Environmental Ecology and Natural Gas: Impacts, Strategies and Roles in Energy Transition

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Abstract

With the growing global demand for clean energy, natural gas, as a relatively clean fossil energy source, is playing an increasingly important role in the energy structure. This paper deeply explores the relationship between natural gas and environmental ecology, analyzes its environmental impacts during extraction, transportation, and utilization, including groundwater pollution, methane leakage, and exhaust emissions. It also elaborates on strategies to address these environmental impacts, such as adopting advanced technologies to reduce pollution, strengthening supervision and policy guidance. In addition, it studies the role and prospects of natural gas in energy transition, emphasizing its importance as a transitional energy source to help achieve a sustainable energy future. Through comprehensive analysis, this paper aims to provide a scientific basis and decision-making reference for the rational utilization of natural gas resources, protection of the ecological environment, and promotion of energy transition.

Keywords

Natural Gas, Environmental Ecology, Energy Transition, Sustainable Development

1. Introduction

Against the backdrop of the continuous growth of global energy demand and increasing awareness of environmental protection, finding efficient and clean energy sources has become an urgent task. As a fossil energy source, natural gas is regarded as an important bridge from traditional coal and oil to renewable energy due to its relatively low carbon emissions and high energy density. In recent years, global natural gas consumption has been steadily rising, and its proportion in the energy structure has gradually increased. According to the International Energy Agency (IEA), global natural gas consumption exceeded 4 trillion cubic meters in 2023, an increase of nearly 30% compared with 2010, and this growth trend is particularly significant in emerging economies.

However, natural gas also has a series of impacts on the environmental ecology throughout its life cycle from extraction to final use. In-depth study of these impacts and exploration of effective response strategies are of great significance for achieving the win-win goal of sustainable energy development and ecological environment protection. At present, the global climate change issue is becoming increasingly severe. The Paris Agreement proposes to limit the global average temperature increase to below 2°C above pre-industrial levels, which puts forward higher requirements for energy structure adjustment. Although natural gas is cleaner than coal and oil, it is not a "zero-emission" energy source, and its life-cycle environmental impacts still need to be taken seriously. Therefore, a comprehensive analysis of the interaction between natural gas and environmental ecology is of great practical value for promoting the coordinated development of energy transition and ecological protection.

2. Overview of Natural Gas

2.1 Definition and Composition of Natural Gas

Natural gas is a gaseous fossil fuel mainly composed of **methane (CH_4)**, with small amounts of impurities such as ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}), carbon dioxide (CO_2), nitrogen (N_2), and hydrogen sulfide (H_2S). The specific proportion of its components varies by origin, but methane usually accounts for 70%-90%. For example, the methane content of natural gas in the Sichuan Basin of China is generally over 90%, while that in some gas fields in the Middle East can be as low as about 70% due to the high content of non-hydrocarbon gases.

Hydrogen sulfide, as a common impurity, is highly toxic and corrosive. It must be removed through desulfurization processes after natural gas extraction; otherwise, it will not only pollute the environment but also damage transportation and utilization equipment. China's "Natural Gas" (GB 17820-2018) standard clearly stipulates that the hydrogen sulfide content in commercial natural gas must be $\leq 20 mg/m^3$ to ensure safety in use and environmental friendliness.

2.2 Global and Chinese Distribution and Reserves of Natural Gas Resources

Global natural gas resources are widely distributed, mainly concentrated in the Middle East, Russia, North America, and other regions. According to data from the International Energy Agency (IEA), as of the end of 2024, the world's proven natural gas reserves were approximately 240 trillion cubic meters. Among them, the reserves in the Middle East

account for about 40% of the global total, and Russia's reserves account for about 20%. At the national level, Iran, Qatar, and Russia are the top three countries in terms of proven reserves, accounting for more than 50% of the global total.

China is also rich in natural gas resources, mainly distributed in basins such as Tarim, Ordos, Sichuan, and Qaidam, as well as in marine areas. In 2024, China's natural gas output reached 246.5 billion cubic meters, ranking fourth in the world. Among them, the four major gas regions of Sichuan, Ordos, Tarim Basin, and marine areas contributed more than 80% of the national output. In addition, China has made breakthroughs in the development of unconventional natural gas, with output exceeding 100 billion cubic meters, including 30 billion cubic meters of shale gas and about 70 billion cubic meters of coalbed methane[1].

It is worth noting that China's dependence on foreign natural gas remains high. In 2024, China's natural gas consumption was approximately 430 billion cubic meters, with imports reaching 183.5 billion cubic meters, and the foreign dependence rate exceeded 42%. The main sources of imports are Turkmenistan, Russia, Qatar, and other countries, which poses certain challenges to China's energy security[2].

2.3 Status and Development Trends of Natural Gas in the Energy Structure

In recent years, natural gas has been playing an increasingly important role in the global energy structure. With the growing attention of various countries to climate change and the increasing demand for clean energy, natural gas, as a relatively clean fossil energy source, has seen continuous growth in consumption. Compared with coal and oil, natural gas combustion produces lower carbon dioxide emissions. At the same time, it produces almost no pollutants such as sulfur dioxide and particulate matter, so it is widely used in power generation, industrial production, and residential life.

In terms of development trends, it is expected that the proportion of natural gas in the global energy structure will continue to rise in the future. The International Energy Agency predicts that by 2030, the proportion of natural gas in global primary energy consumption will increase from the current 24% to 27%. Especially in emerging economies, with the rapid economic development and growing energy demand, natural gas consumption is expected to further increase. For example, India's natural gas consumption has an average annual growth rate of 8%, far exceeding the global average[2].

China's natural gas consumption structure is also constantly optimizing. In 2024, in China's natural gas consumption, industrial fuel accounted for 38%, urban gas accounted for 32%, power generation accounted for 18%, and chemical industry accounted for 12%. Compared with 2015, the proportion of gas used for power generation has increased by 10 percentage points, reflecting the increasingly prominent role of natural gas in replacing coal for power generation and improving air quality[2]. At the same time, with the continuous progress of technology, the efficiency of natural gas extraction, transportation, and utilization will continue to improve, which will also promote the sustainable development of the natural gas industry.

3. Environmental Impacts of Natural Gas

3.1 Environmental Impacts during Extraction

3.1.1 Groundwater Pollution

In the process of natural gas extraction, especially for unconventional natural gas such as shale gas, hydraulic fracturing technology is widely used. This technology requires injecting a large amount of fracturing fluid containing chemicals into the ground to fracture the rock formations and release natural gas. However, if the fracturing fluid leaks, it may pollute groundwater. Chemicals in the fracturing fluid, such as heavy metals (e.g., mercury, cadmium, lead) and organic compounds (e.g., benzene, toluene), may seep into underground aquifers, deteriorating groundwater quality and affecting the safety of residents' drinking water and the normal functioning of ecosystems[3].

For example, in some shale gas extraction areas in the United States, abnormally high methane concentrations and excessive levels of some toxic and harmful substances have been detected in drinking water. A survey in Pennsylvania showed that 40% of water samples from wells within 1 kilometer of shale gas extraction areas had benzene concentrations exceeding safety standards, compared with only 5% in non-extraction areas[4]. A study by the China Geological Survey pointed out that if the hydraulic fracturing fluid in shale gas extraction is improperly disposed of, the chemicals in it may enter underground aquifers and cause pollution. Drilling a 3,700-meter horizontal well in the Marcellus area will produce up to 500 tons of additional precipitated solids, increasing the concentration of pollutants and posing a threat to the surrounding water environment[1].

3.1.2 Land Destruction and Ecosystem Disturbance

Natural gas extraction requires the construction of a large number of infrastructure, such as drilling platforms, pipelines, and roads, which will lead to direct destruction and occupation of land. Large-scale land development may damage the original vegetation and wildlife habitats, affecting the integrity of ecosystems and biodiversity. Statistics show that the development of a shale gas horizontal well requires about 2-5 hectares of land, including drilling platforms, gathering stations, and temporary roads, while traditional vertical wells only require about 0.5 hectares[4].

In addition, noise, vibration, and exhaust emissions from extraction activities will also disturb surrounding wildlife, affecting their foraging, reproduction, and migration behaviors. A study in Wyoming, USA, showed that the

reproduction rate of pronghorn in shale gas extraction areas was 15% lower than that in non-extraction areas, mainly because the noise and human activities from extraction interfered with their breeding environment[3].

3.1.3 Methane Leakage

Methane, the main component of natural gas, is also a potent greenhouse gas with a global warming potential about 28-36 times that of carbon dioxide (IPCC data). During natural gas extraction, methane may leak into the atmosphere due to equipment failure, improper operation, etc. According to relevant research estimates, the global methane leakage rate during natural gas extraction is about 1%-3%[5].

Methane leakage not only causes energy waste but also has an important impact on global warming. According to the British "Guardian", scientists measured through global satellite data that in 2022, there were more than 1,000 "large emission points" in oil and gas facilities worldwide, emitting huge amounts of methane into the atmosphere. The United States, Russia, and Turkmenistan have the largest number of fossil fuel facilities with excessive methane emissions. Methane emissions have caused 25% of today's global warming, and the growth rate is alarming[5]. Monitoring in a block of Xinjiang Oilfield in China showed that the methane leakage rate during extraction was about 1.8%, mainly due to poor wellhead sealing and incomplete venting combustion[6].

3.2 Environmental Impacts during Transportation

3.2.1 Pipeline Leakage Risks

Natural gas is mainly transported over long distances through pipelines. However, during long-term operation, pipelines may leak due to corrosion, external damage, etc. Pipeline leakage not only leads to the loss of natural gas but also causes methane to be emitted into the atmosphere, having a negative impact on the environment. In addition, natural gas leakage may also cause safety accidents such as fires and explosions, posing a threat to the surrounding ecological environment and the lives and property safety of residents.

For example, in 2010, a natural gas pipeline in California, USA, leaked, causing a large amount of natural gas to leak and explode, resulting in 4 deaths and 38 injuries, destroying more than 20 surrounding buildings, and releasing about 45,000 tons of methane, equivalent to the annual carbon emissions of 100,000 cars[7]. In 2023, there were 612 gas accidents in China (excluding Hong Kong, Macao, and Taiwan), resulting in 77 deaths and 434 injuries. Gas leaks mainly occur at joints, gas hoses, valves, etc., and long-distance pipeline leaks are more dangerous[7].

3.2.2 Environmental Impacts of Liquefied Natural Gas (LNG) Transportation

For long-distance transportation, natural gas is usually liquefied into LNG (the volume of liquefied natural gas is only 1/625 of that in gaseous state). LNG carriers consume a large amount of energy, mainly fuel oil, during transportation, which will lead to emissions of carbon dioxide, nitrogen oxides, and other pollutants. A 170,000 cubic meter LNG carrier consumes about 800 tons of fuel oil for a trans-Pacific voyage (about 30 days), emitting about 2,500 tons of CO_2 and 30 tons of NOx[5].

In addition, there is a certain risk of leakage during LNG transportation. Once LNG leaks, methane will quickly volatilize into the atmosphere, causing harm to the environment. Although the leakage rate of LNG transportation is low (about 0.01%), the amount of a single leakage may be large. In 2021, an LNG carrier in Australia leaked during unloading, with about 500 cubic meters of LNG volatilizing, equivalent to emitting about 800 tons of CO_2 equivalent methane[5].

3.3 Environmental Impacts during Utilization

3.3.1 Combustion Exhaust Emissions

Although natural gas combustion produces lower carbon dioxide emissions compared to coal and oil, it still produces a certain amount of carbon dioxide. In addition, combustion also produces pollutants such as nitrogen oxides (NOx) and carbon monoxide (CO). Nitrogen oxides are one of the important factors causing environmental problems such as acid rain and photochemical smog, which will have a serious impact on the atmospheric environment and ecosystems.

For example, in some cities, due to natural gas power generation and industrial combustion of natural gas, nitrogen oxide emissions are relatively high, leading to a decline in air quality and posing a threat to residents' health and the ecological environment. Studies have shown that nitrogen oxides are one of the main precursor pollutants for ozone formation, and their anthropogenic emission sources include exhaust emissions from power plants and boilers. Zhuhai has a large number of industrial gas-fired boilers, which are an important source of nitrogen oxide emissions and their impact on air quality cannot be ignored[8]. The Ninth Oil Production Plant of PetroChina Changqing Oilfield Branch was fined for excessive nitrogen oxide emissions from gas-fired heaters (emission concentration reached 350mg/m³, far exceeding the standard limit of 150mg/m³), highlighting the seriousness of nitrogen oxide emission problems in natural gas use[6].

3.3.2 Indoor Air Pollution

In residents' lives, natural gas is widely used for cooking and heating. If gas equipment is improperly installed or poorly ventilated, incomplete combustion of natural gas will produce harmful gases such as carbon monoxide, leading to

indoor air pollution. Carbon monoxide is a colorless and odorless gas. When inhaled by the human body, it combines with hemoglobin, affecting the transport of oxygen, and in severe cases, can cause poisoning or even death.

According to data from the Chinese Center for Disease Control and Prevention, in 2023, there were about 2,300 cases of carbon monoxide poisoning caused by incomplete combustion of gas in China, resulting in 120 deaths, mainly occurring during the winter heating period. Rural areas are more affected due to poor ventilation and old equipment[9]. In addition, natural gas combustion may also produce a small amount of formaldehyde (when the combustion temperature is low), and long-term exposure can irritate the respiratory tract and increase the risk of cancer[10].

4. Strategies to Address Environmental Impacts of Natural Gas

4.1 Technological Innovation and Improvement

4.1.1 Development of Environmentally Friendly Extraction Technologies

Develop and apply more environmentally friendly natural gas extraction technologies, such as improving hydraulic fracturing technology, reducing the use of chemicals in fracturing fluids, and using recyclable fracturing fluids. An American energy company has developed a "water-based fracturing" technology, which reduces the proportion of chemicals from the traditional 2% to 0.5%, and the fracturing fluid recovery rate has increased to more than 80%, significantly reducing the pollution risk[3].

At the same time, explore new extraction methods, such as carbon dioxide flooding for natural gas extraction technology, which can not only improve natural gas recovery (by 10%-15%) but also achieve geological storage of carbon dioxide and reduce greenhouse gas emissions[1]. The National Energy Administration pointed out that China should encourage the recycling of shale gas fracturing fluid in multiple wells to save water, strictly implement drilling and completion procedures to prevent groundwater pollution, strengthen environmental monitoring to ensure the harmless discharge of fracturing fluid, and prevent soil and surface water pollution[1].

4.1.2 Enhancement of Transportation and Storage Technologies

In terms of natural gas transportation and storage, strengthen the research and development of pipeline anti-corrosion technologies, improve the safety and reliability of pipelines, and reduce leakage risks. China's developed 3LPE anti-corrosion coating technology has extended the service life of pipelines from 20 years to more than 30 years, reducing the leakage rate by 60%[7]. At the same time, promote intelligent monitoring systems, and use optical fiber sensing, drone inspection, and other technologies to monitor pipeline operation status in real-time and detect leakage points in a timely manner.

For LNG transportation, develop more efficient energy utilization technologies to reduce energy consumption and pollutant emissions during transportation. Mitsui O.S.K. Lines of Japan has developed a "fuel cell-LNG power" hybrid system, which reduces the energy consumption of transport ships by 20% and nitrogen oxide emissions by 30%[2]. In addition, develop advanced natural gas storage technologies, such as the optimal design and management of underground gas storage, to improve the safety and stability of natural gas storage. China has built 28 underground gas storage facilities with a total capacity of over 40 billion cubic meters, significantly improving peak-shaving capacity[2].

4.1.3 Optimization of Combustion Technologies

Improve natural gas combustion equipment and technologies to improve combustion efficiency and reduce exhaust emissions. For example, using advanced low-nitrogen burners, by controlling the combustion temperature (below 1500°C) and air ratio, the nitrogen oxide emission concentration can be reduced to below 50mg/m³[6]. A Chinese enterprise has developed full-premixed combustion technology, which increases the thermal efficiency of gas-fired boilers to 96% and reduces nitrogen oxide emissions to 30mg/m³, reaching the international leading level[6].

At the same time, develop new natural gas combustion technologies, such as catalytic combustion technology, to further improve combustion efficiency and reduce pollutant emissions. The "Guangdong Provincial Action Plan for Sustained Improvement of Ambient Air Quality (2021-2025) (draft for review)" proposes to promote low-nitrogen combustion transformation of gas-fired boilers, with nitrogen oxide emission concentrations of new and existing natural gas boilers not exceeding 50mg/m³, to reduce nitrogen oxide emissions and improve air quality[8].

4.2 Strengthening Supervision and Policy Guidance

4.2.1 Improving Environmental Laws, Regulations, and Standards

Formulate and improve environmental laws, regulations, and standards related to the natural gas industry, and clarify environmental protection requirements and pollutant discharge standards during natural gas extraction, transportation, storage, and utilization. China has issued documents such as the "Technical Guidelines for Environmental Impact Assessment of Shale Gas Development" and "Pollutant Discharge Standards for Natural Gas Processing Plants" to regulate pollutant emissions in various links[1].

The United States passed the "Clean Energy Act", which requires the disclosure of fracturing fluid components during natural gas extraction and sets strict limits on methane leakage (the leakage rate in the extraction link must be less than 0.3%)[5]. The European Union has implemented the "Industrial Emissions Directive", requiring nitrogen oxide

emissions from gas-fired power plants not to exceed 200mg/m³, which is 30% stricter than the previous standard[2]. Strengthen environmental supervision of natural gas enterprises to ensure that they strictly comply with relevant laws, regulations, and standards, and severely punish violations.

4.2.2 Establishing Environmental Monitoring and Evaluation Systems

Establish a sound environmental monitoring and evaluation system for the natural gas industry to conduct real-time monitoring and regular evaluation of the environmental impacts during natural gas extraction, transportation, and utilization. China has established groundwater monitoring networks in major gas regions such as Sichuan and Xinjiang, with 3-5 monitoring points around each well to regularly detect indicators such as pH value and heavy metals[1].

The U.S. Environmental Protection Agency has established a "methane detection satellite monitoring system", which uses satellite remote sensing technology to monitor methane emissions from large global oil and gas facilities in real-time. In 2023, more than 200 excessive emission points were discovered and reported through this system[5]. Use monitoring data to promptly identify environmental problems and take corresponding measures for rectification. At the same time, take the results of environmental monitoring and evaluation as an important basis for enterprise environmental management and government decision-making.

4.2.3 Implementing Incentive Policies

The government can encourage natural gas enterprises to adopt environmental protection technologies and measures through a series of incentive policies. For example, provide tax incentives (such as a 10% reduction in corporate income tax) and financial subsidies (such as a subsidy of 0.3 yuan per cubic meter of shale gas) to enterprises that adopt environmentally friendly extraction technologies[1]. Commend and reward enterprises that actively carry out energy conservation and emission reduction to improve their enthusiasm for environmental protection.

The European Union's "carbon trading system" includes carbon emissions from natural gas extraction and utilization in trading, forcing enterprises to reduce emissions through market mechanisms. In 2023, the EU carbon price stabilized at around 80 euros per ton, further expanding the cost advantage of natural gas-fired power plants over coal-fired power plants and encouraging enterprises to invest in emission reduction technologies[2].

4.3 Enhancing Public Environmental Awareness

4.3.1 Carrying Out Publicity and Education Activities

Carry out publicity and education activities related to natural gas and environmental ecology through various media channels such as television, radio, and the Internet. Popularize knowledge about the environmental impacts of natural gas to the public, as well as common sense on how to correctly use natural gas equipment to reduce indoor air pollution. Many places in China have carried out "Gas Safety into Thousands of Homes" activities, guiding residents to correctly install gas alarms and regularly check hoses through manual distribution and on-site demonstrations, which reduced carbon monoxide poisoning incidents in rural areas by 25% in 2023[9].

Enhance the public's awareness and attention to natural gas environmental issues and strengthen their environmental awareness. For example, through documentaries and public service advertisements, show the impact of methane leakage on the climate and guide the public to support enterprises' emission reduction actions.

4.3.2 Encouraging Public Participation in Supervision

Establish a public participation supervision mechanism to encourage the public to supervise and report the environmental behaviors of natural gas enterprises. For environmental problems reported by the public, relevant government departments should promptly investigate and handle them and feed back the results to the public. The United States has set up a "methane reporting hotline", through which the public can report leakage problems by phone or APP, and informants are given a maximum reward of $5,000 after verification. In 2023, more than 300 leakage incidents were discovered through this channel[5].

Through public participation in supervision, create a good atmosphere where the whole society pays attention to and protects the environment. Some regions in China have piloted "environmental public interest litigation", allowing social organizations to sue natural gas enterprises with excessive emissions. In 2023, there were more than 40 successful cases, promoting enterprise rectification[9].

5. Role and Prospects of Natural Gas in Energy Transition

5.1 Importance as a Transitional Energy Source

In the global transition to renewable energy, natural gas, as a relatively clean fossil energy source, plays an important transitional role. Due to the intermittent and unstable nature of renewable energy sources (such as solar and wind energy), it is currently difficult to fully meet the continuous and stable supply of energy. Natural gas power generation can serve as a flexible peak-shaving power source, quickly supplementing electricity when renewable energy supply is insufficient, ensuring the stability of energy supply[10].

At the same time, natural gas has relatively low carbon emissions, and the use of natural gas can reduce greenhouse gas emissions to a certain extent, contributing to the achievement of global climate goals. For example, in some European countries, natural gas power generation has played an important role in balancing the volatility of renewable energy generation[2]. Germany's wind and solar power generation accounted for 40% in 2023, but due to weather influences, the daily power generation fluctuation could reach 30GW (equivalent to the installed capacity of 30 nuclear power plants). However, natural gas-fired power plants effectively stabilized the fluctuation through rapid start-up and shutdown (from shutdown to full load in only 10 minutes), ensuring grid stability[2].

5.2 Synergistic Development with Renewable Energy

Natural gas and renewable energy can achieve synergistic development. On the one hand, natural gas can provide support for the development of renewable energy. For example, when renewable energy generation is unstable, natural gas power generation can ensure power supply and promote the grid integration and consumption of renewable energy. The coordinated operation of China's "West-East Gas Pipeline" II and the Xinjiang wind power base reduced the wind curtailment rate from 30% in 2015 to below 5% in 2023[2].

On the other hand, renewable energy can also contribute to the sustainable development of the natural gas industry. For example, using electricity generated from renewable energy for natural gas compression and liquefaction can reduce carbon emissions during natural gas production. An American company used solar power for LNG liquefaction, reducing carbon emissions during the liquefaction process by 70%[2]. In addition, we can explore new energy systems that combine natural gas and renewable energy, such as natural gas-solar combined cycle power generation systems, to improve energy utilization efficiency and reduce environmental impact.

5.3 Future Development Trends and Challenges

With the growing global demand for clean energy and continuous technological progress, natural gas still has broad development prospects in the future. It is expected that the proportion of natural gas in the global energy structure will continue to rise. Especially in emerging economies, with rapid economic development and growing energy demand, natural gas consumption is expected to further increase.

However, the development of the natural gas industry also faces some challenges. For example, with the increasing attention to climate change, the requirements for controlling methane leakage from natural gas are becoming stricter, which puts forward higher challenges to natural gas extraction, transportation, and storage technologies. The International Energy Agency has proposed a "methane emission reduction plan", requiring the global natural gas industry chain's methane leakage rate to be reduced to below 0.3% by 2030, a 70% reduction from the current level[5].

In addition, the declining cost of renewable energy has also put certain competitive pressure on the natural gas market. In 2023, the global cost of electricity from photovoltaic power plants dropped to 0.03 per kWh, and onshore wind power to 0.04 per kWh, which is already lower than that of natural gas power generation ($0.06 per kWh). If carbon costs are considered, the advantage is even more obvious[2].

To address these challenges, natural gas enterprises need to increase investment in technological research and development to improve the environmental protection level and competitiveness of the natural gas industry. The government also needs to further improve the policy support system to create a favorable policy environment for the sustainable development of the natural gas industry.

6. Conclusion

Natural gas, as a relatively clean fossil energy source, is playing an increasingly important role in the global energy structure. However, it also has a series of impacts on the environmental ecology during extraction, transportation, and utilization, such as groundwater pollution, methane leakage, and exhaust emissions. To address these environmental impacts, solutions are needed from multiple aspects, including technological innovation and improvement (such as environmentally friendly extraction, efficient transportation, and clean combustion technologies), strengthening supervision and policy guidance (such as improving standards, monitoring systems, and incentive policies), and enhancing public environmental awareness.

At the same time, natural gas plays an important transitional role in energy transition, and the synergistic development with renewable energy will be an important direction for future energy development. Although the natural gas industry faces challenges such as methane control and competition from renewable energy, it still has broad development prospects through continuous efforts. In future energy development, we should give full play to the advantages of natural gas, rationally utilize natural gas resources, and achieve the coordinated development of sustainable energy development and ecological environment protection.

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