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Research on the Integrated Development of the Oil and Gas Industry with Emerging Industries: Logic, Pathways and Countermeasures

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Abstract

Driven by the "Dual Carbon" goals, constrained by energy security, and accelerated by the new round of scientific and technological revolution, the oil and gas industry is transforming from a supplier of fossil fuels alone into a comprehensive energy service provider. Integrated development with emerging industries such as new energy, hydrogen, carbon capture, utilization and storage (CCUS), and the digital economy has become a central proposition for the high-quality development of the oil and gas sector. Grounded in the theory of industrial convergence, this paper outlines the internal logic and policy support behind the integration of the oil and gas industry with emerging industries, systematically examines the current status and main pathways of such integration, and analyzes the practical constraints involving technology and cost, institutions and mechanisms, data foundations, and standards. The study indicates that the oil and gas industry should build on its endowments in resources, pipelines, technology and personnel; uphold the principle of "stabilizing oil and increasing gas while establishing the new before replacing the old"; and, through strengthening top-level design, advancing technological breakthroughs and demonstrations, improving market mechanisms, and consolidating digital and human-capital foundations, construct in an orderly manner a modern energy industrial system in which oil, gas and new energy develop in coordination, thereby achieving green and low-carbon transformation while safeguarding national energy security.

Keywords

Oil and gas industry; emerging industries; industrial convergence; new energy; hydrogen; CCUS; digital transformation.

1. Introduction

Oil and gas are foundational industries bearing on national energy security and the economic lifeline. For a long period, the oil and gas industry has taken the exploration, development, refining and processing of fossil energy as its core business, forming an industrial system of substantial scale and complete value chains. As global consensus on addressing climate change has deepened and China's Dual Carbon strategy has advanced, the energy mix has undergone profound adjustment. The oil and gas industry faces both transition pressures stemming from the peaking of refined-oil demand and tightening low-carbon constraints, and the historical opportunity to deeply integrate with emerging industries and reshape its competitiveness [1-2].

In terms of policy orientation, the state has successively issued a series of documents including the Fourteenth Five-Year Plan for the Modern Energy System and the Action Plan for Carbon Peaking Before 2030, which define the objectives of building a modern energy system and promoting the green and low-carbon transition of energy, and treat new energy and hydrogen as priority strategic emerging industries [1][3]. The Fifteenth Five-Year Plan for the

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Development of Oil and Gas further proposes building a modern oil and gas industrial system; while maintaining the bottom line of energy security and steadily advancing the green transition, it incorporates CCUS targets into a national plan for the first time, charting the direction for the integration of the oil and gas industry with emerging industries [2].

Against this background, how the oil and gas industry can break away from path dependence on conventional business and achieve deep integration with emerging sectors such as new energy, hydrogen, CCUS and the digital economy constitutes both a major strategic issue concerning national energy security and green low-carbon transition, and a practical task for the high-quality development of oil and gas enterprises. Based on the theory of industrial convergence, this paper systematically explores, from the perspectives of logic, pathways and countermeasures, the internal mechanisms and implementation approaches through which the oil and gas industry integrates with emerging industries, with the aim of providing reference for its transformation and upgrading.

2. Internal Logic and Policy Support for Integration with Emerging Industries

2.1. Theoretical meaning of industrial convergence

Industrial convergence refers to the dynamic process in which, driven by technological innovation and deregulation, the technological, product, market and organizational boundaries between originally independent industries gradually blur, overlap and permeate one another, ultimately giving rise to new industries or new business formats. Its internal mechanism comprises three progressive levels: technological, business and market convergence. The generalizability of underlying technologies—such as digitalization and clean technologies—provides the technical basis for convergence; firms reorganize their business processes on shared technology platforms to form new business formats; and these new formats ultimately reshape the industrial structure through market expansion. For the oil and gas industry, convergence with emerging sectors such as new energy, hydrogen and CCUS is, in essence, a process in which the oil and gas value chain extends and reorganizes toward low-carbon, digital and comprehensive directions under the impetus of the technological shifts toward energy decarbonization and intelligence.

2.2. Internal drivers of integration

The integration of the oil and gas industry with emerging industries is not an externally imposed extension of policy, but an inevitable choice resulting from the combined effect of multiple internal drivers.

First, the rigid pressure of carbon constraints. Oil and gas extraction, refining and end-use processes emit substantial amounts of carbon; under the carbon peaking and carbon neutrality targets, the industry faces clear and binding emission-reduction requirements. The Action Plan for Carbon Peaking Before 2030 calls for vigorously developing new energy and accelerating the substitution of fossil fuels, which objectively requires oil and gas enterprises to adjust their energy-use structure and business layout and to offset existing emissions through negative-carbon technologies such as CCUS [3].

Second, the dual demands of energy security and supply structure. China relies heavily on imported oil and gas, and enlarging domestic exploration and development remains necessary to ensure supply security; at the same time, the diversification and decarbonization of the energy system require oil and gas enterprises to develop in coordination with new energy, forming a complementary and mutually supporting supply pattern [1-2].

Third, the pressure from evolving market structure and profitability models. Long-term decline in refined-oil demand and irreversible new-energy substitution make it difficult to sustain the

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traditional profit model that relies solely on oil-price dividends and scale expansion. Enterprises need to expand into new businesses such as advanced materials, new energy, hydrogen and CCUS to rebuild sources of value [7].

Fourth, the enabling conditions provided by technological change. The maturing of digital, intelligent and clean technologies creates the conditions for the oil and gas industry to open up new business formats through technological convergence, lower transition costs and raise efficiency [10].

2.3. Policy support

A relatively systematic policy-support system has taken shape at the national level, creating institutional space for the integration of the oil and gas industry with emerging industries. In overall planning, the Fourteenth Five-Year Plan for the Modern Energy System takes the building of a modern energy system as its main thread and emphasizes green and low-carbon transition [1]; the Fifteenth Five-Year Plan for the Development of Oil and Gas defines the construction of a modern oil and gas industrial system and steady green transition [2]. In specific fields, the Medium- and Long-Term Plan for the Hydrogen Industry (2021–2035) establishes hydrogen as an important component of the national energy system and a strategic emerging industry [4]; the guidance opinion on promoting the integrated development of coal and new energy issued by the National Energy Administration advances coordination between traditional and new energy at the institutional level, encourages energy enterprises to transform into comprehensive energy service providers, and offers a convergent model that can serve as a reference for the oil and gas sector [5]; the Energy-Sector Energy-Conservation and Carbon-Reduction Action Plan (2026–2028) sets out concrete tasks for decarbonizing energy use in oil and gas production and supply, and for CO2-EOR and storage projects [6]. Together, these policies constitute the institutional environment for the integration of the oil and gas industry with emerging industries.

3. Current Status of Integration with Emerging Industries

In recent years, the major domestic oil and gas enterprises have incorporated integration with emerging industries into their development strategies, and the trend has moved from exploratory starts toward accelerated advancement.

At the corporate strategy level, the three major state-owned oil and gas enterprises have each formulated distinctive transition pathways. China National Petroleum Corporation (CNPC) has set the direction of "oil and gas as the mainstay, green as the complement," transforming into an integrated energy company covering oil, gas, heat, electricity and hydrogen; China Petroleum & Chemical Corporation (Sinopec) strives to build itself into China's largest hydrogen company and to develop integrated oil, gas, hydrogen, electricity and non-fuel-energy services; China National Offshore Oil Corporation (CNOOC) draws on its offshore advantage to expand the potential of integrated refueling businesses for oil, gas, electricity and hydrogen [7]. Their practices indicate that a consensus on integrated development has taken shape, and strategic planning is moving toward business implementation.

At the demonstration-project level, a number of landmark projects have been launched. Sinopec began construction at the Shengli Oilfield of the country's first full-chain, million-tonne-scale, low-concentration CCUS demonstration project, scheduled for completion and commissioning by the end of 2028, in which low-concentration flue gas captured from coal-fired power plants will be entirely used for CO2-EOR and storage in the oilfield [8]; CNOOC has advanced the country's first offshore CO2 storage demonstration project, achieving an organic combination of carbon storage and enhanced oil production [9]. In the digital domain, building intelligent production and operations systems based on digital twins and artificial intelligence has become

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an industry trend, and deep-water oil and gas production platforms already possess remote-controlled production capability and have markedly reduced energy consumption [10].

Overall, integration has extended from isolated attempts in particular segments into a systematic layout spanning new energy, hydrogen, CCUS, the digital economy and other fields; however, its depth, maturity and scale remain at an early stage, and the different pathways differ markedly from one another.

4. Main Pathways of Integration with Emerging Industries

Integration may be pursued at the technological, business and market levels, giving rise to a set of interconnected implementation pathways. Table 1 summarizes the principal pathways and their key features.

Table 1. Main pathways of oil and gas integration with emerging industries

Integration pathway	Main carrier	Typical direction
Integration with new energy	Oil and gas blocks, pipeline facilities	Wind and solar development, geothermal utilization, comprehensive energy services
Integration with hydrogen	Hydrogen-production units, storage and transport network, hydrogen refueling stations	Gray and blue hydrogen, green-hydrogen substitution, hydrogen transport
Integration with CCUS	Hydrocarbon reservoirs, EOR and storage projects	CO2-EOR, large-scale storage and utilization
Integration with the digital economy	Smart oilfields, industrial foundation models	Data-driven exploration and development, intelligent production and operations
Synergy with advanced materials and chemicals	Refining units, high-end chemical products	High-end chemicals, biodegradable materials, carbon materials

4.1. Integration with the new-energy industry

Relying on existing advantages in mineral-rights areas, land resources, grid access and engineering teams, oil and gas enterprises vigorously develop wind, solar and geothermal businesses, promote clean substitution of energy used in oil and gas production, and form an energy-supply structure featuring coordinated "oil and gas plus new energy." On the one hand, distributed wind and solar generation are laid out across oil and gas fields and along pipelines to supply green electricity for production and to reduce emissions in the production stage. On the other hand, enterprises expand comprehensive energy services, supplying complementary power, heat and gas to mining areas and surrounding regions, and gradually shift from single energy suppliers toward comprehensive energy service providers [1][5]. As a transition fuel, natural gas plays a peak-shaving role in accommodating the volatility of new energy, providing a practical interface for the complementary integration of the two energy sources.

4.2. Integration with the hydrogen industry

Hydrogen is a key lever for the oil and gas industry to achieve a clean transition and extend its value chain. Oil and gas enterprises possess the feedstock, technology and engineering base for hydrogen production: by-product hydrogen from refining can be recovered and reused at low cost; natural gas can be reformed into gray or blue hydrogen; and green hydrogen can be

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produced by electrolyzing water with renewable power over the long term [4]. In the storage and transport segment, enterprises can upgrade and repurpose natural-gas pipelines and refueling facilities to develop hydrogen storage, transport and refueling networks, lowering the cost of hydrogen infrastructure. In the application segment, expanding hydrogen into refining hydrogenation, transport fuels and industrial feedstock opens new business space. By constructing an integrated hydrogen value chain covering production, storage, transport, refueling and utilization, the oil and gas industry can consolidate its traditional strengths while advancing toward the clean-hydrogen industry [4][7].

4.3. Integration with the CCUS industry

CCUS is a strategic integration pathway that delivers both emission-reduction and production-increment value for the oil and gas sector. Hydrocarbon reservoirs—particularly depleted oil and gas fields and suitable basins—are natural sites for geological CO2 storage and CO2-EOR. Injecting captured CO2 into reservoirs enables large-scale geological storage and supports carbon reduction, while enhanced oil recovery raises crude-oil recovery, yielding dual benefits of emission reduction and production growth [6][8]. At the national level, it has been explicitly proposed to leverage the oil and gas industry's full CCUS value-chain advantage, and to arrange CO2-EOR and storage projects in basins such as Ordos, Bohai Bay, Junggar and the Pearl River Mouth [6]; a target has been set for annual CO2 injection through CCUS to reach the tens-of-millions-tonne level by 2030 [2]. With the advancement of million-tonne-scale demonstration projects, CCUS in the oil and gas industry is moving from technical demonstration toward large-scale, industrial application and has become a landmark pathway of integration between oil, gas and emerging industries.

4.4. Deep integration with the digital economy

The penetration of the digital economy is reshaping the entire process of oil and gas exploration, development, production and operations. Supported by big data, artificial intelligence, digital twins and the Internet of Things, oil and gas enterprises build smart oilfields and automate and intelligentize geological modeling, reservoir numerical simulation, wellbore diagnosis, pipeline-network analysis, and intelligent allocation of production and injection, thereby markedly raising exploration and development efficiency and operational management [10]. The application of industrial foundation models shifts core work such as seismic-wave solving and dynamic geological modeling from experience-driven manual analysis to data- and algorithm-driven processes, substantially shortening processing cycles and overall costs [10]. Digital transformation not only improves the efficiency and safety of conventional business, but also gives rise to new formats such as data services and intelligent maintenance, creating broad scope for integration between the oil and gas sector and the digital-economy industry.

4.5. Synergy with new materials and high-end chemicals

Refining and petrochemical operations are the key link through which the oil and gas value chain extends toward high added value. Through synergy with strategic emerging industries such as advanced materials and high-end chemicals, enterprises can convert their feedstock advantage into product advantage, developing high-end polyolefins, carbon fiber, biodegradable materials and other advanced-material products, and upgrading the chemical product mix from bulk basic products toward high-end specialized products. This pathway helps enterprises optimize the product mix and upgrade the value chain against the backdrop of declining refined-oil demand, strengthening earnings stability, and it also aligns with national policy guidance toward the high-end, diversified and low-carbon development of the petrochemical industry [1][5].

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5. Challenges Faced by Integration with Emerging Industries

Despite the positive progress achieved, integration still faces multiple practical constraints on the whole.

First, technology and cost bottlenecks. Key technologies such as green-hydrogen production and large-scale CCUS are not yet fully mature, and unit costs remain high. Compared with gray hydrogen, green hydrogen still lacks economic competitiveness; capture, transport and storage costs for CCUS remain elevated, and commercial operation faces substantial economic obstacles, making it difficult to rely entirely on market mechanisms for a self-sustaining cycle in the short term [4][8].

Second, institutional, regulatory and investment constraints. Oil and gas, new energy and hydrogen fall under distinct management systems and market rules; cross-sector integration encounters institutional barriers in planning coordination, approval procedures, grid connection and consumption, carbon trading and green-certificate mechanisms. Integration projects require large-scale investment with long payback periods, and under volatile oil prices, firms' willingness to invest and risk-bearing capacity are constrained [2][5].

Third, shortcomings in data foundations and standards. Data silos remain prominent in the oil and gas industry; insufficient sharing of data across disciplines and systems constrains the large-scale application of artificial-intelligence models. Meanwhile, standards and specifications in emerging fields such as hydrogen and CCUS are not yet well established, and the safety-regulation system needs improvement, which affects the orderly development of integrated industries [4][10].

Fourth, shortages of talent and organizational capability. Emerging integrated businesses create strong demand for multidisciplinary talent. The traditional talent structure of oil and gas enterprises centers on oil and gas disciplines, with relatively limited reserves of specialists in new energy, digitalization and carbon management; the organizational mechanisms and incentive arrangements likewise need corresponding adjustment.

6. Countermeasures and Recommendations

To address these challenges, integration should be advanced on multiple fronts while safeguarding the bottom line of energy security, upholding the principle of "stabilizing oil and increasing gas, establishing the new before replacing the old, and substituting in an orderly manner."

First, strengthen top-level design and planning coordination. At the national and industry levels, coordinate the planning of oil and gas, new energy, hydrogen and CCUS; define the priority fields, spatial layout and phased objectives of integrated development; establish cross-departmental coordination mechanisms; and improve the institutional alignment of oil, gas and new energy in grid connection, consumption and carbon trading, so as to remove institutional and regulatory barriers to convergence [1-2][5].

Second, increase investment in key technology R&D and demonstration dissemination. Around core technologies such as green-hydrogen production, low-cost CCUS and digital twins, organize coordinated industry-university-research efforts to reduce technical costs; expand the scale of CCUS and green-hydrogen demonstration projects in an orderly way, accumulate engineering experience and operational data through demonstration, and gradually move technologies from demonstration toward commercialization [4][6][8].

Third, improve market mechanisms and diversified financing. Improve the carbon market, green-certificate and green-power trading mechanisms, and bring the emission-reduction value of the oil and gas sector and the negative-carbon contribution of CCUS into market pricing; innovate green-finance instruments to channel social capital into integration projects and

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spread investment risk; and provide necessary policy support for strategically valuable integration projects that remain uneconomic during their growth stage [2][5].

Fourth, consolidate digital and data foundations. Accelerate the development of industry data standards; promote the interconnection and sharing of data across the whole chain of exploration, development, production and operations; build an industry-level data middle platform; and strengthen cybersecurity and data governance to provide high-quality data support for AI foundation models and smart oilfield development, thereby driving deep integration of digital technology with oil and gas operations [10].

Fifth, strengthen multidisciplinary talent development. Optimize the talent structure; on the basis of oil and gas expertise, strengthen the training and recruitment of specialists in new energy, hydrogen, carbon management, data science and artificial intelligence; and improve assessment, incentive and organizational mechanisms suited to emerging businesses, in order to stimulate corporate innovation vitality.

7. Conclusion

The integrated development of the oil and gas industry with emerging sectors such as new energy, hydrogen, CCUS and the digital economy is an inevitable trend arising jointly from the Dual Carbon strategy, energy security and technological change. The examination in this paper shows that the sector has reached a consensus on transforming into a comprehensive energy service provider, with increasingly clear integration pathways covering new-energy coordination, hydrogen value-chain extension, CO2-EOR and storage, digital transformation, and high-end chemical synergy, accompanied by a number of landmark demonstration projects. Nonetheless, integration remains at an early stage and faces practical constraints in technology and cost, institutions and mechanisms, data foundations and personnel.

Looking ahead, the oil and gas industry should uphold the principle of "stabilizing oil and increasing gas, establishing the new before replacing the old"; on the premise of safeguarding national energy security, strengthen top-level design, advance technological R&D, improve market mechanisms, consolidate digital foundations and cultivate multidisciplinary talent, and orderly promote deep integration with emerging industries to build a modern energy industrial system featuring coordinated development of oil, gas and new energy. Only by pursuing transition while holding the safety bottom line and enhancing value through convergent innovation can the oil and gas industry realize high-quality and sustainable development amid the energy revolution.

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