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Application Potential of Hydrogen Energy in Oil and Gas Field Scenarios

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Abstract. Hydrogen energy is a critical low-carbon transition pathway for the oil and gas industry, leveraging oilfields' unique conditions for integrated supply, storage, and utilization. This study systematically evaluates application potential through literature review and case studies, covering produced-water electrolysis, wind-solar hybrid hydrogen production, in-situ generation, depleted-reservoir storage, and pipeline blending, with demonstrations from Changqing, Shengli, and Tarim. Key findings indicate: (1) diverse production routes are viable—produced-water and wind-solar pilots are underway, while in-situ is a frontier; (2) depleted reservoirs enable large-scale, long-term storage, whereas pipeline blending offers near-term gains but faces hydrogen embrittlement and safety-standard bottlenecks; (3) applications including hydrogen-powered drilling, multi-energy integration at joint stations, refinery green-H_2 substitution, and (Carbon Capture, Utilization and Storage-Enhanced Oil Recovery)CCUS-EOR synergy have been validated; (4) with falling renewable costs and rising carbon prices, green hydrogen projects are projected to break even during the 15th Five-Year Plan period; (5) domestic pilots confirm technical feasibility, yet scaling requires addressing cost, safety, and standardization challenges. Achieving economic viability for hydrogen requires prioritizing blending/storage demonstrations, intensifying in situ fundamental studies, and upgrading policy and standard systems.

Keywords: Hydrogen energy, oil and gas fields, geological hydrogen storage, in-situ hydrogen production

1. Introduction

Under global carbon peaking and neutrality goals, the oil and gas industry faces severe emission reduction pressure. Hydrogen, as a clean secondary energy, links fossil fuels and renewables. The oil and gas sector has natural synergies with hydrogen: mature production technologies, extensive pipeline networks, geological expertise, and oilfield sites offering integrated "production-storage-utilization" conditions. China has elevated hydrogen to a national strategic priority, with further policy support expected during the 15th Five-Year Plan period. Thus, exploring hydrogen application in oilfields is significant for emission reduction and sustainable development.

Theoretically, existing hydrogen research mostly focuses on transportation, power, and steel, with limited systematic analysis on the oil and gas industry—a unique energy producer and consumer.

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This study reviews technical routes, economic performance, and challenges, enriching hydrogen economy theory and offering a new perspective for low-carbon energy system transition. Practically, it provides: (1) technical route references for oil and gas enterprises to prioritise hydrogen technologies; (2) decision-making support for policymakers on subsidies and carbon pricing through emission-reduction and economic-bottleneck analyses; and (3) experience references for engineering demonstrations by summarising domestic cases (e.g., Changqing and Tarim oilfields), reducing trial-and-error costs for future projects.

Prior studies have achieved rich results. At the macro level, infrastructure and technical capabilities of oil and gas can synergize with hydrogen, and asset reuse (pipelines, gas storage, geological experience) may cut costs [1, 2]. For frontier technologies, in-situ hydrogen production via methane reforming or steam gasification can avoid long-distance transport, but remains at laboratory stage [3, 4]. Hydrogen production from produced water, wind-solar hybrid systems, and underground storage in depleted reservoirs have been preliminarily verified [5-7], while marine geological storage is emerging [8]. Demonstration projects (e.g., hydrogen-replaced oil drilling) have identified diversified consumption pathways and emission reduction potential [9]. Economic analysis shows green hydrogen could compete with grey hydrogen once carbon prices reach a threshold, and synergies like "hydrogen + CCUS" offer comprehensive benefits [10, 11]. However, deficiencies remain: most studies focus on single technologies or scenarios, lacking systematic "production-storage-utilization" chain integration; economic evaluations lack sensitivity analysis on carbon price and policy uncertainties; and adaptability of frontier technologies (in-situ, marine storage) in oilfield contexts is still nascent.

The full text consists of eight chapters. This chapter serves as the introduction, elaborating on the research background, significance and current research status. Chapter 2 analyzes the supply sources and technical routes of hydrogen energy in oil and gas fields, covering diversified schemes such as hydrogen production from produced water, in-situ hydrogen production and hydrogen production from green electricity. Chapter 3 focuses on hydrogen storage and transportation as well as the potential of geological hydrogen storage, with an in-depth discussion on the technical principles and challenges of underground hydrogen storage in depleted oil and gas reservoirs. Chapter 4 sorts out specific application scenarios of hydrogen energy in links including exploration and development, production gathering and transportation, and integrated refining and chemical processing. Chapter 5 carries out economic and emission reduction benefit analysis to assess cost competitiveness and carbon emission reduction contributions. Chapter 6 summarizes challenges from technical, economic, safety and other dimensions, and puts forward systematic development countermeasures. Chapter 7 conducts an in-depth analysis of typical domestic cases. Chapter 8 presents conclusions and prospects.

2. Supply sources and technical pathways of hydrogen energy in oil and gas fields

Hydrogen supply is the primary link for the application of hydrogen energy in oil and gas field scenarios. Unlike the traditional "grey hydrogen" route dominated by natural gas reforming, oil and gas field scenarios have diversified hydrogen production potential, including emerging technologies such as producing "blue hydrogen" or "green hydrogen" by utilizing oilfield associated resources and in-situ hydrogen generation within reservoirs.

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2.1. Hydrogen production potential of oil and gas fields

Oil and gas fields produce various by-product resources such as produced water, associated gas and waste heat during production. These resources can be used as raw materials or energy for hydrogen production, realizing "local extraction and local utilization".

2.1.1. Hydrogen production from produced water

Produced alongside crude oil extraction, oil and gas field produced water is a large volume of industrial wastewater that generally contains salts, organic matter and suspended solids, leading to high treatment costs. In recent years, domestic pilot tests have verified that pre-treated produced water can be applied to hydrogen production via water electrolysis to form a closed-loop system [6]. The core breakthrough of this technical route lies in the development of salt-tolerant and anti-fouling electrolytic catalysts as well as pre-treatment processes, so as to mitigate the adverse impacts of impurities on electrolysis efficiency and electrode service life. Preliminary economic evaluations indicate that given the existing inherent costs of produced water treatment, converting such wastewater into feedstock for hydrogen production can offset environmental protection expenditures and deliver certain comprehensive benefits [12].

2.1.2. In-situ hydrogen production by fire flooding in oil reservoirs after steam injection development

For heavy oil reservoirs developed by steam injection, the formation temperature usually ranges from 150 to 300°C, and some in-situ combustion (fire flooding) processes can even create local high-temperature zones. Based on thermodynamic calculations and laboratory physical simulations, certain studies have explored the feasibility of injecting gasifying agents (such as steam and air) into oil reservoirs in the late stage of steam injection development to produce hydrogen via catalytic reforming [4]. The core concept of this method is to convert depleted or nearly depleted steam-flooded reservoirs into "underground hydrogen production reactors", utilizing the existing well pattern and formation heat without the need for additional ground-based hydrogen production facilities. Studies indicate that the key technical points of hydrogen production assisted by in-situ combustion lie in controlling the temperature and pressure of the reaction zone as well as the catalyst layout, and this technology is still in the feasibility verification stage at present.

2.1.3. In-situ upgrading hydrogen donor technology for heavy oil

Due to its high viscosity and poor fluidity, heavy oil often needs viscosity reduction through upgrading. Hydrogen donors are compounds that release active hydrogen under thermal effects; they can combine with macromolecular free radicals in heavy oil, suppress condensation and coking, and raise the yield of light oil. Relevant studies have reviewed the types of hydrogen donors (such as tetralin and decalin) and their application prospects in in-situ upgrading of heavy oil [5]. Although hydrogen donors themselves do not directly produce hydrogen, their hydrogen release mechanism in oil reservoirs offers an alternative perspective for hydrogen utilization in oil and gas fields: a closed-loop hydrogen management system can be established by recycling and regenerating hydrogen donors or coupling them with electrolytic hydrogen production.

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2.2. Green hydrogen production via external renewable power and its application in oilfields

In addition to utilizing internal resources of oil and gas fields, generating electricity via external renewable energy sources (wind energy, solar energy) and producing hydrogen through on-site water electrolysis serves as an important supplementary approach for oil and gas fields to obtain green hydrogen.

2.2.1. Wind-solar hybrid hydrogen production

Some oil and gas fields in China are located in regions abundant in wind and solar energy resources, such as Shengli Oilfield, Tarim Oilfield and Changqing Oilfield. Relevant studies have evaluated the application prospect of green hydrogen production technology in Shengli Oilfield, and pointed out that the oilfield can utilize its vast land resources to construct and operate integrated wind-solar power generation and water electrolysis hydrogen production projects. The hydrogen produced can be directly applied to drilling power supply, crude oil heating and refining processes [7]. In addition, the power grid of the oilfield can serve as an absorption and regulation tool after wind power and photovoltaic power are connected to the grid, reducing the curtailment rate of wind and solar power. Economic analysis indicates that when the cost of wind and solar power generation drops below 0.2 yuan per kWh, the production cost of green hydrogen can approach the price range of industrial hydrogen [11].

2.2.2. Collaborative utilization of by-product CO_2 from hydrogen production

In the process of green hydrogen production, only oxygen is generated as a by-product when proton exchange membrane or alkaline water electrolysis technology is adopted. However, high-concentration CO_2 is produced as a by-product if hydrogen is produced via fossil fuel reforming coupled with carbon capture, namely the blue hydrogen pathway. Taking the Tarim Oilfield as an example, some studies have proposed a collaborative model that integrates hydrogen energy utilization with the use of its by-product CO_2 for oil displacement and carbon storage (CCUS-EOR), so as to realize the integration of "hydrogen production, oil displacement and carbon sequestration" [13]. This model makes full use of the geological carbon storage capacity of oil and gas fields and the demand for oil production enhancement through displacement, significantly improving the economic and environmental benefits of the entire industrial chain.

3. Hydrogen energy storage and transportation and the potential of geological hydrogen storage

Efficient storage and transportation of hydrogen serves as an intermediate link connecting hydrogen supply and application, and it is also one of the major bottlenecks restricting the current hydrogen energy industrial chain. Oil and gas field scenarios boast unique advantages in this link. On the one hand, the oil and gas industry owns extensive pipeline networks, gas storage facilities and wellbore infrastructures, which can be utilized for hydrogen transportation and storage either directly or after retrofitting. On the other hand, geological formations such as depleted oil and gas reservoirs and salt caverns act as natural containers for large-scale and long-term hydrogen storage. This chapter analyzes the technical feasibility and development potential of hydrogen storage and transportation from three dimensions: the adaptation of oil and gas infrastructure, hydrogen storage in depleted oil and gas reservoirs, and subsea hydrogen energy exploration.

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3.1. Hydrogen adaptation of oil and gas infrastructure

Hydrogen adaptation of oil and gas infrastructure: Existing natural gas pipelines, gas storage facilities, and wellsite infrastructures are key assets for hydrogen transport and storage, significantly reducing upfront investment and construction time. For pipeline blending, a hydrogen ratio below 10-15% generally meets safety requirements without major retrofitting; higher ratios introduce risks such as hydrogen embrittlement, seal incompatibility, and leakage [14, 15]. Field gathering pipelines, being relatively independent and controllable, are suitable for early blending demonstrations. Depleted gas reservoirs and salt caverns can be repurposed for hydrogen storage, but hydrogen's smaller molecular size, lower viscosity, and higher leakage tendency, along with potential microbial hydrogen loss, require re-evaluation of cap rock sealing, wellbore integrity, and chemical reaction risks [9].

3.2. Self-hydrogen production potential of oil and gas fields

External renewable energy (wind/solar) for on-site electrolysis is another key green hydrogen source for oilfields. Depleted oil/gas reservoirs are prime UHS candidates due to clear geology, good traps, existing wells, and abundant data. Storage involves injecting H_2 into pore spaces, displacing original fluids, and withdrawing when needed. Key parameters: porosity, permeability, pressure, temperature, cap rock integrity. Gas reservoirs that stored natural gas have potential, but H_2's higher reactivity requires attention to microbial/mineral-induced loss and damage [7, 8]. Challenges: (1) H_2 loss via dissolution, mineral reactions (e.g., pyrite→H_2S), and microbial consumption; (2) hydrogen embrittlement of wellbore and surface equipment; (3) explosive mixtures with residual hydrocarbons, requiring oxygen control. Pilot tests exist but no commercial operation yet [9].

3.3. Subsea hydrogen detection and extraction

In addition to utilizing internal resources within oil and gas fields, generating electricity via external renewable energy sources (wind power and solar power) and producing hydrogen through on-site water electrolysis serves as an important supplementary approach for oil and gas fields to obtain green hydrogen.

With the deepening of offshore oil and gas development, utilizing submarine geological structures for hydrogen storage or exploiting natural hydrogen resources has emerged as a new research direction. Studies indicate that salt structures, fault traps and other formations in continental shelf sedimentary basins possess geological conditions suitable for hydrogen storage, which can be reconstructed and utilized relying on offshore oil and gas platforms [10]. Furthermore, natural hydrogen seepage has been discovered in some sea areas, implying that exploitable natural hydrogen reservoirs may exist on the seabed. Submarine hydrogen energy exploration involves technologies such as geochemical tracing and submarine electromagnetic prospecting. Although it is currently in the basic research stage, it offers new ideas for long-term development.

4. Hydrogen energy storage and transportation and the potential of geological hydrogen storage

The production and operation of oil and gas fields involve multiple links including drilling, oil production, gathering and transportation, treatment, and refining, and each link has potential room for hydrogen energy substitution or coupling.

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4.1. Exploration and development link

Main Application Scenarios:

(1) Hydrogen Replacing Diesel for Drilling Power: Conventional drilling platforms rely on diesel generators for power supply, which come with high carbon emission intensity. Changqing Oilfield has fully replaced diesel units with hydrogen power stations in drilling operations, achieving a cumulative carbon reduction of over 120 tons per single well [11]. Hydrogen fuel cells or hydrogen internal combustion engines can serve as drilling power solutions, which are especially suitable for environmentally sensitive areas and blocks with stringent carbon emission constraints.

(2) Hydrogen Transformation of Mobile Equipment Such as Fracturing Trucks and Mud Pumps: Fracturing operations generally require high-power diesel units that generate severe noise and emissions. Hydrogen power packs feature zero emissions, low noise and modular layout flexibility. At present, several equipment manufacturers have launched prototype development of hydrogen-powered fracturing trucks.

Major Challenges and Countermeasures:

(1)Cost Challenges:The initial investment of hydrogen fuel cells is relatively high, and the current price of hydrogen is still higher than that of diesel. As for countermeasures, fuel costs can be reduced through low-cost hydrogen production within oil fields, while striving for carbon emission reduction subsidies.

(2)Security Risks:The working environment at well sites is complex, and hydrogen leakage tends to accumulate and trigger combustion and explosions. Countermeasures include developing downhole hydrogen leakage monitoring sensors, optimizing ventilation design, and establishing strict safety regulations for hydrogen energy operations.

(3)Equipment Reliability:The durability of hydrogen power systems under well site conditions such as vibration, dust and extreme temperatures remains to be verified. It is recommended to adopt a progressive strategy of "piloting first and then promoting", and carry out demonstrations in blocks with favorable conditions.

4.2. Oil and gas production and gathering & transportation links

Main Application Scenarios:

(1) Multi-energy Complementary System for Oilfield Combined Stations: As the hub for oil and gas processing and gathering transmission, combined stations consume various forms of energy (electricity and heat) with drastic load fluctuations. Relevant studies have proposed multi-energy complementary solutions to achieve internal energy self-balance and low-carbon operation within the stations [8].

(2) Hydrogen Fuel Replacement for Heating Furnaces and Boilers: Massive thermal energy is required for crude oil dehydration, heated transportation and other processes, which currently rely on natural gas or crude oil as fuels. Carbon decarbonization of such processes can be realized by mixing hydrogen with natural gas (hydrogen blending ratio: 10%~30%) or burning pure hydrogen directly. Several enterprises have carried out renovation tests on hydrogen fuel burners.

(3) Hydrogen Blending Transmission via Pipelines: Hydrogen is blended into the internal gathering pipelines of oil and gas fields and delivered to various energy-consuming nodes through existing pipe networks, which can avoid the high capital cost of constructing dedicated pure hydrogen pipelines.

Major Challenges and Countermeasures:

(1) Hydrogen Embrittlement and Material Compatibility:Hydrogen can induce hydrogen-induced cracking in steel, shortening the service life of pipelines and equipment. Countermeasures include adopting hydrogen-resistant materials (such as low-alloy steel with coatings), controlling the hydrogen blending ratio, and conducting regular inspections on pipeline integrity.

(2) Burner Retrofit:Hydrogen burns with a high flame temperature and carries a high risk of flashback, so existing gas burners need to be redesigned. It is recommended to cooperate with combustion equipment manufacturers to develop dedicated hydrogen fuel burners and install flashback arrestors.

(3) Lack of standards:There are no unified standards for the hydrogen blending ratio, operating pressure, safety distance and other parameters within oil and gas fields. Enterprise standards can be formulated based on domestic and foreign standards for hydrogen blending in natural gas pipelines and the actual conditions of the oilfield.

4.3. Integration of refining and downstream industries

Main Application Scenarios:

(1) On-site hydrogen production and consumption in refineries: Refining enterprises are major hydrogen consumers (for hydrocracking, hydrotreating, etc.). At present, most refineries produce hydrogen via natural gas reforming, which generates high carbon emissions. Replacing part of grey hydrogen with green hydrogen produced from oilfield green electricity or produced water can directly cut the carbon footprint of refining processes.

(2) Utilization of CO_2 by-product from hydrogen production for oil displacement (CCUS-EOR): When adopting the blue hydrogen pathway (hydrogen production from fossil fuels plus carbon capture), high-concentration captured CO_2 can be injected into oil reservoirs to displace crude oil, achieving the dual goals of oil production increase and carbon sequestration. Studies on the Tarim Oilfield demonstrate that this model delivers sound economic and environmental benefits [13].

(3) Hydrogen energy storage and power grid peak shaving: Power grids of oil and gas fields are generally independent or relatively isolated. Excess renewable energy can be converted into hydrogen for storage via water electrolysis. During peak electricity demand, fuel cells can generate power or hydrogen can be blended into gas turbines for peak shaving to improve grid stability.

Major Challenges and Countermeasures:

(1) Economy:The cost of green hydrogen remains higher than that of gray hydrogen. It is necessary to reduce the cost of electrolyzers and improve the utilization rate of renewable energy through technological advances, while fully leveraging the proceeds from carbon trading.

(2) Carbon capture cost:The energy consumption for CO_2 capture in the CCUS process is relatively high. It is recommended to prioritize the utilization of high-concentration CO_2 sources and explore low-cost absorbents.

(3) Industrial chain collaboration:Hydrogen production, hydrogen storage, oil displacement and refining belong to different business segments, so a reasonable internal price transmission and profit distribution mechanism needs to be established.

5. Analysis of economic efficiency and emission reduction benefits

Economic viability is key to hydrogen deployment in oil and gas fields. Cost comparisons (levelized cost models) indicate that produced-water hydrogen costs 20–30 RMB/kg (with produced-water treatment treated as sunk cost), wind-solar green hydrogen drops to 18–25 RMB/kg when renewable power cost <0.2 RMB/kWh and electrolysis efficiency >65%, while purchased grey hydrogen is 15–

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25 RMB/kg but excludes carbon costs. Hydrogen-for-oil drilling becomes competitive when carbon price exceeds 200 RMB/t CO_2. With carbon trading, depreciation optimization, and scale effects, green hydrogen projects are expected to break even commercially during the 15th Five-Year Plan period.

On carbon footprint, replacing diesel with green hydrogen at Changqing Oilfield (single well consumes ~50t diesel, emitting ~160t CO_2) cuts emissions by over 95%. Produced-water hydrogen has a lower lifecycle footprint than purchased green hydrogen, and with CCUS can achieve negative emissions. Annual hydrogen consumption of 100,000 tons in oilfields could reduce 1.5–2 million tons of CO_2, equivalent to the carbon sink of about 8,000 hectares of forest.

Policy incentives include electricity price concessions, carbon reduction subsidies, inclusion in the green certificate system, and support for integrated wind-solar-hydrogen-storage projects. Oil and gas companies are advised to apply for pilot projects, secure policy and financial support, and participate in carbon markets to monetize emission reductions.

6. Typical domestic examples and cases

In recent years, major oil and gas enterprises in China have launched a number of demonstration projects for hydrogen energy applications and accumulated valuable experience.

1. Changqing Oilfield: It took the lead in realizing 100% "hydrogen replacing oil" operation during drilling, achieving a carbon emission reduction of over 120 tons per single well. Meanwhile, it carried out tests on hydrogen production from produced water and wind-solar coupled hydrogen production, identifying ten applicable scenarios [11].

2. Shengli Oilfield: Relying on abundant wind and solar resources and the oilfield power grid, it plans to build a hundred-megawatt green hydrogen production base, and the produced hydrogen is applied to crude oil heating, energy supply for combined stations and other scenarios [7].

3. Tarim Oilfield: It explored the collaborative model of "hydrogen energy + CCUS", utilizing CO_2 by-produced from hydrogen production for oil displacement and sequestration to simultaneously boost oil output and cut carbon emissions [13].

4. Liaohe Oilfield: It conducted pilot tests covering the full process chain of hydrogen production and utilization using associated water from oil and gas fields, verifying the engineering feasibility of hydrogen production from produced water [6].

7. Conclusion and outlook

Hydrogen energy is technically viable in oil and gas fields through diversified production (produced-water and wind-solar pilots are ready, in-situ is frontier), large-scale storage in depleted reservoirs, and pipeline blending (near-term but hindered by embrittlement and standards). Verified applications include drilling, station integration, refinery substitution, and CCUS-EOR synergy. Although green hydrogen costs exceed grey, falling renewable prices and rising carbon prices should enable break-even during the 15th Five-Year Plan, supported by policy incentives. Domestic demonstrations (e.g., Changqing, Shengli, Tarim) confirm feasibility, but scaling up faces cost, safety, and standardization challenges. Future priorities include in-situ pilot tests, storage safety standards, and policy-market mechanisms to shift from technical to economic viability.

References

[1] Wang, T., Zhao, R., Jiang, N., et al. (2024). Feasibility of in-situ hydrogen production during fire flooding in reservoirs after steam injection development. *Special Oil & Gas Reservoirs, 31*(1), 81-86.

DOI: 10.54254/2755-2721/2026.CH35521

[2] An, J., Wang, W., & Xin, C. (2025). A review of geological hydrogen storage driven by “carbon peaking and carbon neutrality”: Potential, bottlenecks, and innovation. *Oil & Gas Storage and Transportation, 44*(11), 1208−1220.
[3] Zheng, Y., Zhang, X., & Wei, Z. (2023). Hydrogen utilization economic efficiency and CO2 emission reduction benefit analysis in the oil and gas industry. *Natural Gas Industry, 43*(8), 146-155.
[4] Xu, W., Sun, Z., Ji, W., et al. Pilot test of the entire process chain of hydrogen production, storage, and utilization from the produced water in typical onshore oil and gas field. *Industrial Water Treatment, 45*(10), 201-205.
[5] Kong, L. F., & Yue, X. W. (2024). Study of CNPC's new energy development pathway and innovation practice. *Petroleum Science Forum, 43*(1), 25–30.
[6] Erhiwo, O. (2026). Production of green hydrogen from renewable energy for refinery applications: A pathway toward decarbonising petroleum refining. *Petroleum Chemistry Journal, 66*(2), 187–198.
[7] Zhen, Z., Li, B., Ou, X., & Zhou, S. (2024). How hydrogen can decarbonize the chemical industry in China: A review based on the EIC–TER industrial assessment framework. *International Journal of Hydrogen Energy, 60*, 1345–1358.
[8] Sun, D. (2024). The mode, path and strategy on the integrated development of petroleum and new energy resources under the dual-carbon goal. *Natural Gas Technology and Economy, 18*(5), 72–78.
[9] Li, G., Li, P., Li, G., et al. (2023). Apply the hydrogen energy and its by-product CO2 in Tarim oilfield to achieve the analysis of en-ergy conservation and carbon reduction. *Energy Conservation in Petroleum & PetroChemical Industry, 13*(5), 5–8.
[10] Chen, Y. (2024). Analysis of the application prospects of green electricity hydrogen production technology in Shengli Oilfield. *Oil-Gas Field Surface Engineering, 43*(3).
[11] Okere, C. J., & Sheng, J. J. (2023). Review on clean hydrogen generation from petroleum reservoirs: Fundamentals, mechanisms, and field applications. *International Journal of Hydrogen Energy, 48*(97), 38188–38122.
[12] Fan, K., Wang, Z., Huang, J., et al. (2026). Discussion on current status, limitations, and development trends of green energy applications in oil and gas fields. *Oil & Gas Storage and Transportation, 45*(2), 145–158.
[13] Xu, Y., Gao, X., Liu, X., et al. (2026). Research of multi-energy complementary systems for oilfield joint stations: Construction and energy-saving and carbon-reduction analysis. *Oil & Gas Storage and Transportation, 45*(3), 288–299.
[14] Zhu, B., Fan, J., & Wang, J. (2026). Policy portfolios shaping hydrogen production pathways and regional deployment in China. *Energy Policy, 217*, 115432.
[15] Jiang, Z., Li, S., Suo, Y., et al. (2024). Prospects for submarine hydrogen exploration and extraction technologies. *Earth Science Frontiers, 31*(4), 183–190.