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The Construction of China's OGRs Strategic Reserve System

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Abstract: As an important strategic resource, hydrocarbon resources guarantee national energy security worldwide. As a major consumer of hydrocarbon resources, China urgently needs to establish a strategic reserve system to promote high-quality development. This paper analyses the current situation of China's oil and gas resources reserves and identifies existing problems. I propose that the technical level of exploration and exploitation should be upgraded through capital investment and technological innovation and the scale of storage should be expanded by optimizing the construction of reserve bases, enhancing the emergency warning capability of oil and gas resources by constructing an emergency plan system, and optimizing the specific operation strategies via legislation, administration, and commerce. Such efforts will provide policy references to guarantee China's energy security.

Keywords: Oil and Gas Resources; Strategic Reserve System; Exploration and Exploitation; Storage; Emergency Warning.

1. Introduction

As important energy resources and raw chemical materials, oil and gas resources (OGRs) are the mainstay of the global energy market and play a significant role in national economies. After the first oil crisis, the concept of a strategic petroleum reserve (SPR) was proposed to promote a stable supply of national petroleum[1]. Following the initial oil crisis, the SPR emerged as a strategy to ensure a steady oil supply within the nation.

Based on the concept of SPR, this paper proposes the concept of a strategic OGR, which is the minimum amount of oil and gas that a country must reserve to cope with oil and gas supply and demand problems caused by wars, natural disasters, and market turmoil. This reserve is based on the one-day oil and gas consumption of a country. Creating a sufficient strategic stockpile of OGRs is crucial for ensuring the energy security in China.

Section two of this paper organizes and analyses the related literature and reveals the research direction of this study. Section three primarily illustrates the present state of China's OGR reserves and analyses the problems they face. Section four proposes a reasonable strategic plan for China's OGR reserves. Section five summarizes the main findings.

2. Literature Review

2.1. Research on China's Strategic OGR Reserves

Recently, scholars have conducted relevant research on building strategic reserve systems for OGRs. However, most of these studies have focused on a single energy sources. Relevant studies such as those on oil reserves [2-3], or studies related to natural gas reserves [4-6]. However, China's energy security relies heavily on both oil and gas, and Wu (2014) mentioned that ensuring simultaneous oil and gas availability is central to China's forthcoming strategy for energy security[7].

To study specific strategies for energy reserves, most scholars choose to analyse the reserve system locally. For example, from the perspective of the exploration and development technology of oil and gas, reserve scale optimisation, and reserve base construction [8-10]. This part of the research is more inclined toward the improvement of a single link of the reserve system, which some scholars consider from an operational perspective, such as from the perspective of legislation, regulation, energy imports[11-13] and other aspects, to propose countermeasures for the strategic reserve of OGRs. Few scholars have combined the reserve system of China's OGRs with specific operational strategies to propose a systematic program for constructing strategic OGR reserves, which is the focus of this study.

2.2. Research on Strategic International OGRs

Scholars have also studied the strategic energy reserves of certain countries worldwide [14-16]. A number of studies have been focused the country's strengths or characteristics in terms of strategic energy reserves. For example, Bai and Dahl (2018) assessed the performance of the US SPR under different scenarios through modelling and concluded that better management could significantly increase the value of the US SPR[17]. In addition, Kitamura and Managi (2017) analysed a hypothetical energy supply disruption in a Japanese exporting country and argued that the Japanese government and corporate oil reserves play an important role in energy security[18]. Scholars have also considered the opposite perspective, such as Halser and Paraschiv (2022a), who analysed the impact of Germany's embargo on natural gas in the context of the war in Ukraine and advocated for safeguarding the country's energy security through initiatives such as accelerated deployment of renewable energy sources and careful enforcement of storage quotas[19]. Hölsgens (2019) reviewed the history of Dutch energy and argued that dependence on oil has increased the country's energy risk, and they proposed methods of mitigating the risk through government involvement and other means[20].

Based on specific analyses of the energy policies of these countries, scholars have started to compare energy policies

between different countries. Konopelko et al. (2023) compared the energy policies adopted by Poland and Germany in response to the energy crisis in the short term, providing important inputs for enhancing national and regional energy security[21]. Jiang et al. (2023) summarised the energy blockchain policies of China and the US from 2016 to 2022 and compared the differences between the two countries to provide targeted recommendations for the practice of energy blockchain in China[22]. On this basis, this study proposes that the lessons learned from representative countries should be combined with data on the construction of China's strategic OGR reserves to construct a strategic reserve program for OGRs that suits China's national conditions.

To summarise, existing studies on oil and gas reserves in China are scattered and lack systematic analyses of the strategic OGR reserves. Second, most of the existing studies have only studied either oil or gas, with very few combining the experiences and lessons learned to make relevant recommendations on China's energy policy from multiple perspectives. Based on the shortcomings of existing studies, this paper draws on the experiences of the US and Japan in terms of management systems, reserve construction, and international energy cooperation and summarises the lessons learned from Germany in terms of energy reserves, energy transition, and emergency warning. In addition, it focuses on the construction and development of OGRs in the phases of exploration and extraction, storage construction, and emergency warning to build a comprehensive strategic reserve system for China's OGRs at the legislative, administrative, and commercial levels.

3. Status of China's Strategic OGR Reserves

3.1. Analysis of the Current Status of OGRs

3.1.1. Distribution and Development

Oil resource allocation in China is notably centralised to eight basins, including Bohai Bay, Song Liao, and Tarim [23], while natural gas resources in China are mainly distributed in 11 basins concentrated in remote areas in the northwest and southwest, including Tarim, Sichuan, and Ordos. As of 2020, China's total geological deposits of oil, natural gas, shale gas, and coalbed methane amounted to 422 × 10^8 tons(t), 16.88 × 10^{12} cubic meters(m^3), 2× 10^{12} cubic meters (m^3), and 7259.11 × 10^8 cubic meters (m^3).

Although conventional oil and gas have abundant geological resources, they are distributed across different age strata and exhibit different deep burial conditions. Oil resources are concentrated in shallow and medium-depth layers, whereas natural gas resources are predominantly distributed in medium and deep layers. Complex geological conditions have increased the difficulty of extracting OGRs, and as of 2021, the cumulative rate of natural gas production has only reached 20%.

The exploration of OGRs has entered a phase of development that emphasises both the conventional and unconventional. Unconventional oil and gas accounted for 41% of the country's cumulative proven OGRs, and production accounted for 20% of total oil and gas production. In terms of the exploitation of different types of unconventional oil and gas, in addition to the exploration and development of shale gas, different types of unconventional OGRs have been explored, which has reached a large scale. However, the development of other unconventional OGRs, such as tight gas, is mostly in the early to middle stage[24].

China's marine OGRs account for 20–30% of China's total OGRs, and as of 2022, 60% of the country's incremental oil and gas production has come from the sea. Currently, the primary locations for extraction activities are Bohai Bay, eastern and western parts of the South China Sea, and the East China Sea. However, they are mostly concentrated in shallow waters, and the extraction of oil and gas in the deep-sea region constitutes a comparatively minor percentage. The remaining proven technically recoverable reserves of oil and gas in China's oceans and seas account for 34% and 52% of the total oil and gas reserves, respectively; thus, considerable room for exploitation remains. Overall, the exploration and development of unconventional, deep and marine OGRs are key areas for future research.

3.1.2. Reserve Construction

Based on the 90-day reserve standard of the International Energy Agency (IEA), the State Council approved the Medium- and Long-Term Plan for National Oil Reserves (2008-2020) in 2008, and the construction of the national oil reserve base is expected to be completed in three stages within 15 years [7]. Fig 1 illustrates the three-stage process of building the oil reserve base [25]. As of 2020, currently published information shows that China has built nine national oil reserve bases [26], and by utilising reserve depots and some social enterprise storage capacities, 3773 × 10^5 t of crude oil has been reserved. However, combined with current consumption, China's oil reserve capacity is expected to be approximately 80 days, which is lower than the target of 100 days in the medium- and long-term plans.

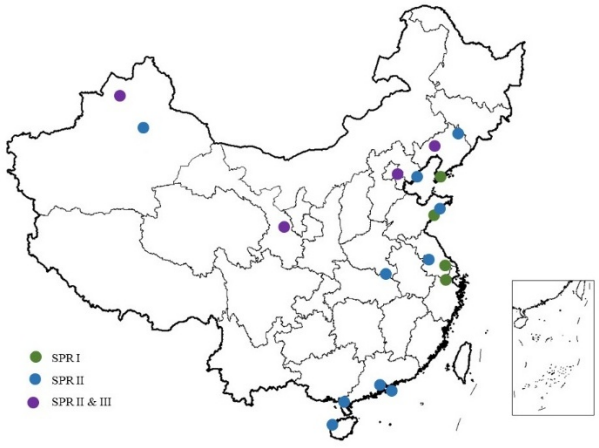


Fig 1. Distribution map of China's oil reserve base construction. (Source: Authors based on Energy in China's New Era)

Approximately 87% of China's natural gas reserves are allocated across the central and western areas, whereas the main consumer market is located in the densely populated and economically developed eastern region of the country. The problem of peak-to-valley differences of up to four to ten times has been plaguing China for a long time, and for this reason, the "West-to-East Natural Gas Pipeline" as well as the simultaneous planning of storage tanks have been used to address the present dilemma of dividing the supply and demand for natural gas. However, China's trunk gas pipelines span a total distance of 11.6×10^5 km, which is only 20% of that of the US [27]. In recent years, China has strengthened the large-scale commercialisation of underground natural gas storage[28] and built 27 natural gas storage reservoirs (PetroChina 23, Sinopec 3, Hong Kong, and China 1).

3.1.3. Supervision and Management

China's regulatory framework for the oil and gas sector has seen notable progress in establishing laws, regulations, and the makeup of regulatory bodies. Regarding legal and regulatory frameworks, the oil and gas law and regulation system encompasses oil and gas exploration and exploitation, the oil and gas storage sector, pipeline transit, and market trading, and it has initially established a complete set of oil and gas regulations. China's oil and gas regulatory institutional system has been developed. Pertinent institutions and departments oversee the investigation and utilisation of oil and gas, determination of prices, oversight of market activities, and environmental safeguarding of oil and gas, as shown in Fig. 2. Relevant organisations under different government departments are responsible for the operation of industries related to OGRs.

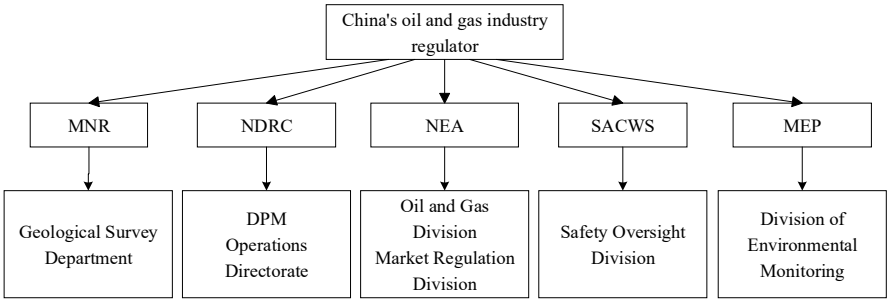


Fig 2. China's oil and gas regulatory agency system.
(source: Authors based on Chinese government website, https://www.gov.cn/home/2023-03/29/content_5748953.htm)

3.2. Existing Problems Associated with China's OGRs

3.2.1. Development and Exploration Difficulties

First, the proportion of conventional OGRs remaining for exploration and development is relatively small, which makes exploration more difficult, and the quality of the remaining OGRs is generally poor. The proportion of "low-grade" resources, such as low-permeability and extra-low-permeability resources, has increased to 64%. Second, more than 60% of the OGRs are located under complex surface conditions, making oil and gas exploration difficult. For example, the automation level of offshore drilling platforms is generally low, and the core technology of offshore drilling equipment is not sufficiently mature, especially the key equipment applicable to deep-water and ultra-deep-water drilling operations, which typically fall short of fulfilling the demands of expanding reserves and production levels [29]. Overall, China's OGR development has entered a stage with a high exploration degree. However, the stage presents difficulty in utilisation and high development costs. Moreover, traditional development technology is facing a serious challenge in balancing the substantial increase in production and the need to reduce costs.

3.2.2. Inadequate OGR Construction

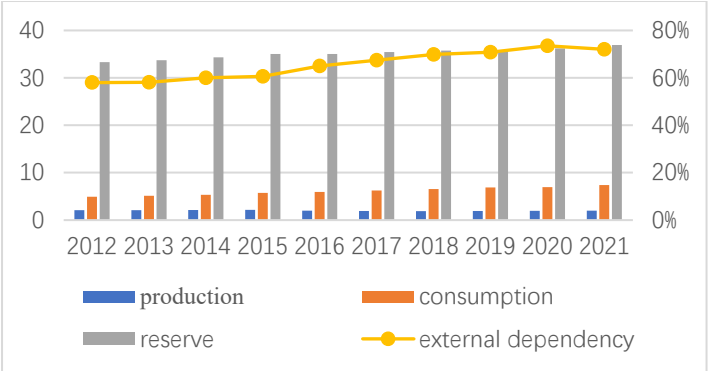


Fig 3. A. China's Oil Production, Consumption, and External Dependence, 2012-2022 (in billion tons)

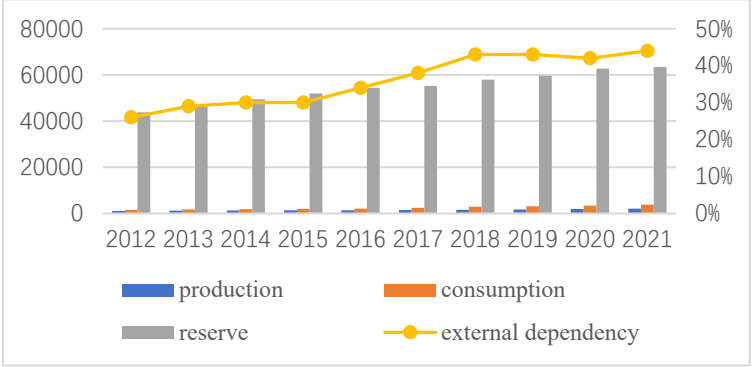


Fig 3. B. China's Natural Gas Production, Consumption and External Dependence, 2012-2022 (in billion cubic meters)

Compared to the fast-growing consumption, the growth trend of China's OGRs in terms of production and reserves is

insufficient, and the total supply of OGRs is unable to meet the total demand and is highly dependent on external imports; China's external dependence on crude oil continued to exceed 70% and its dependence on natural gas continued to exceeds 40% after 2018, as shown in Fig. 3[30,31].

Despite the successful development of oil reserve bases meeting medium- and long-term objectives, the magnitude and management of reserve bases remain imperfect, with the strategic specialisation and size of oil reserves still awaiting enhancement. The medium- and long-term plans propose that by 2020, oil reserves should reach a reserve capacity of 100 days. Although the overall number of reserve bases has been built to meet the target, the volume of strategic oil reserves is still far from reaching the target.

For natural gas reserve construction, due to the distance between the resource place and the consumption place is too far, the peak-valley gap is constantly widening, and the present maximum capacity of gas storage significantly trails the peak demand. In addition, owing to the challenges posed by extended construction durations and substantial investments, gas storage investors generally include only few major state-owned enterprises, such as PetroChina and Sinopec. Moreover, foreign investors have not shown strong enthusiasm , which results in the slow progress of construction [27]. Thus, the construction of gas-storage facilities has progressed slowly.

3.2.3. Inadequate Regulatory System

First, the legal regulations on oil and gas have weak foundations. No high-level basic energy laws or industry laws have been introduced, resulting in no authoritative legal basis for the actual regulatory process, which affects the authority and effectiveness of the regulation. Second, current legal documents are relatively outdated, and the majority of the current laws and regulations fail to align with the comprehensive reform and growth requirements of the oil and gas sector, necessitating revisions and enhancements.

Moreover, there is a lack of separation between the government and supervision in terms of regulatory responsibilities, and an autonomous regulatory entity for oil and gas is absent. As shown in Fig 2, China's oil and gas industry management and regulatory functions are dispersed among several government departments. On the one hand, thus makes it impossible for the regulation of the oil and gas industry to carry out independent work and weakens the professionalism of the regulation. On the other hand, there are too many regulatory bodies, and the regulatory functions are dispersed, which results in a lack of clarity in the division of labour among departments and cross-functioning of the departments, which will affect the efficiency of the regulation.

4. Methods for Constructing China's OGR Reserve System

The lessons learned from these countries can provide a reference for the construction and operation of China's OGR reserve systems. Starting from the general level, the construction and development of OGRs focuses on the stages of exploration and extraction, storage construction, and emergency warning. Moreover, the overall technical level of exploration and extraction should be enhanced by increasing capital investment and technological innovation, expanding the scale of reserves by formulating medium- and long-term planning objectives and improving the construction of reserve bases, enhancing the emergency warning capability of OGRs by constructing emergency regulations and planning systems, and constructing specific operation strategies for legislation, administration, and commerce, as shown in Fig 4.

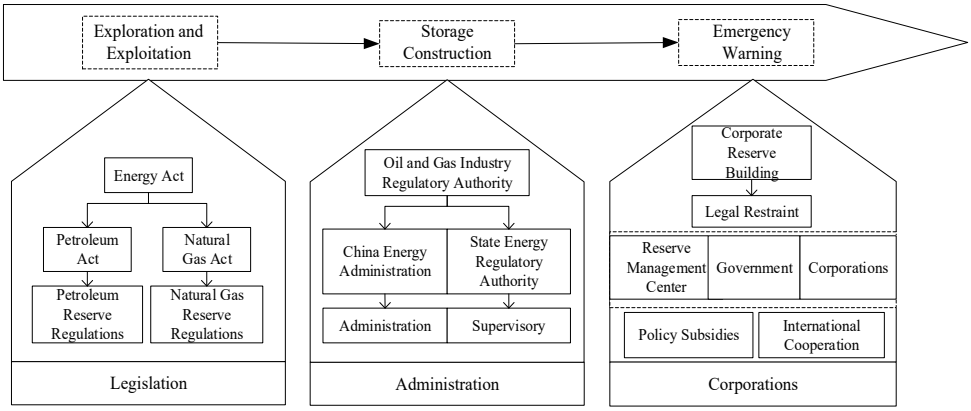


Fig 4. Planning map of the strategic reserve system for OGRs

4.1. Assessing the Main Links of China's Strategic OGR Reserves

4.1.1. Upgrading Exploration and Development Technologies

The scale-effective development of OGRs relies on continuous scientific and technological innovations and requires the support of financial investment to help improve technological exploration and development.

We formulated targeted technological plans for different fields and types of OGRs. It is important to safeguard offshore and land-based resources together, and conventional and non-conventional resources are equally important. In the field of onshore OGRs, extraction companies should implement technological innovation to promote the construction of key projects in several key basins, including the "Gas Daqing" in the Sichuan Basin, the "Deep Oil and Gas Daqing" in the Tarim Basin, and the "Oil and Gas Super Basin" in the Ordos Billion-Ton Class. Moreover, the development of marine-based OGRs should be increased, which requires in-depth drilling and research on the core technology for marine exploration and development, such as deep-water drilling and extraction equipment. In the field of unconventional oil and gas, a comprehensive layout is required for the different varieties of unconventional OGRs, such as shale gas, tight gas, coalbed methane. Such a layout will be based on basic research, technological research and development, industrialisation, and integrated planning. Ac comprehensive

plan should also be constructed for the development of resources in China's old oil and gas regions. Based on existing reserves, we will continue to promote the fine exploration of the remaining OGRs in the old regions and increase capital investments for exploration and reduce exploration risk. Such work will ensure the addition of 1 billion tons of new geological reserves in the Fourteenth Five-year Plan.

4.1.2. Increasing the Storage Scale

Improving the layout of reserves, expanding their scale, and fully utilising the strategic role of oil reserves in crisis scenarios are all important goals. Regarding the construction of reserve bases, the principles of safety and convenience should be considered when selecting feasible sites, and consideration should be given to selecting reserve bases near transportation hubs. Moreover, experience in constructing reserve bases and obtaining oil and gas imports from external sources should also be considered. **Second**, stable and diversified oil supply partner countries should be identified. The stability of OGR imports can be enhanced by measures such as diversifying import sources and establishing mutually beneficial diplomatic relations with other countries. **Finally**, it is imperative to increase the scale of financial savings by promoting the crude oil savings system project, following the principle of build-as-you-store, collecting and storing at an opportune time, and identifying declines in global oil prices to accelerate the improvement of China's crude oil savings and ensure that the planning task is accomplished promptly.

As a clean energy source, natural gas will show more resilient future development trends than oil, and the demand for natural gas and reserve capacity requirements will increase. **First**, construction of gas storage should be prioritized. Based on an in-depth analysis of China's underground gas storage technology, we should prioritize the exploration of construction programs and implementation methods to provide scientific and technological bases for the construction of gas storage and ensure the safe operation of the gas storage throughout its life cycle. **Second**, at the provincial level, joint efforts should be made to coordinate the establishment of cross-regional large- and medium-sized basement gas storage clusters and establish a basement gas storage cluster based on the formation of regional networks and synergies in Northeast China, North China, the middle and lower reaches of the Yangtze River, and the Pearl River Delta. **Third**, the construction of the natural gas pipeline network should be accelerated. According to the Medium- and Long-Term Oil and Gas Pipeline Network Plan, the goal of reaching 16.3×10^4 km of pipeline network should be realized by 2025. Overall, a multi-level gas storage system will be established using underground storage tanks and coastal LNG receiving stations as the mainstays, which will be supported by the interconnection of pipeline networks.

4.1.3. Conduct Emergency Early Warning Studies

China should improve its emergency management system for OGRs and systematically enhance its ability to prevent, warn, act upon, and recover from emergencies. During the natural gas supply crisis, Germany successively activated first- and second-level energy emergency programmes for natural gas. China can draw on Germany’s experience to mitigate the impact of emergencies by implementing early warning systems for OGR crises and ensuring the emergency guarantee of OGRs. At the same time, by drawing on Japan's experience, shortages in the OGR supply in the event of domestic natural disasters or other crises should be taken into consideration. Regarding the functional positioning of OGR reserves, external risks and domestic non-traditional security risks must be avoided. Moreover, efforts should be made to improve oil and gas early warning and emergency management capabilities in all aspects.

From a comprehensive perspective, an emergency response system for OGRs can be constructed, as shown in Fig. 5, based on an emergency legal system that provides legal guarantees for energy crises. Moreover, this system should promptly formulate response measures that address the severity of the emergency and carefully plans all aspects of emergency preparedness and emergency response to ensure accurate, standardised, and efficient guidelines for emergency response actions. Emergency planning includes the establishment of special emergency organisation systems, monitoring and early warning systems, and emergency reserve systems to provide organizational, informational, and resource security for emergencies. These five components interact with each other and are interconnected; together, they provide for the emergency response function of OGRs.

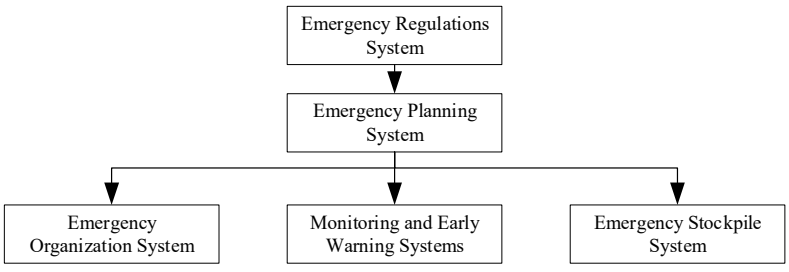


Fig 5. Framework for an emergency response system for OGRs.

4.2. Optimizing the Operation of China's Strategic Reserve System for OGRs

4.2.1. Improving National Laws

First, the legislative process for the basic laws of OGRs should be promoted. Some developed countries have introduced basic laws on the overall oil and gas industry before finalising legislation on oil and gas reserves. China should form a system of energy laws and regulations guided by the Energy Law and actual energy characteristics. Based on the principles of prioritizing important factors and realizing mutual support, separate energy laws such as the Petroleum Law and Natural Gas Law will be introduced in turn.

Second, reserve-related regulations, such as Oil and Gas Reserve Regulations, should be introduced. Presently, there are no systematic specialised reserve regulations for China’s oil and gas industry. The US Energy Policy and Reserve Act

and Japan's Petroleum Reserve Law provide legal protection and support for specific OGR reserves. It can be seen that if the National Energy Administration and other units jointly issue oil reserve regulations that determine the specific content of the strategic oil reserves, more powerful protection for oil storage work can be realized. At the same time, reserve regulations further clarify China's strategic OGR reserves in terms of implementing main management, reserve construction management, reserve fund management, and other aspects of specific legal regulations.

4.2.2. Sound Regulatory System

As a typical natural monopoly industry, the regulatory system of OGRs should be improved as a prerequisite for the effective implementation of strategic reserves of gas resources.

The separation of government and supervision and the establishment of relatively independent administrative and regulatory bodies are also required, as shown in Fig 6. The National Energy Administration (NEA) [32] has established different departments that are responsible for industrial policies, plans, and preferential policies related to petroleum resources, organising and implementing major scientific research projects, and guiding relevant industry management functions. In the independent regulator model, the regulator of the oil and gas industry is independent of traditional government departments and is not subject to administrative intervention or government influence. A National Energy Regulatory Authority (NERA) can be set up to assume the main energy supervisory responsibilities, and a petroleum supervisory authority can be set up under the energy supervisory authority of this big national authority. Petroleum supervisory responsibilities that are dispersed across ministries and departments can be centralized under the petroleum supervisory authority to promote clarity of the division of labor. The government can also adopt basic laws, such as the Energy Law and other laws. In addition, the government should empower supervisory authorities to operate autonomously through basic laws, such as the Energy Law.

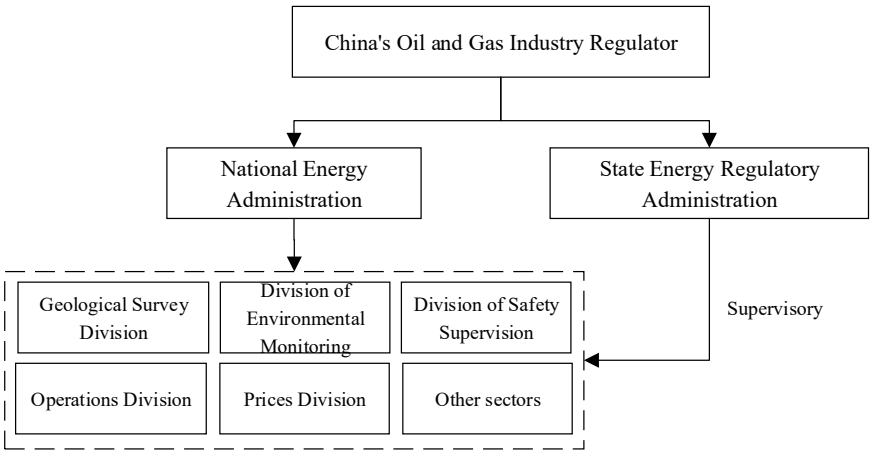


Fig 6. Institutional map for the regulation of OGRs

4.2.3. Encourage Enterprises to Strengthen Reserve Capacity Building

A strategic reserve model should be established, with national reserves as the mainstay and corporate reserves as a complement. Considering national oil and gas security as well as corporate benefits, legal and financial measures should be actively taken to incentivise companies to engage in strategic reserves and build a multi-level national strategic resource reserve system.

At the corporate reserve level, laws must be formulated to ensure that companies are held responsible for relevant strategic reserves in addition to normal commercial reserves, and a crisis governance model should be developed in which the whole society participates together. At the management level, a multilevel management mechanism can be set up for OGR reserve management under the leadership of the National Energy Administration. Cooperation should be realized among reserve companies operated by the state, several major groups of PetroChina, Sinopec, and CNOOC, and subordinate enterprises. To promote commercial reserves, oil resources reserves, tax exemptions or subsidies, low-interest loans and other means should be adopted to reduce the pressure on corporate funds. Moreover, social funds should be increased to realize civil savings by issuing special bonds and establishing credit preferences. in addition, China can also learn from the experience of the US and Japan and encourage enterprises to actively participate in the affairs of international energy organizations through offshore investments and international energy markets and improve the discourse power of China's OGRs. From a global perspective, national and commercial reserves share a common strategic purpose, and specific management practices should exploit local enthusiasm and ensure that overall interests are maximised.

5. Conclusion and Policy Implications

Adequate strategic OGR reserves provide a basic guarantee of maintaining the security of national OGRs. This paper summarises the current situation of China's OGR reserves, systematically analyses the current problems of China's OGR reserves, and provides feasible solutions for reasonably building China's strategic OGR reserves. It focuses on the backbone of OGR reserves, starting from the process of exploration and development, reserve construction, and early warning and emergency response. Moreover, it proposes the integration of the planning process, development of an overall strategy, and the embodiment of the strategy in legislation, administration, implementation, and commercial statutes to create a diversified OGR strategic reserve system that is adapted to the needs of China's social development.

This study uses theoretical research to provide policy suggestions for strategic reserve systems. In the future, we

will consider choosing a strategic evaluation index system, establishing a relevant optimisation model, and quantitatively evaluating and analysing China's OGRs strategic reserve system using empirical research to make the article more convincing.

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