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Exploration, Development, and Production of Oil and Gas in China: Current Status, Challenges, and Strategic Directions

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Abstract

As a critical component of China's energy security framework, the oil and gas sector plays a pivotal role in balancing economic growth, industrial demand, and environmental transitions. This paper provides a comprehensive analysis of China's oil and gas exploration, development, and production (EDP) landscape, focusing on key trends, technological advancements, structural challenges, and strategic responses. Through an examination of domestic resource distribution, production dynamics, import dependencies, and innovation-driven solutions, the study highlights the sector's evolving role in China's energy mix. Data from authoritative sources (e.g., National Bureau of Statistics of China, CNPC, CNOOC, Sinopec, and the International Energy Agency) are integrated to assess the current state and future outlook. The findings underscore the urgency of enhancing domestic resource efficiency, accelerating technological breakthroughs, and optimizing the oil-gas transition to support China's dual-carbon goals (carbon peak by 2030, carbon neutrality by 2060).

Key Words

Exploration;Development;Production;Petroleum; China;CNPC

1. Introduction

China's energy system has undergone rapid transformation over the past four decades, transitioning from a coal-dominated structure to a more diversified mix that includes oil, natural gas, renewables, and nuclear power. Despite the growing share of non-fossil energy, oil and natural gas remain indispensable for meeting transportation fuel demand, industrial feedstock requirements, and seasonal energy flexibility. As of 2023, oil and gas accounted for approximately 28% of China's total primary energy consumption (oil: ~18%; gas: ~10%), with imports covering over 70% of crude oil and 45% of natural gas demand, respectively (National Bureau of Statistics of China, 2024). This heavy reliance on external supply chains

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poses significant risks to energy security, necessitating sustained investment in domestic exploration, development, and production (EDP) to stabilize supply and mitigate geopolitical vulnerabilities.

This paper systematically examines China's oil and gas EDP sector through three lenses: (1) the geological and resource distribution characteristics of domestic basins; (2) the technological and operational advancements driving production efficiency; and (3) the structural challenges (e.g., maturing fields, deepwater barriers, cost pressures) and strategic responses (e.g., unconventional resources, digitalization, international cooperation). By integrating quantitative data and qualitative insights, the analysis aims to provide a holistic understanding of China's oil and gas EDP trajectory in the context of energy security and low-carbon transitions.

2. Resource Base and Geological Characteristics

2.1 Domestic Oil and Gas Reservoirs: Distribution and Potential

China's oil and gas resources are distributed across 16 major sedimentary basins, which can be categorized into three groups based on exploration maturity and resource richness:

- **Mature Basins (High Exploration Intensity)**: Including the Songliao Basin (Northeast), Bohai Bay Basin (Eastern Coast), Ordos Basin (North-Central), and Tarim Basin (Northwest). These basins account for over 80% of cumulative oil and gas production but are now characterized by declining reserves-to-production (R/P) ratios. For instance, the Songliao Basin (home to the Daqing Oilfield, China's largest conventional oilfield) has an R/P ratio of ~8 years, with remaining recoverable reserves concentrated in deep and ultra-deep layers (below 3,500 meters) (CNPC, 2023).
- **Semi-Mature Basins (Moderate Exploration)**: Such as the Sichuan Basin (Southwest), Junggar Basin (Northwest), and Qaidam Basin (Qinghai). These regions host significant unconventional resources (e.g., tight oil, shale gas) and have seen accelerated development in recent years. The Sichuan Basin, for example, is China's leading shale gas producer, contributing over 60% of national output (CNOOC, 2023).
- **Frontier Basins (Low Exploration but High Potential)**: Including the South China Sea deepwater zones, the Qiangtang Basin (Tibet), and the Yilan-Yitong Basin (Northeast). These areas remain underexplored due to technical (e.g., deepwater drilling), environmental (e.g., fragile ecosystems), and logistical constraints, but preliminary assessments suggest substantial hydrocarbon potential—particularly in deep and ultra-deep formations (greater than 6,000 meters) (Sinopec, 2022).

Resource Estimates: According to the Ministry of Natural Resources (MNR, 2022), China's

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technically recoverable oil reserves stand at approximately 3.6 billion tons (25 billion barrels), with proven reserves of 3.8 billion tons (as of 2023). Natural gas reserves are estimated at 63 trillion cubic meters (technically recoverable), including 8.8 trillion cubic meters of shale gas and 1.2 trillion cubic meters of coalbed methane (CBM). Proven natural gas reserves reached 6.7 trillion cubic meters in 2023, with the Sichuan Basin alone accounting for 35% of the total.

2.2 Unconventional Resources: Shale Oil, Shale Gas, and Tight Oil/Gas

To offset the decline in conventional fields, China has prioritized the development of unconventional hydrocarbons, particularly shale gas and tight oil.

- **Shale Gas**: The Sichuan Basin's Longmaxi Formation (Lower Silurian) is the core play, featuring high organic content (TOC > 2%), favorable brittleness indices, and moderate burial depths (2,000–3,500 meters). By 2023, China's annual shale gas production exceeded 25 billion cubic meters (bcm), with the Fuling Shale Gas Field (operated by Sinopec) alone producing over 10 bcm—making it one of the world's largest commercial shale gas projects outside North America (CNOOC, 2023). However, challenges such as complex faulted structures, low permeability (nanodarcy scale), and water-intensive hydraulic fracturing (fracking) limit scalability in other basins (e.g., the Yangtze Platform).
- **Tight Oil**: Primarily located in the Ordos Basin's Changqing Oilfield (Triassic Yanchang Formation) and the Junggar Basin's Mahu Sag (Jurassic), tight oil reservoirs require horizontal drilling and multi-stage fracturing to achieve economic flow rates. Production reached approximately 3 million tons in 2023, with the Changqing Oilfield contributing over 60% of the total.
- **Coalbed Methane (CBM)**: China holds the world's third-largest CBM reserves (estimated at 1.2 trillion cubic meters), primarily in the Qinshui Basin (Shanxi Province) and the Ordos Basin. Despite decades of exploration, CBM production remains modest (~6 bcm in 2023) due to low well productivity, high dewatering costs, and competition from conventional gas.

3. Production Dynamics and Operational Trends

3.1 Crude Oil: Declining Conventional Output and Regional Shifts

China's crude oil production peaked at 199 million tons (approximately 4.0 million barrels per day, mb/d) in 2015 but has since stabilized at around 195–200 million tons (2023: 209 million tons, or ~4.2 mb/d) due to intensified efforts in mature field revitalization and unconventional

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development (National Bureau of Statistics, 2024).

- **Key Producing Regions**: The Bohai Bay Basin (operated by CNOOC) remains the largest contributor, accounting for ~30% of national output (60–65 million tons/year), with major fields like Penglai 19-3 (offshore) and Jidong Oilfield. The Ordos Basin (CNPC) follows, producing ~35 million tons/year, primarily from tight oil in the Changqing Oilfield. The Tarim Basin (Xinjiang, CNPC) contributes ~25 million tons/year, with deep reservoirs (4,000–8,000 meters) requiring advanced drilling technologies.
- **Challenges**: Conventional oilfields face declining recovery factors (average ~25–30%, compared to global best practices of 35–45%) due to reservoir heterogeneity, water flooding inefficiencies, and high water cuts (some fields exceed 90%). Revitalization strategies include polymer flooding, steam injection (for heavy oil), and enhanced oil recovery (EOR) techniques, which have improved recovery by 3–5 percentage points in pilot projects (CNPC, 2023).

3.2 Natural Gas: Accelerated Growth Driven by Unconventional Sources

Natural gas production has grown steadily, from 124 bcm in 2010 to 229 bcm in 2023, with an average annual growth rate of 5.8% (CNOOC, 2023). This growth is primarily fueled by unconventional resources:

- **Conventional Gas**: Dominated by the Sichuan Basin (Ordovician–Permian carbonate reservoirs) and the Tarim Basin (Cretaceous sandstones), conventional gas accounts for ~60% of total output (135 bcm in 2023). The Sichuan Basin's Puguang Gas Field (CNPC) is the largest single conventional source, producing ~10 bcm/year.
- **Unconventional Gas**: Shale gas (25 bcm) and tight gas (30 bcm) collectively contribute ~24% of production. The Sichuan Basin's shale gas boom has been instrumental in reducing reliance on imports, while tight gas from the Ordos Basin supplements regional supply.

3.3 Offshore and Deepwater: Strategic Frontiers

Offshore oil and gas (operated by CNOOC) play a critical role in diversifying supply sources. In 2023, offshore production reached 55 million tons of oil and 22 bcm of gas, with the Bohai Bay (35 million tons oil, 10 bcm gas) and the South China Sea (20 million tons oil, 12 bcm gas) as the core areas.

- **Deepwater Challenges**: The South China Sea's deepwater zones (depths > 1,500 meters) host significant hydrocarbon potential (estimated reserves of 15–20 billion barrels of oil

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equivalent), but development is hindered by harsh environments (typhoons, high pressures), complex geology, and high capital expenditures. The Lingshui 17-2 Gas Field (China's first deepwater self-operated project, operational since 2021) produces ~3 bcm/year, demonstrating China's growing capability in deepwater E&P (CNOOC, 2023).

4. Technological Advancements and Innovation

To address the complexities of mature fields, unconventional resources, and frontier basins, China has invested heavily in E&P technologies, achieving notable breakthroughs in the following areas:

4.1 Seismic Imaging and Reservoir Characterization

Advanced 3D and 4D seismic technologies (e.g., wide-azimuth, full-waveform inversion) have improved reservoir delineation accuracy, particularly in complex structures like the Tarim Basin's buried hills and the Sichuan Basin's faulted shale formations. High-resolution logging tools (e.g., nuclear magnetic resonance, microresistivity imaging) enable real-time monitoring of reservoir properties during drilling.

4.2 Drilling and Completion Techniques

- **Horizontal Drilling**: Widely applied in tight oil (Ordos Basin) and shale gas (Sichuan Basin), with lateral sections exceeding 2,000 meters to maximize contact area.
- **Multi-Stage Fracturing**: Domestic fracturing fleets (developed by Sinopec and service companies) now support up to 30 stages per well, using proppants (e.g., ceramic beads) to sustain fracture conductivity.
- **Deep/ Ultra-Deep Drilling**: Breakthroughs in drilling fluids, casing materials, and downhole motors have enabled operations in the Tarim Basin's 8,000-meter-deep Tazhong Block, where oil was discovered in 2022 (CNPC, 2023).

4.3 Enhanced Oil Recovery (EOR) and Digitalization

- **EOR Methods**: Polymer flooding (improving sweep efficiency), CO_2 injection (pilot projects in the Jilin Oilfield), and microbial EOR (experimental stages) are being tested to boost recovery factors.
- **Digital Oilfields**: Integration of the Internet of Things (IoT), artificial intelligence (AI), and big data analytics enables real-time production optimization. For example, the Changqing Oilfield's "digital oilfield" system reduces manual intervention by 40% and improves reservoir management efficiency by 25% (CNPC, 2023).

5. Challenges and Strategic Responses

Despite progress, China's oil and gas EDP sector faces persistent challenges:

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5.1 Resource Quality Degradation and Maturing Fields

Over 70% of remaining conventional reserves are located in deep (3,000–5,000 meters), high-pressure, or high-sulfur formations, which require more expensive and technically demanding extraction methods. Mature fields (e.g., Daqing, Shengli) face declining output and rising operating costs (break-even prices for some fields exceed $60/barrel).

5.2 Import Dependency and Geopolitical Risks

China imported 520 million tons of crude oil (10.5 mb/d) and 169 bcm of natural gas in 2023, with over 75% of oil and 40% of gas sourced from politically sensitive regions (e.g., Middle East, Russia). Supply chain disruptions (e.g., Red Sea shipping risks, sanctions on Russian gas) highlight the need for domestic supply buffers.

5.3 Environmental and Regulatory Constraints

Unconventional development (e.g., shale gas fracking) faces water usage concerns (especially in arid basins like the Ordos), while flaring and methane emissions require stricter controls to align with China's carbon neutrality goals.

5.4 Strategic Responses

To mitigate these challenges, China has adopted a multi-pronged strategy:

1. **Deepening Domestic Exploration**: Prioritizing frontier basins (e.g., South China Sea deepwater, Qiangtang Basin) and unconventional resources (e.g., tight oil in the Junggar Basin, CBM in Shanxi).
2. **Technology Innovation**: Investing in AI-driven reservoir simulation, autonomous drilling rigs, and next-generation fracturing materials to reduce costs and improve efficiency.
3. **Supply Chain Resilience**: Expanding strategic petroleum reserves (targeting 100 days of import coverage) and diversifying import sources (e.g., increasing LNG contracts with Qatar, Mozambique).
4. **Low-Carbon Integration**: Promoting CCUS (carbon capture, utilization, and storage) in oilfields (e.g., the Shengli Oilfield's pilot project stores 1 million tons CO_2/year) and transitioning toward cleaner gas-fired power to complement renewables.

6. Conclusion

China's oil and gas EDP sector remains a cornerstone of national energy security, balancing the dual imperatives of meeting immediate demand and transitioning toward a low-carbon future. While conventional resources are maturing, the development of unconventional hydrocarbons (shale gas, tight oil), offshore deepwater projects, and digital technologies has unlocked new growth potential. However, challenges such as resource quality degradation,

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import dependency, and environmental constraints necessitate sustained investment in innovation, infrastructure, and policy coordination. Moving forward, China's ability to optimize its oil-gas transition—leveraging domestic resources while accelerating renewables integration—will be critical to achieving its dual-carbon targets and ensuring long-term energy resilience.

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