interconnected trading mechanisms, and complementary trading products. Carbon prices influence corporate abatement costs and demand for green certificates; when carbon prices are high, enterprises prefer purchasing green certificates to offset emissions, thereby driving up green certificate prices . However, China's current carbon-to-electricity price transmission rate is less than 10%, far below the 80%-95% transmission rate in the EU's mature carbon market, indicating significant room for synergy improvement .

3. Feasibility Analysis of Hydrogen-Ammonia-Alcohol Participation in Electricity-Green Certificate-Carbon Markets

Grid-connected renewable hydrogen production projects demonstrate high compatibility with electricity market rules in terms of energy value, flexibility regulation value, and capacity reliability value, making participation in energy, ancillary services, and capacity markets entirely feasible. Grid-connected projects can be decomposed into two entities: the supporting renewable energy generation facility and the hydrogen production load, both of which meet current electricity market access conditions.

Regarding the green certificate market, the March 2025 "Implementation Rules for Renewable Energy Green Certificate Issuance (Trial)" (Draft for Comments) issued by the National Energy Administration proposed that renewable electricity from wind/solar hydrogen (ammonia/alcohol) projects be issued non-tradable green certificates. Off-grid hydrogen projects produce green hydrogen with clearly traceable renewable energy sources, and their environmental value can be quantified and traded through green certificates, with relatively simple green traceability making them attractive for enterprises seeking to fulfill green power consumption targets.

Regarding the carbon market, the national carbon emission trading market requires annual greenhouse gas emissions of at least 26,000 tons CO2 equivalent for inclusion. Renewable hydrogen production processes have very low carbon emissions and do not meet inclusion criteria, thus cannot directly participate in the national carbon emission trading market [5]. However, the December 2025 CCER methodology for renewable hydrogen production provides a methodological basis for hydrogen projects to participate in the national voluntary greenhouse gas emission reduction market. The emission reduction from substituting green hydrogen for gray hydrogen is calculated using coal-to-hydrogen (19 tCO2/tH2) or natural gas-to-hydrogen (9 tCO2/tH2) as baseline, demonstrating significant emission reduction benefits.

Table 1. Tsummarizes the feasibility of different types of renewable hydrogen projects participating in various markets

Market	Grid-connected	Off-grid	Assessment
Energy market	Fully feasible	Not feasible	Spot + Medium/long-term
Ancillary services	Feasible	Not feasible	Peak/Frequency/Reserve
Capacity comp.	Partially feasible	Not feasible	H2 storage applicable
Green cert.	Tradable (on-grid)	Non-tradable	Attribute proof
Carbon market	Indirect	Indirect	Quota surplus model
Voluntary market	CCER dev.	CCER dev.	2025 methodology

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4. Trading Rules for Participation in Electricity-Green Certificate-Carbon Markets

4.1 Electricity Market Trading Rules

For the energy market, renewable hydrogen projects must meet grid connection technical standards, possess electricity market trading qualifications, and install necessary metering and communication equipment. Where the renewable energy power source and hydrogen production load belong to different investors, they participate in the electricity market in aggregated form; where they belong to the same investor, they participate as an integrated entity. For the ancillary services market, hydrogen production equipment must meet technical access requirements including AGC response within 5 seconds and +/-30% rated power regulation within 15 minutes[13]. .

4.2 Green Certificate Market Trading Rules

For green certificate issuance, grid-connected wind/solar hydrogen and off-grid wind/solar hydrogen projects receive non-tradable green certificates for their self-generated self-consumption electricity; grid-connected projects participating in green power trading automatically receive corresponding green certificates for their grid-purchased electricity. The certification process follows a four-step procedure of "enterprise application - third-party verification - regulatory authority review - certificate issuance" to ensure authoritative and credible certification outcomes. Green certificates are valid for 2 years (with the production month as month 0) and are canceled upon expiration. .

4.3 Carbon Market Trading Rules

For the voluntary emission reduction market, the CCER methodology for renewable hydrogen electrolysis applies to new projects, excluding retrofits or expansions of existing facilities. Projects must consume renewable electricity from the project's own renewable power plant, and the project's own renewable power plant and hydrogen products must not participate in other greenhouse gas voluntary emission reduction trading mechanisms .

For emission reduction accounting, the emission reduction from green hydrogen substituting for gray hydrogen equals (baseline carbon emissions minus green hydrogen carbon emissions per unit) multiplied by green hydrogen production volume. Projects must satisfy five principles: additionality, authenticity, conservativeness, uniqueness, and sustainability. The additionality principle requires that without CCER development, the project would not be economically viable. The uniqueness principle stipulates that projects cannot simultaneously apply for green certificates or other emission reduction certificates.

5. Feasible Pathways and Cost Allocation Mechanism

5.1 Multi-market Participation Pathways

For electricity market pathways, grid-connected renewable hydrogen projects can participate in both spot and medium/long-term trading. In medium/long-term trading, projects can sign multi-year Power Purchase Agreements (PPAs) with electricity suppliers to lock in electricity prices and reduce price volatility risks. In spot trading, electrolyzers adjust real-time load based on price signals, increasing hydrogen production during low-price periods and reducing production during peak-price periods, thereby optimizing production timing to reduce electricity costs.

For carbon market pathways, three primary participation models exist: (1) CCER Development Model - applicable to independent renewable hydrogen projects, generating additional revenue through CCER development and sales in the voluntary emission reduction market; (2) Carbon Quota Offset Model - applicable to key emission units with self-built hydrogen production facilities, achieving carbon quota surplus through green hydrogen substitution that reduces carbon emission

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intensity; (3) International Carbon Credit Development - applicable to hydrogen export projects, requiring compliance with international carbon credit standards .

5.2 Cost Allocation Mechanisms

Renewable hydrogen cost allocation should follow four fundamental principles: economic viability, equity, dynamic adjustment, and policy guidance. Cost allocation can be approached through four dimensions: energy value, environmental value, flexibility value, and policy backstop .

Based on current market price assessments, the green certificate market can facilitate approximately 2%-5% of hydrogen production cost recovery, primarily covering fixed costs of renewable energy power plants. The electricity energy market can facilitate approximately 20%-25% (varying by region), covering electricity costs as variable expenses. The carbon market can facilitate approximately 8%-10%, using CCER or carbon quota revenue to offset the incremental cost between green and gray hydrogen. The ancillary services market can facilitate approximately 3%-5%, based on estimated energy storage revenue. Remaining costs are allocated through the hydrogen market, with government subsidies providing backstop support for costs not covered by market mechanisms .

Table 2. Cost Recovery Contributions from Each Market for Renewable Hydrogen Production

Cost Recovery Channel	Recovery %	Primary Coverage
Green certificate market	2%-5%	Renewable plant fixed costs
Electricity energy market	20%-25%	Electricity variable costs
Ancillary services market	3%-5%	Peak/Frequency revenue
Carbon market (CCER)	8%-10%	Green-gray H2 incremental cost
Government subsidy	Backstop	Uncovered market costs

6. Conclusions and Policy Recommendations

This paper systematically investigated the multi-value market realization mechanism for hydrogen, ammonia, and alcohol. The main conclusions are as follows:

(1) The electricity market, green certificate market, and carbon market demonstrate high goal consistency in promoting low-carbon energy transformation, but the current collaborative mechanism among the three markets still requires optimization. China's carbon-to-electricity price transmission rate is less than 10%, far below the EU's 80%-95% level, constraining synergy effectiveness.

(2) Grid-connected renewable hydrogen projects demonstrate high compatibility with electricity market rules regarding energy value, flexibility regulation value, and capacity reliability value, making participation in energy, ancillary services, and capacity markets entirely feasible. The December 2025 CCER methodology for renewable hydrogen provides a methodological foundation for carbon market participation.

(3) The green certificate market can facilitate approximately 2-5% of hydrogen production cost recovery, the electricity energy market 20-25%, the carbon market 8-10%, and the ancillary services market 3-5%. Multi-market collaboration can provide approximately 35-45% of cost recovery for renewable hydrogen production, with the remainder requiring allocation through the hydrogen market and government subsidy support.

Based on the above analysis, the following policy recommendations are proposed: First, accelerate improvement of the electricity-green certificate-carbon market collaboration mechanism and enhance carbon-to-electricity price transmission efficiency. Second, expand CCER methodology coverage to promote inclusion of more hydrogen, ammonia, and alcohol projects in the voluntary emission reduction market. Third, establish a hydrogen certificate system to enable transformation of green electricity environmental attributes into hydrogen green value. Fourth, improve cost allocation mechanisms to achieve a smooth transition from "policy dependence" to "market autonomy."

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