

Exploration of the Integrated Development Path of Oil and Gas and New Energy Industry-Based on Literature Research and Thinking

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Abstract

Driven by the "double carbon" goal, the integration and development of China's oil and gas industry and new energy has become a key path to promote the transformation of energy structure and realize green and low-carbon development. At present, China has adopted policy guidance (For example, the Action Plan for Accelerating the Integration and Development of Oil and Gas Exploration and Development and New Energy) Promote oil and gas enterprises to practice "integration of wind, light and storage" and green hydrogen production (Xinjiang Kuqa 20,000 tons/year project), offshore wind power and CCUS technology application, initially formed a multi-energy complementary system. However, development is still subject to technical bottlenecks (low-cost hydrogen production, safe storage and transportation), institutional and mechanism barriers (complex approval, limited land) and insufficient market incentives (lagging green electricity transactions). The future path needs to focus on four dimensions: one is to build a smart energy system of "wind, gas and hydrogen storage" to promote electrification of production and system reengineering; the other is to strengthen policy coordination, simplify approval and activate carbon market mechanism.(such as CCUS carbon sink trading); third, breaking through technical bottlenecks such as green hydrogen preparation and geothermal development; fourth, leading international competition and cooperation through demonstration projects (such as zero-carbon oil fields). Research shows that the core of integrated development lies in the three-dimensional linkage of policies, technologies and markets, and finally realizes synergy between stable oil and gas production and emission reduction, providing China with solutions for global energy transformation.

Keywords

Integration of Oil and Gas and New Energy; Multi-Energy Complementary Policy Synergy; CCUS; Double-carbon Goal.

1. Introduction

As one of the largest energy consumers in the world, China's energy demand continues to increase, but it also faces problems such as unbalanced energy structure and severe environmental pollution. Under this background, promoting the deep integration of the oil and gas industry with new energy and strategic emerging industries has become a key path to

achieve this goal. To meet these challenges, the industry urgently needs to explore innovative paths, leveraging new capabilities and The Group will continue to strengthen the synergy between the development of energy and strategic emerging industries, complete the green and low-carbon transformation and improve the quality of development .

With the increasing demand for clean and renewable energy and the continuous progress of related technologies, the oil and gas industry faces resource depletion and environmental protection pressure, and the new energy industry welcomes important development opportunities. Large-scale application of new energy such as wind energy and solar energy promotes diversification of energy supply, gradually reducing dependence on traditional oil and gas resources and improving the stability and security of the energy system .

2. Strategic Significance of Integrated Development of Oil and Gas and New Energy

Security is the basic requirement for building an energy system. China's energy consumption is huge. The proportion of crude oil and natural gas imported from abroad has reached 73% and more than 40%, respectively. There is high uncertainty in source channels, and the level of self-sufficiency is relatively weak. It is particularly urgent to promote the comprehensive integration of traditional fossil energy and emerging renewable energy. Relying on the oil and gas industry to cooperate with low-carbon resources such as wind power, solar energy, geothermal energy, biomass and hydrogen energy, it can help the energy consumption system to transform into clean and low-carbon, strengthen diversified supply guarantee strength, and improve the operation efficiency of the whole system, laying a reliable foundation for realizing the vision of carbon peak and carbon neutralization .

3. Current Situation of Integration and Development of Oil and Gas and New Energy Industries

At present, the coordinated development of oil and gas and new energy is in a critical period of policy-driven and large-scale application. Actively promote the "integration of wind, solar and storage" project, large-scale green hydrogen production (For example, Xinjiang Kuqa annual output of 20,000 tons of green hydrogen project) and other practices, initially formed a comprehensive energy supply structure with oil and gas as the core and coupling various new energy sources . However, there are still many constraints in the integration process, such as immature technologies such as hydrogen energy low-cost preparation and safe storage and transportation, cumbersome approval mechanisms and institutional barriers such as land use constraints, and imperfect supporting policies such as green electricity market-oriented trading and carbon revenue mechanisms. It is urgent to promote integration to a higher level by strengthening policy coordination, breaking through key technologies and deepening market mechanisms.

In the context of the continuous deepening of the "double carbon" goal, it is particularly urgent for oil and gas field enterprises to accelerate low-carbon transformation. These enterprises should vigorously promote clean energy substitution on the production side, fully implement low-carbon operation methods, and build an integrated energy supply system that integrates multiple energy forms and coordinates and complements each other. In addition, clean energy substitution should also be regarded as a strategic fulcrum to support the large-scale and industrialized development of new energy businesses, and promote the rapid transformation of the energy structure into a green and low-carbon direction. Specifically, we should focus on providing clean electricity to the outside world. We will comprehensively promote the organic

integration and coordinated development of oil and gas and new energy with the two major priorities of green hydrogen and internal improvement of energy self-sufficiency.

4. Oil and Gas Exploration and Development and New Energy Integration Development Market

In the global fight against climate warming, carbon neutrality is becoming a key development goal for most countries. China has made it clear that it will achieve a "double carbon" vision of carbon peak by 2030 and carbon neutrality by 2060, so as to drive the transformation of its energy system towards clean and low-carbon. As a sector with high carbon emissions, the traditional oil and gas industry is under increasing emission reduction requirements, and it is necessary to reduce carbon footprint with the help of new energy technologies and clean processes, and maintain energy supply security in the process, and finally build a sustainable model that takes into account green mining and low carbon supply chain.

4.1. Market Force

In 2023, the National Energy Administration issued the Action Plan for Accelerating the Integration and Development of Oil and Gas Exploration and Development and New Energy (2023-2025), which clearly states that new energy technologies should be used to improve oil and gas recovery efficiency and reduce carbon emissions, while prioritizing these projects in the overall energy development layout.[7] For example, it is expected that by 2025, relying on green electric-assisted tertiary oil recovery technology, oil production will increase by more than 2 million tons and natural gas supply will increase by 7.5 billion cubic meters. The policy provides the market with clear growth prospects and investment priorities.

4.2. Market Application Status

4.2.1. Integration of Onshore Oil and Gas and Wind-Solar Power Generation

In key areas such as Daqing, Changqing and Shengli oilfields, centralized wind and solar power generation projects have been promoted to replace fuel consumption in oil and gas production and reduce operating costs by increasing electrification rate.

4.2.2. Synergy of Offshore Oil and Gas and Wind Power

Offshore wind power can provide green power for oil and gas platforms, gradually replacing decentralized gas power generation. For example, in areas with shore power conditions, high-proportion offshore wind power supply mode has been piloted and promoted, and floating wind power applications are explored for deep offshore platforms.

4.2.3. Energy Storage and Multi-Energy Complement

New energy storage technology (such as electric and thermal dual storage) is applied on a large scale in the upstream of oil and gas for peak shaving and emergency standby, and cooperates with natural gas peak shaving power station to improve system stability.

4.3. Market Challenges

At present, due to the natural condition of "abundant coal resources and relative shortage of oil and natural gas", China's oil and gas industry remains highly dependent on foreign countries, and its bargaining power is weak in the international trading system. The resulting energy supply risks cannot be ignored. Based on the new energy security concept, promoting the reform of market-oriented mechanism has become an important direction to solve the strategic dilemma in the oil and gas field and enhance the security guarantee capability. Before launching an in-depth discussion, we should first systematically review the evolution and reform process of China's oil and gas market, and analyze the key problems and challenges that arise between them .

4.3.1. Institutional and Institutional Obstacles

The approval process of new energy projects is complicated, land resources are limited, and there is no effective connection between oil and gas and new energy planning, resulting in low resource utilization efficiency. For example, the ownership of wind and light resources development rights in oil and gas Kuangqu is unclear, which restricts the project landing.

4.3.2. Technological Difficulties

Low-cost hydrogen production, hydrogen storage and transportation, geothermal and oil and gas collaborative development and other technologies are not yet mature, and the commercial application of CCUS (carbon capture and storage) lags behind. In addition, the prediction accuracy of new energy generation power is insufficient, which may affect the stability of oil and gas production.

4.3.3. Insufficient Market Incentives

The existing policies have limited support for green electricity trading and partition sales, oil and gas enterprises face high investment risks in developing new energy sources, while financial subsidies and carbon market mechanisms are not yet perfect.

4.4. Future Trend

From the perspective of strategic deployment of petroleum companies, the development of new energy business involves multi-faceted strategic thinking. Oil and gas companies need to scientifically plan the development direction of new energy based on their resource conditions and regional characteristics to reduce homogeneous competition and form distinctive businesses. structure [10]. First, the introduction of new energy will help change the situation of traditional oil and gas companies with a single business type and enhance their ability to adapt to market changes. During the downturn, new energy can help alleviate the pressure brought by the decline of oil and gas revenue; during the boom stage of the industry, the profits of the oil and gas sector can provide funds and resources for the expansion of new energy, thus improving the overall profit model. Secondly, the technical foundation, professional talents, capital strength and market channels accumulated by the long-term development of oil and gas enterprises provide good conditions for the cultivation and expansion of new energy business .

5. Problems Faced by the Integration of Oil and Gas Exploration and Development and New Energy

5.1. Insufficient Carrying Capacity of Power Grid and Great Difficulty in Regulation

With the significant increase in the proportion of wind-solar power generation in the power system, relay protection imbalance and power flow reversal occur in the power grid, and the capacity of power systems in some areas to accept new energy is close to saturation. In addition, the current scale of energy storage facilities is insufficient and the wind-solar collaborative control system is not perfect, and the safe and stable operation of power grids faces more uncertainties [13]. This reflects the prominent constraints existing in the power grid links in the green transformation of current energy structure in China and the world. Addressing these challenges requires system-level planning and technological innovation.

(1) Strengthen the construction of power grid infrastructure: build and strengthen cross-regional transmission channels, solve the problem of reverse distribution of resources and loads, and improve the ability of large-scale optimization of resource allocation.

(2) Vigorously develop energy storage systems: actively promote the construction of various forms of energy storage facilities such as pumped energy storage and electrochemical energy storage to provide the necessary flexibility and buffer capacity for the power grid.

(3) Deepen the reform of power market: establish and improve auxiliary service market, capacity market and spot market, guide flexible resources such as energy storage, virtual power plant and demand side response to participate in power grid regulation through market price signals, and create favorable economic environment for consumption of new energy.

5.2. Insufficient Coordination Planning for New Energy and Oil and Gas Development

There is a problem of uncoordinated development between oilfield power grid and new energy access, and new energy access is limited due to lack of systematic top-level design in some areas. It is necessary to optimize the access scheme through grid and power supply collaborative planning model, but technical complexity and cost control challenges are still faced during implementation .

(1) Active distribution network management technology: Virtual Power Plant (VPP): aggregates scattered wind, solar, energy storage and controllable loads into a "virtual power plant" to receive unified dispatching instructions and realize collaborative optimization. Flexible interconnected devices such as intelligent soft switch (SOP) and energy storage converter (PCS) realize flexible and accurate control of distribution network power flow and solve problems such as power inversion and voltage over-limit.

(2) High-precision prediction technology: deploy wind and solar power prediction system and load prediction system, use big data and AI algorithm to improve prediction accuracy, provide reliable basis for intraday rolling optimization scheduling, and reduce uncertainty.

(3) Adaptive transformation technology of protection system: research and application of new protection principles and new devices adapted to high proportion of new energy access, such as protection based on wide area information, adaptive protection, etc., to ensure power grid security.

5.3. Bottleneck of Resource Utilization and Limitation of Economic Benefit

Solar energy and wind energy are greatly affected by seasons and climates, so it is difficult to supply energy independently and stably. They need to rely on energy storage or traditional energy supplement, resulting in low economic benefits of solar thermal and wind power projects.[15] For example, the thermal load and solar thermal output change reversely in winter and summer, making it difficult to configure.

(1) To build a new power system with "integration of source, grid, load and storage", optimize the whole through intelligent dispatching, demand side response (make load adapt to power supply) and multi-energy complementarity (wind-solar, water-fire and storage coordination), and reduce the requirements for stability of single power supply.

(2) Establish a mature electricity market, so that wind and energy storage projects can obtain diversified revenue streams by participating in auxiliary service markets (such as peak shaving and frequency modulation), rather than just selling electricity.

In a word, the economic dilemma of wind and solar projects is a typical "system problem", which cannot be viewed only from the "power generation technology" itself, but must be placed in the grand framework of the entire energy system, and the way out can be found through collaborative innovation of technology, market and system.

5.4. Shortcomings in Technical and Management Experience

Oilfield enterprises lack experience in wind power, photovoltaic development management and power system operation, and lack professional support. Meanwhile, new modes such as green electricity trading and intelligent microgrid need to be further explored, and the existing power grid architecture is insufficient for high proportion of new energy sources.

6. Development Path of Integration of Oil and Gas Exploration and Development and New Energy in Oilfield

Changqing Oilfield listed new energy as one of the three main businesses juxtaposed with oil and gas exploration and development as early as 2021, formulated the "14th Five-Year Plan for Green Low Carbon and New Energy," and coordinated multi-energy development through the concept of "energy equivalence".[17] The upgrading enlightenment of this strategic positioning: traditional energy enterprises need to break through the single energy supply thinking, incorporate new energy into the core business system, and realize strategic transformation through institutional guarantee and resource tilt.

6.1. Green Electricity Substitution and Cleaner Production

The renewable energy supply capacity is easily affected by geographical and meteorological conditions, and there are obvious fluctuations, which makes it difficult to achieve stable and reliable independent power supply and meet the continuous production energy requirements of oil fields; the development of such projects is also easily limited by geographical and ecological protection, with significant individual differences, which is less scalable than traditional oil and gas development mode. Meanwhile, oil and gas enterprises generally lack corresponding engineering design, construction and operation and maintenance management systems. Therefore, such enterprises should, on the premise of objectively evaluating their own capabilities and limitations, comprehensively coordinate short-term benefits and strategic layout, and gradually establish a new energy business system that suits the actual situation of the enterprise and has unique competitiveness. Actively promote energy efficiency improvement, clean energy replacement, and implement low-carbon measures in the whole process.

6.1.1. Dissipating Green Electricity Locally

Self-supply of energy is realized through wind power and photovoltaic power generation in Kuangqu and its surrounding areas, replacing traditional thermal power or gas-fired power generation. For example, Daqing Oilfield has completed 1.4 million kilowatts of integrated wind-solar-storage project, and Tarim Oilfield has realized "zero-carbon operation" of pumped irrigation through photovoltaic transformation, with an annual emission reduction of 3410 tons of carbon dioxide.

6.1.2. Electrification of Production Links

Electric fracturing and electric heating for heavy oil recovery are promoted to reduce natural gas consumption. Qinghai Oilfield uses electric fracturing instead of diesel power in Ganchaigou oil field to start clean production mode; Jilin Oilfield uses green electricity and geothermal instead of natural gas heating to reduce gas consumption by 600,000 cubic meters every year.

6.2. Multi-energy Complementarity and Integrated Energy Supply

Based on the actual situation of the region and the enterprise, systematically summarize the existing experience and shortcomings in the development of new energy technologies and industries, coordinate various elements and resource types, comprehensively promote and accurately position the new energy development strategy and spatial layout of the enterprise. Coordinate the overall land space planning and renewable energy development, rationally allocate the enterprise's own land resources, and effectively guarantee the construction land required for renewable energy projects. Scientific assessment of non-electric power enterprises' independent consumption potential for new energy power, combined with the characteristics of supply and demand in different seasons, optimize the allocation of new energy power acceptance capacity, and continuously improve consumption efficiency. SASAC shall formulate policies to support non-electric power enterprises and electric power

enterprises to build efficient cooperation models, and promote the tripartite synergy of power generation, power grid and power consumption. Encourage traditional energy enterprises and power grid enterprises to jointly build joint ventures in the form of mixed ownership, and jointly promote the construction of new energy systems by optimizing power supply structure, enhancing power grid adaptability, improving electricity price mechanism and other diversified measures.

6.2.1. Integrated Development of Wind, Wind and Storage

Under the background of existing energy structure, oil and gas field enterprises have unique resource conditions: onshore oil fields and gas areas are usually rich in wind and light resources, have superior foundation for new energy construction, and have broad space for sustainable large-scale development. Based on this advantage, enterprises shall adhere to ecological protection priority, closely combine local characteristics, deeply implement multi-energy collaborative integration strategy, and actively promote the construction of wind power and photovoltaic power generation projects in oil and gas Kuangqu and adjacent areas.

6.2.2. Geothermal and Hydrogen Synergy

Geothermal resources are developed for oil field heating. For example, geothermal heating area of China Petrochemical Company exceeds 84 million square meters; large-scale production of green hydrogen (such as 20,000 tons of green hydrogen project in Kuqa, Xinjiang) is used to replace traditional energy. Developing hydrogen business has become a key path for green and low-carbon transformation of oil and gas field enterprises, and promoting green hydrogen project is an effective entry point for building a new energy base integrating "source, grid, load and storage".

6.3. Technological Innovation and Low Carbon Processes

Under the background of global promotion of energy structure transformation and realization of carbon peak carbon neutralization goal, promoting the synergistic integration of oil and gas and new energy has become a key measure for energy system reform. In March 2023, the National Energy Administration issued the Action Plan for Accelerating the Integration and Development of Oil and Gas Exploration and Development and New Energy (2023-2025), which clearly puts forward promoting the integrated development of oil and gas exploration and development and new energy as a key task to provide policy basis and support for the green and low carbon process of the whole industry. This document focuses on the problems such as high initial investment, imperfect supporting facilities and difficulties in grid connection and consumption that are common in the new energy field, and proposes to realize coordinated development relying on the oil and gas industry foundation to break through the above bottlenecks and help the clean and low carbon energy system to move forward.

The policy orientation reflects five main characteristics: first, accelerate the electrification rate of oil and gas production links; second, promote the implementation of clean substitution in production energy consumption; third, support the sustainable transformation of traditional oil and gas regions; fourth, build pilot projects for low carbon or even zero carbon oil and gas fields; and fifth, improve supporting policies and mechanisms. This series of measures defines the implementation path for the deep integration of the two energy systems and strengthens institutional support.

6.3.1. Carbon Capture, Utilization and Storage (CCUS) Technology System Innovation

CCUS technology has become the core technology for the integration of oil and gas and new energy. China's oil and gas enterprises have formed a basically mature full-process technology system. China Petroleum has established a complete CCUS/CCS technology and standard system. By the end of 2023, the cumulative injection of CO exceeds 7 million tons (accounting for about 70% of the total amount of China) and the oil increase exceeds 2 million tons.

In terms of technological innovation, breakthroughs have been made in the basic theory of CO₂ miscible flooding in continental sedimentary reservoirs, and mass transfer miscible has become an important mechanism for CO₂ flooding to greatly enhance oil recovery. For low-permeability fault-block reservoirs, gravity flooding development mode of "continuous gas injection at the top 10 and punctual gas injection at the middle and lower parts" has been innovatively applied, which has significantly improved oil recovery efficiency.

China CNOOC successfully put into operation China's first offshore carbon dioxide storage demonstration project in "Enping 15-1" oilfield cluster, which means that the offshore CCUS technology has achieved key progress. This project has constructed a complete set of processes and equipment systems covering capture, injection and storage, which can achieve 300,000 tons of carbon dioxide storage scale every year, and the total storage capacity is estimated to reach 1.46 million tons.

6.3.2. Hydrogen and Oil and Gas Industry Integration Technology Innovation

As a bridge energy source, hydrogen energy has made important progress in application technology in oil and gas industry. In August 2025, China Petroleum successfully put into trial operation key technology research and demonstration application project of gas hydrogen doping utilization in old urban industrial park of Yumen City, Gansu Province, creating a technical precedent for integrated application of natural gas and new energy. The project establishes a full-process application scheme of "blending-transmission-end-use-trade measurement", which solves key technical problems such as gas hydrogen doping process, hydrogen adaptability of terminal equipment, risk identification and control, etc.

The project has achieved flexible adjustment of 5% to 20% hydrogen doping ratio of natural gas, providing technical support for the commercial application of hydrogen energy chain. The technology converts surplus new energy power into stable energy products through electrolysis and hydrogen production, and opens up a new path for the consumption of wind and solar resources through natural gas pipelines.

6.3.3. New Energy and Oil and Gas Facilities Integration Technology Innovation

A breakthrough was made in the integration technology of oil and gas facilities and new energy power generation systems, realizing the intensive development mode of "wind and scenery in the same field and wind and scenery in the same stage." Huaneng "Huanghai No.1" anti-wave floating photovoltaic platform completed the upgrading and transformation of "wind and scenery in the same platform", realizing the integration application of "vertical axis wind turbine + floating photovoltaic" in the deep sea.

This innovative design develops a wind-solar collaborative control algorithm to coordinate the output characteristics of wind turbines and photovoltaics, and constructs a fusion monitoring system to form a comprehensive platform for wind and solar energy gradient utilization. Vertical axis wind turbines and photovoltaic systems share sea infrastructure and operation and maintenance channels, effectively improving energy output efficiency per unit sea area, and providing important technical reference for large-scale development of composite energy fields.

6.3.4. Carbon Sequestration Combined with Oil Displacement Technology

As of May 2025, Jilin Oilfield has nearly 4 million tons of carbon dioxide buried stock, ranking the first 11 in the country, and its emission reduction effect is equivalent to planting 34 million trees or stopping more than 2 million economy cars for one year. By using carbon dioxide as oil recovery medium, its production efficiency is increased by 25% compared with traditional water flooding, and annual oil increase of more than 200,000 tons is realized.

6.4. Exploring Production System Reengineering

At present, there are significant differences in the development status of various types of clean energy. Although solar thermal power generation is expected in the future, its cost is still high;

geothermal resources are abundant, but limited by technical development and resource exploration, and cannot be widely deployed in the near future; waste heat utilization has achieved certain results, but the overall application scope is still relatively limited. In general, in the future, the main clean energy that can support large-scale development and utilization will still be green power represented by wind power and photovoltaic power. However, there are natural defects in wind-solar power generation, and its output is intermittent and unstable. The actual available hours are small, which makes it difficult to directly match the production system that requires continuous and stable power supply, and it is impossible to realize high-proportion and large-scale access applications in a short period of time.

Facing this realistic challenge, oil and gas field enterprises must promote systematic transformation, restructure the existing production mode, and strive to build a new production system that adapts to the characteristics of wind and rain fluctuations. Make full use of power resources during low periods, improve energy efficiency, and systematically reduce overall energy consumption costs. Through the above measures, the oil and gas production process will be fully adapted to the characteristics of renewable energy, and the proportion of non-fossil energy in energy consumption for exploration and development will be gradually increased, so as to promote the steady transformation of the industry towards green and low-carbon high-quality development.

6.5. Policy Guarantee and Mechanism Innovation

6.5.1. Construction of Policy Guarantee System: Multi-level Collaborative Promotion

China has formed a multi-level policy guarantee system led by national strategy, supported by ministries and commissions and practiced with local characteristics, providing clear direction guidance and institutional support for the integrated development of oil and gas and new energy.

In March 2023, the National Energy Administration issued the Action Plan for Accelerating Oil and Gas Exploration and Development and New Energy Integration Development (2023-2025)", which became a programmatic document guiding integrated development. The plan focused on improving the level of oil and gas electrification, promoting energy substitution, promoting the transformation of old areas, building low-carbon projects and strengthening policy mechanisms, and established a systematic policy framework. The plan emphasized overall planning of oil and gas facilities and new energy development, and effectively solved key problems such as high investment, weak infrastructure and consumption difficulties in the new energy field through 12 industrial integration.

At the ministerial coordination level, multi-sectoral policy synergy has been formed. In November 2024, the State Administration of Market Supervision and the National Energy Administration established a collaborative supervision mechanism to promote work in five aspects: policy coordination, joint inspection, information sharing, clue transfer and training exchange. This collaborative model effectively broke down industry barriers and provided policy convenience for the approval, construction and operation of integration projects.

At the local level, characteristic policy exploration is presented. Guangzhou City has issued pilot work plans and management rules for the application of biofuel oil for international navigation ships, and established a full-chain support system of "standard formulation-base construction-industrial development-policy breakthrough." Ordos has explicitly promoted the demonstration of hydrogen doping in natural gas pipeline network and the construction of integrated energy supply stations for oil, gas, electricity and hydrogen in the pilot construction of national carbon peak, and plans to build about 45 hydrogen refueling stations by 2025. Henan Province has set up a special science and technology fund to support key technologies such as localization of shale gas development equipment and cost reduction of green hydrogen preparation, and promote the deep integration of "production, study and application".

6.5.2. Mechanism Innovation Practice: Multi-dimensional Breakthrough Exploration

Focusing on the actual needs of integrated development, China has carried out a series of mechanism innovations in technical standards, market incentives, collaborative management and regulatory assessment, providing institutional guarantee for policy implementation.

Important progress has been made in technical standard system innovation. For new technologies and new formats emerging in the process of integration and development, industry associations and enterprises have jointly formulated group standards to fill the gaps in standards. In the CCUS field, China Petroleum has established a full-process technology and standard specification system, providing operational guidelines for carbon capture, transportation, storage and utilization. In the field of gas hydrogen doping, Yumen Project has established the application scheme and evaluation system of the whole process of "Blending-Transmission-End-Use-Trade Measurement", laying a standard foundation for the safe application of different hydrogen doping ratios.

Market mechanism innovation has stimulated integration vitality. The practice of green financial policy in Daqing and other old oil areas has achieved remarkable results. By the end of May 2023, the banking industry in Daqing City had issued 6.67 billion yuan of loans for wind power photovoltaic projects and provided 1.06 billion yuan of insurance guarantee. At the same time, the carbon market mechanism has been gradually improved. The ten-million-ton CCUS projects launched by enterprises such as China Petrochemical and Shell explore the economic transformation of environmental benefits through carbon trading, providing additional income sources for the integration 13 projects.

The collaborative management mechanism has made breakthroughs across fields. The collaborative supervision mechanism established by the State Administration of Market Supervision and the National Energy Administration has broken the traditional management mode of division of departments and improved supervision efficiency through regular work coordination, joint inspection and information sharing. At the local level, Guangzhou City has established a working mechanism of multi-department and territorial government collaboration to carry out joint research, standard research and facility construction for biodiesel pilot projects. Ordos promotes the "integration of oil, gas, electricity and hydrogen" energy supply station model, which integrates management resources of different energy categories and realizes infrastructure sharing and operational efficiency improvement. This cross-department and cross-field coordination mechanism effectively solves the coordination problems in integrated development].

The oil depot safety management supervision and assessment method establishes the principle of "prevention first, safety first", and adopts the combination of regular and irregular assessment methods to conduct comprehensive assessment from six dimensions of fire safety, safe production, personnel quality, equipment management and environmental protection. The assessment results are directly related to reward and punishment measures. Excellent units will be notified and rewarded, and unqualified units will face the punishment of suspension of production for rectification, fine and even revocation of business qualification. The quantitative assessment mechanism provides institutional guarantee for the safe and standardized operation of high-risk fusion projects such as CCUS and gas hydrogen doping.

6.6. Main Revelation

Under the background of achieving carbon peak and carbon neutralization, the key to promoting the deep integration of oil and gas and new energy lies in: relying on the three-dimensional interaction of policy coordination, technological breakthrough and market mechanism innovation, establishing a coordinated development paradigm of "supply security-low carbon conversion-value creation". The specific paths include: ① At the policy level, efforts should be made to eliminate institutional barriers, and special planning and simplified approval

should be adopted to promote oil and gas field enterprises to obtain new energy development qualifications.(e.g. Daqing Oilfield Wind, Solar and Reservoir Integration Project);② Key problems need to be overcome at the technical level, focusing on the development of low-cost green hydrogen production (e.g. Xinjiang Kuqa Project) and CCUS large-scale application (such as Qilu Petrochemical Million Tons Project) and smart energy system;③ Internal vitality should be stimulated at the market level, with the help of green electricity trading and carbon income mechanism (such as CCUS carbon assets of China Petrochemical Company) and distributed transactions to improve the economy of the project;④ Pilot projects shall be taken as the guide at the implementation level, such as promoting carbon neutralization demonstration area of Shengli Oilfield and offshore wind power supply project of Bohai Oilfield. Through the above measures, the complementary win-win situation of oil and gas and new energy business will be finally realized, which will not only enhance the national energy security guarantee capability (such as 30% increase in natural gas production), but also promote the reduction of carbon intensity in the industry (such as 3410 tons carbon reduction in Daqing), contributing China practice and China wisdom to the green transformation of world energy.

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