

Natural Gas Supply-Demand Imbalance, Energy Security, and Industrial Competitiveness in Iran

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Abstract

Energy security is a critical prerequisite for sustainable economic and industrial development. In Iran, it is of particular importance due to the dominant role of natural gas in the national energy mix. This study examines the structure of energy consumption, analyzes the natural gas supply-demand imbalance, and evaluates its implications for energy security and the competitiveness of energy-intensive industries. The research adopts an applied descriptive-analytical approach and utilizes data obtained from Iran's Energy Balance Sheets, reports of the Ministry of Petroleum, the Ministry of Energy, the National Iranian Gas Company, the Iranian Parliament Research Center, the International Energy Agency (IEA), and the financial statements of publicly listed companies. The findings reveal that the extensive dependence of the residential, power generation, and industrial sectors on natural gas, together with rapid demand growth, investment constraints, infrastructure limitations, and high energy intensity, has significantly exacerbated the gas supply-demand imbalance and increased vulnerabilities in the country's energy security. The analysis further indicates that energy-intensive industries, particularly the petrochemical, steel, and cement industries particularly the petrochemical, steel, and cement industries, are highly exposed to gas supply disruptions. Such constraints result in production losses, reduced export performance, higher operating costs, and an erosion of competitive advantages in both domestic and international markets. The study also identifies several policy measures for mitigating the imbalance, including reforming the natural gas pricing system, improving energy efficiency, expanding the deployment of renewable energy, encouraging industrial participation in upstream gas field development, and implementing effective demand-side management programs. The study concludes that the Natural Gas Supply-Demand Imbalance in Iran is not merely an energy-sector concern but a strategic challenge with far-reaching consequences for industrial development, economic growth, and long-term energy resilience.

Keywords: Natural Gas Supply; Energy Security; Energy-Intensive Industries; Energy Efficiency

چکیده

امنیت انرژی پیش شرط بنیادین توسعه پایدار صنعتی و اقتصادی است؛ امری که در ایران به دلیل سهم مسلط گاز طبیعی در سبد انرژی کشور اهمیتی دوچندان دارد. این پژوهش کاربردی با رویکردی توصیفی تحلیلی و اتکا به داده‌های ترازنامه انرژی، مراجع رسمی داخلی و آژانس بین‌المللی انرژی، به واکاوی ساختار مصرف، ناترازی گاز و پیامدهای آن بر امنیت انرژی و رقابت‌پذیری صنایع انرژی‌بر می‌پردازد. یافته‌ها نشان می‌دهد وابستگی مفرط بخش‌های خانگی، نیروگاهی و صنعتی به گاز، هم‌زمان با رشد فزاینده تقاضا، شدت مصرف بالا و تنگنای سرمایه‌گذاری و زیرساختی، کسری گاز را تشدید کرده است. کانون این آسیب‌پذیری متوجه صنایع انرژی‌بر، به ویژه پتروشیمی، فولاد و سیمان، است که با قطعی‌های دوره‌ای گاز مواجه‌اند؛ امری که به توقف تولید، افت صادرات، جهش هزینه‌های سربار و فرسایش مزیت‌های رقابتی انجامیده است. به منظور مهار این بحران، راهکارهایی نظیر اصلاح نظام قیمت‌گذاری، ارتقای بهره‌وری، توسعه تجدیدپذیرها، مدیریت تقاضا و مشارکت صنایع در بالادست میادین گازی پیشنهاد می‌شود. در نهایت، این مطالعه تصریح دارد ناترازی گاز در ایران فراتر از یک چالش فنی در بخش انرژی، تهدیدی راهبردی برای تاب‌آوری اقتصادی و پیشران‌های صنعتی کشور است.

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1. Introduction

Energy is widely recognized as one of the most critical foundations of economic, industrial, and social development worldwide. Reliable and sustainable access to energy is a prerequisite for economic growth, improved public welfare, and the achievement of sustainable development goals. In recent decades, population growth, industrial expansion, rapid urbanization, and the proliferation of advanced technologies have significantly increased global energy demand. Under these circumstances, energy security has become a major concern for governments, policymakers, and economic stakeholders, occupying a central position in national strategic planning. Any disruption in energy supply or increase in instability within energy markets can have far-reaching consequences for production, employment, economic growth, and national security (BP, 2023; IHS Markit, 2023; U.S. Energy Information Administration [EIA], 2023).

The concept of energy security has undergone substantial transformation over the past several decades. Initially, energy security was primarily associated with the continuous supply of petroleum resources and guaranteed physical access to fossil fuels. However, successive energy crises, increasing volatility in energy prices, growing environmental concerns, and emerging challenges related to climate change have considerably broadened its scope. Today, energy security extends beyond the mere availability of energy resources and encompasses several dimensions, including the diversification of energy sources, the reliability of production and transmission infrastructure, economic sustainability, resilience to disruptions and crises, environmental considerations, and equitable access to energy services. Consequently, international organizations such as the International Energy Agency and the World Energy Council have developed various frameworks and indicators to assess and compare the energy security performance of countries (Energy Outlook Assessment [EOA], 2023; IHS Markit, 2023).

One of the most widely recognized frameworks in this field is the World Energy Council's Energy Trilemma Index, which evaluates countries' performance based on three core dimensions: energy security, energy equity, and environmental sustainability. This framework highlights that achieving sustainable energy security requires balancing reliable access to energy, environmental protection, and the fulfillment of economic and social needs. In other words, countries that rely solely on the abundance of energy resources while neglecting energy diversification, efficiency improvements, and environmental sustainability are likely to face significant energy security challenges in the long term (Energy Outlook Assessment [EOA], 2023).

Iran, endowed with vast oil and natural gas reserves, has long been considered a major player in the global energy market. Despite this strategic advantage, the country's energy production and consumption structure remain heavily dependent on fossil fuels, particularly natural gas. According to official statistics, more than 97% of Iran's primary energy supply is derived from oil and natural gas, while the contribution of renewable and

other low-carbon energy sources to the national energy mix remains limited. Although this dependence has historically provided relatively affordable and reliable access to energy for various sectors of the economy, it has also created significant structural vulnerabilities within the country's energy system. The concentration of energy supply on a limited range of resources reduces the flexibility of the energy sector and increases its exposure to supply disruptions, investment constraints, and fluctuations in domestic demand. Consequently, maintaining the sustainability and reliability of energy supply has become an increasingly important challenge for policymakers and energy planners in Iran (BP, 2023; National Iranian Oil Company [NIOC], 2022; U.S. Energy Information Administration [EIA], 2023).

An examination of Iran's energy balance indicates that natural gas constitutes the backbone of the country's energy system, with the residential, industrial, power generation, and petrochemical sectors exhibiting a high degree of dependence on this energy carrier. In recent years, increasing domestic consumption, growing demand across various sectors, and investment constraints associated with international sanctions have transformed the natural gas supply-demand imbalance into one of the most significant challenges facing Iran's energy sector. This imbalance has been particularly pronounced during the colder months of the year, leading to fuel supply restrictions for industries and power plants and imposing substantial economic costs on the productive sector. Furthermore, the heavy reliance of the country's power plants on fossil fuels, particularly natural gas, has increased the vulnerability of electricity generation to disruptions in gas supply. Consequently, any interruption or limitation in the availability of natural gas can directly affect electricity supply security and undermine the reliability of the national power system (Ministry of Petroleum, 2022; National Iranian Gas Company [NIGC], n.d.; National Iranian Oil Company [NIOC], 2022).

The energy security literature commonly highlights four principal dimensions: availability, reliability, affordability, and environmental sustainability (IHS Markit, 2023).

In addition to the issue of dependence on fossil fuels, Iran's energy intensity remains considerably higher than that of many countries around the world. A substantial portion of the country's energy production is lost during the processes of extraction, conversion, transmission, and final consumption, indicating significant potential for improvements in energy efficiency. The continuation of this trend not only exacerbates energy imbalances but also imposes considerable economic and environmental costs on the country, potentially undermining the long-term competitiveness of its industries (Energy Outlook Assessment [EOA], 2023; National Productivity Organization of Iran, 2023).

Among the various sectors of the economy, mining and mineral-based industries are among the largest energy consumers in Iran. Industries such as steel, cement, copper, aluminum, ceramics and tiles, and other mineral-processing sectors account for a substantial share of the country's natural gas and electricity consumption. Since energy constitutes a critical production input in these industries, any constraint on the supply of energy carriers can significantly affect production levels, operating costs, competitiveness, and profitability. In recent years,

supply restrictions resulting from natural gas shortages and electricity deficits during different seasons have further highlighted the importance of energy demand management and the diversification of energy supply sources within these industries. These challenges underscore the need for policies aimed at enhancing energy efficiency, improving supply reliability, and strengthening the resilience of energy-intensive industrial sectors (National Iranian Gas Company [NIGC], n.d.; National Productivity Organization of Iran, 2023).

From a risk management perspective, the heavy concentration of national energy consumption around a single energy carrier, particularly natural gas, has increased the vulnerability of Iran's economy to both domestic and external shocks. International sanctions, investment constraints, the aging of parts of the energy infrastructure, growing domestic demand, and the impacts of climate change are among the factors that may jeopardize the security of energy supply. Therefore, identifying the structure of energy consumption, assessing the degree of dependence of different economic sectors on various energy carriers, and analyzing the implications of this dependence are essential prerequisites for developing effective strategies to enhance national energy security (Ministry of Petroleum, Vice Presidency for Planning, n.d.; Parliament Research Center of the Islamic Republic of Iran, n.d.).

Accordingly, this study focuses on Iran's energy balance structure and examines energy consumption patterns in energy-intensive industries in order to analyze the current situation and identify the principal challenges facing the country's energy security. The research seeks to provide a comprehensive understanding of the existing dependencies within the energy system, clarify the role of energy-intensive industries in national energy consumption, and contribute to the development of effective policy measures aimed at strengthening energy resilience, improving energy efficiency, and enhancing the overall security and sustainability of the country's energy system.

2. Research Methodology

This study is applied in terms of its objective and adopts a descriptive–analytical research design. The study population consists of Iran's energy-intensive industries, among which the petrochemical, steel, and cement sectors were selected as representative case studies. The data utilized in this research were collected from the following sources:

- Iran's Energy Balance Sheets
- Reports published by the Ministry of Petroleum
- Reports of the Ministry of Energy
- Reports of the National Iranian Gas Company (NIGC)
- Publications of the Iranian Parliament Research Center
- Reports of the International Energy Agency (IEA)
- Financial statements of publicly listed companies

Data were analyzed using a policy analysis framework and a trend-comparative approach (National Iranian Oil Company [NIOC], 2022; National Iranian Gas Company [NIGC], n.d.; Parliament Research Center of the Islamic Republic of Iran, n.d.; Securities and Exchange Organization of Iran [CODAL], n.d.; Tavanir, 2023).

3. Natural Gas Status in the World and Iran

Natural gas is one of the most important energy carriers worldwide and, due to its lower environmental impact compared with other fossil fuels, plays a significant role in energy supply and the transition toward a low-carbon economy. According to 2023 statistics, the United States, with production exceeding 1,070 billion cubic meters, was the world's largest producer of natural gas, followed by Russia and Iran in second and third place, respectively. In terms of consumption, the United States, Russia, China, and Iran rank among the largest natural gas consumers globally.

With approximately 6% of global natural gas production and consumption, Iran occupies a prominent position in the international energy market. However, the majority of the country's natural gas production is consumed domestically. Rapid growth in demand, particularly in the residential, power generation, and industrial sectors, has intensified the natural gas supply–demand imbalance in recent years. This situation has created significant challenges for the country's energy security and has further underscored the necessity of improving energy efficiency, strengthening demand-side management, and implementing effective energy consumption policies (BP, 2023; U.S. Energy Information Administration [EIA], 2023).

3.1. Concentration of Global Natural Gas Reserves

Global natural gas reserves are unevenly distributed, with a substantial share concentrated in a limited number of countries. Iran, Russia, Qatar, and Turkmenistan collectively possess nearly half of the world's proven natural gas reserves. This high degree of concentration has enhanced the geopolitical significance of natural gas and positioned countries with large reserves as key actors in global energy security. Among the world's gas fields, the South Pars–North Dome field, shared between Iran and Qatar, is recognized as the largest known natural gas field in the world and contains a significant proportion of global gas reserves (BP, 2023; U.S. Energy Information Administration [EIA], 2023).

3.2. The South Pars Gas Field and Its Importance for Iran

The South Pars gas field is Iran's most important source of natural gas supply and the largest gas field in the world. It provides more than 70% of the country's natural gas consumption and plays a crucial role in electricity generation, feedstock supply for the petrochemical industry, mineral-processing industries, and residential energy consumption.

The development of this field over the past two decades has significantly contributed to increasing Iran's gas production capacity and expanding the country's energy infrastructure. Despite these advantages, the heavy dependence of the national energy system on a single shared field represents a strategic risk. Any decline in production or disruption in the operation of South Pars could adversely affect multiple sectors of the economy and jeopardize national energy security (National Iranian Gas Company [NIGC], n.d.; South Pars Gas Complex [SPGC], n.d.).

3.3. A Comparison of Iran and Qatar in Developing the Shared Gas Field

Although Iran and Qatar share the world's largest natural gas field, the two countries have followed markedly different development paths. Through substantial foreign investment, access to advanced technologies, and the expansion of its liquefied natural gas (LNG) industry, Qatar has become one of the world's leading natural gas exporters. In contrast, the development of South Pars in Iran has progressed more slowly due to investment constraints and the impact of international sanctions. This divergence demonstrates that the mere possession of abundant energy resources is not sufficient to secure economic benefits. Rather, the effective management, investment, and utilization of energy resources play a decisive role in creating economic value, strengthening competitiveness, and enhancing energy security (International Gas Union [IGU], 2022; South Pars Gas Complex [SPGC], n.d.).

4. Indicators and Trends of Natural Gas Consumption in Iran

4.1. Energy Intensity and Energy Transition

Energy intensity is one of the most important indicators for assessing energy efficiency and is measured as the ratio of energy consumption to gross domestic product (GDP). According to international reports, Iran's energy intensity is approximately 85% higher than the global average, reflecting high levels of energy consumption and relatively low efficiency across various sectors of the economy. Factors such as extensive energy subsidies, low energy prices, and the large share of energy-intensive industries are among the primary causes of this situation. Furthermore, Iran's position in the Energy Transition Index remains below the global average, with little noticeable improvement in recent years. This highlights the need for comprehensive energy policy reforms, the adoption of advanced technologies, and greater efficiency improvements throughout the energy sector (Energy Outlook Assessment [EOA], 2023; National Productivity Organization of Iran, 2023).

4.2. Trends in Natural Gas Consumption and Supply–Demand Imbalance

Natural gas is the dominant energy carrier in Iran and supplies a substantial share of the country's residential, industrial, and power generation energy needs. Despite significant growth in natural gas production in recent years, rapidly increasing consumption has led

to a persistent gas supply–demand imbalance. An examination of consumption trends during the 2010s indicates that natural gas demand expanded at a faster rate than supply capacity, gradually widening the gap between production and consumption. One of the defining characteristics of natural gas consumption in Iran is its pronounced seasonal fluctuation. During the colder months of the year, residential gas demand rises sharply, often resulting in supply constraints for industries and power plants. This situation imposes significant economic costs, including reduced industrial output and increased energy supply expenditures (Ministry of Petroleum, Vice Presidency for Planning, n.d.; National Iranian Gas Company [NIGC], n.d.; Parliament Research Center of the Islamic Republic of Iran, n.d.).

4.3. Future Outlook for Natural Gas Consumption

Forecasts of future natural gas supply and demand suggest that, if current trends continue, Iran's gas deficit is likely to increase substantially in the coming years. Conversely, the implementation of energy conservation measures, improvements in energy efficiency, and the gradual reform of pricing policies could significantly mitigate this imbalance. Therefore, effective demand-side management and the reduction of energy intensity are among the most critical requirements for maintaining long-term energy security and ensuring the sustainability of the country's energy system (Ministry of Petroleum, Vice Presidency for Planning, n.d.; Parliament Research Center of the Islamic Republic of Iran, n.d.; Planning and Budget Organization of Iran, 2023).

5. Impacts of Natural Gas Imbalance on Industry and the Production Sector

In recent years, the natural gas supply–demand imbalance has emerged as one of the most significant challenges facing Iran's industrial and energy sectors. Constraints in natural gas supply, particularly during the colder months of the year, have not only threatened energy security but have also imposed substantial economic costs on the country's major energy-intensive industries (Ministry of Petroleum, Vice Presidency for Planning, n.d.; Parliament Research Center of the Islamic Republic of Iran, n.d.).

5.1. Impact of Natural Gas Imbalance on the Petrochemical Industry

The petrochemical industry, as one of Iran's most important sources of export revenue, is highly dependent on natural gas. This dependence is particularly pronounced in methanol, ammonia, and urea production facilities, where natural gas serves not only as an energy source but also as the primary feedstock. In recent years, winter gas shortages have led to production disruptions and reduced profitability in many gas-based petrochemical plants. In contrast, facilities utilizing more diversified feedstocks have been less vulnerable to gas supply constraints. These findings suggest that the persistence of gas imbalances could significantly undermine the competitiveness and revenue-generating capacity of Iran's

petrochemical industry (National Iranian Gas Company [NIGC], n.d.; National Petrochemical Company [NPC], n.d.; Securities and Exchange Organization of Iran [CODAL], n.d.).

5.2. Impact of Natural Gas Imbalance on Electricity Generation

The power generation sector is one of the largest consumers of natural gas in Iran, with the majority of the country's electricity produced by gas-fired thermal power plants. During periods of gas shortages, power plants are often forced to rely on alternative fuels such as diesel fuel and fuel oil (mazut). While this substitution ensures continued electricity generation, it increases production costs and generates considerable environmental impacts. Moreover, limitations in fuel supply can compromise the stability of the electricity grid and increase the risk of widespread power outages, thereby affecting both economic activities and public welfare (National Iranian Gas Company [NIGC], n.d.; Parliament Research Center of the Islamic Republic of Iran, n.d.; Tavanir, 2023).

5.3. Vulnerability of Energy-Intensive Mineral Industries

Mineral-based industries, including steel, cement, aluminum, and ferroalloy production, are among the largest energy consumers in Iran. In addition, the petrochemical sector is the country's largest consumer of natural gas feedstock. Gas supply restrictions have resulted in lower production of methanol, urea, and ammonia, reducing not only corporate profitability but also national export revenues.

The steel industry is particularly vulnerable to gas shortages, as more than 80% of Iran's steel production is based on the direct reduction process, which relies heavily on natural gas. Consequently, winter gas curtailments have led to reductions in crude steel production and exports. Similarly, the cement industry, one of the most energy-intensive sectors of the economy, faces increased production costs and significant environmental consequences when alternative fuels are used.

Analysis of energy consumption data for Iran's mineral industries indicates that the steel sector alone accounts for approximately 62.7% of total natural gas consumption within this group, while the cement industry represents about 32.3%. This high concentration of energy use means that natural gas imbalances directly affect the performance of strategically important industries. In practice, supply constraints typically result in reduced gas allocations to steel and cement producers, thereby limiting production capacity, exports, and employment opportunities.

From the perspective of industrial economics, this pattern reflects the strong dependence of industrial competitiveness on a subsidized production input. Such competitiveness has largely been built on access to inexpensive energy rather than on innovation, technological advancement, or productivity improvements. Consequently, when gas supply imbalances emerge, the competitive advantage of these industries is significantly weakened, exposing structural vulnerabilities within the country's industrial development model (National

Petrochemical Company [NPC], n.d.; Securities and Exchange Organization of Iran [CODAL], n.d.; Tavanir, 2023).

6. Energy Policy and the Energy Business Model in Iran

The natural gas imbalance in Iran is not merely the result of increasing consumption or production constraints; rather, it is deeply rooted in the country's energy policy framework and business model. Over the past decades, Iran's economy has been heavily dependent on revenues generated from oil and natural gas, and this dependence has significantly shaped the country's economic and industrial policies. Within this context, subsidized energy pricing has provided short-term support to consumers and industries; however, in the long run, it has contributed to rising demand, weakened investment incentives, and exacerbated imbalances within the energy sector. Furthermore, the development of Iran's energy industry has faced numerous challenges, including investment constraints, international sanctions, aging infrastructure, and the absence of an efficient financing system. These factors have prevented energy supply growth from keeping pace with increasing demand, resulting in a widening gap between production and consumption. Consequently, energy imbalance has evolved from a purely technical issue into a broader economic and strategic challenge (Ministry of Petroleum, Vice Presidency for Planning, n.d.; Parliament Research Center of the Islamic Republic of Iran, n.d.; Planning and Budget Organization of Iran, 2023).

In recent years, policymakers have sought to address this challenge through the gradual adjustment of natural gas prices for industrial consumers, the implementation of energy efficiency and conservation programs, and the establishment of energy intensity reduction targets within the Seventh National Development Plan. Nevertheless, the effectiveness of these measures depends on achieving an appropriate balance among three key objectives: energy security, industrial competitiveness, and economic sustainability (National Productivity Organization of Iran, 2023; Planning and Budget Organization of Iran, 2023).

An examination of Iran's energy business model indicates that the factors contributing to energy imbalance can be categorized into demand-side and supply-side drivers. On the demand side, low energy prices, inefficient consumption patterns, and high energy intensity have accelerated the growth of energy demand. On the supply side, investment limitations, restricted access to advanced technologies, and the limited economic attractiveness of energy projects have constrained the expansion of production capacity. The continuation of these conditions poses a significant threat not only to energy security but also to economic growth, industrial production, and the country's foreign exchange earnings (Ministry of Petroleum, Vice Presidency for Planning, n.d.; Parliament Research Center of the Islamic Republic of Iran, n.d.).

Therefore, transitioning toward a sustainable energy business model requires the gradual reform of energy pricing mechanisms, improvements in energy efficiency, increased

investment, technological advancement, and the diversification of energy sources. Achieving these objectives can contribute to reducing the natural gas imbalance while simultaneously enhancing energy security and strengthening the resilience of the national economy (Energy Outlook Assessment [EOA], 2023; Planning and Budget Organization of Iran, 2023).

7. Natural Gas Imbalance and Industrial Competitiveness

Industrial competitiveness is a function of production costs, productivity, product quality, and the ability to ensure a stable and reliable supply. The natural gas supply–demand imbalance adversely affects all four of these factors.

The main consequences of the gas imbalance include:

- Increased production costs;
- Reduced capital productivity;
- Lower operational capacity of industrial facilities;
- Higher investment risk; and
- Declining export performance.

As a result, the competitive advantage of Iranian industries in global markets is weakened (Energy Outlook Assessment [EOA], 2023; Parliament Research Center of the Islamic Republic of Iran, n.d.; Planning and Budget Organization of Iran, 2023; Securities and Exchange Organization of Iran [CODAL], n.d.)

8. Proposed Solutions for Securing Energy Supply in Energy-Intensive Industries

An assessment of the natural gas supply–demand imbalance indicates that addressing this challenge requires a combination of short-term, medium-term, and long-term measures. Short-term solutions are primarily aimed at crisis management and maintaining production continuity, whereas medium- and long-term strategies focus on enhancing the sustainability of energy supply and reducing industrial dependence on natural gas.

8.1. Short-Term Solutions

The most important short-term measures include underground natural gas storage, the production and storage of synthetic natural gas (SNG), the utilization of alternative liquid fuels, and the limited development of solid fuel alternatives. Although these measures can be implemented relatively quickly, they are not capable of fundamentally resolving the gas imbalance and mainly serve to mitigate the adverse effects of supply shortages and energy crises (International Gas Union [IGU], 2022; Ministry of Petroleum, Vice Presidency for Planning, n.d.; Parliament Research Center of the Islamic Republic of Iran, n.d.).

8.2. Medium-Term Solutions

In the medium term, key measures include the recovery and utilization of flare gas, the optimization of energy consumption in buildings and industrial facilities, the implementation of industrial energy audits, and the reform of energy pricing and tariff structures. These initiatives can contribute to reducing natural gas consumption, improving energy efficiency, and partially alleviating the gap between energy supply and demand (National Productivity Organization of Iran, 2023; Planning and Budget Organization of Iran, 2023).

8.3. Long-Term Solutions

Long-term strategies encompass the expansion of renewable energy sources, industrial investment in oil and gas field development, the establishment of energy-saving certificate markets, the production and storage of liquefied natural gas, the adoption of hydrogen technologies in the steel industry, and the consolidation of industrial facilities to improve operational efficiency. Although these measures require substantial investment and longer implementation periods, they offer more sustainable and effective solutions for addressing the country's energy imbalance and strengthening long-term energy security (Energy Outlook Assessment [EOA], 2023; International Gas Union [IGU], 2022; Planning and Budget Organization of Iran, 2023).

8.4. Priority Policy Recommendations

Based on the findings of this study, the following five measures are identified as the highest-priority strategies for energy-intensive mineral industries:

- Establishing a gas allocation prioritization system based on industrial value added and energy efficiency performance;
- Expanding the use of renewable energy sources, particularly solar and wind power plants located in proximity to industrial facilities;
- Conducting comprehensive energy audits and developing energy efficiency benchmarks for energy-intensive industries;
- Promoting energy self-sufficiency through industrial participation in the development of oil and gas fields; and
- Gradually reforming the energy pricing system and developing an energy-saving certificate market to strengthen incentives for energy-efficiency investments.

Overall, international experience demonstrates that addressing energy imbalances cannot be achieved solely through increasing energy production. Success in this area requires a comprehensive approach that combines supply expansion, demand-side management, pricing reform, and improvements in energy efficiency. Therefore, the simultaneous implementation of these measures can provide a more sustainable pathway for securing energy supply in energy-intensive mineral industries and mitigating the adverse impacts of natural gas imbalances on the national economy (Ministry of Petroleum, Vice Presidency for

Planning, n.d.; National Productivity Organization of Iran, 2023; Parliament Research Center of the Islamic Republic of Iran, n.d.; Planning and Budget Organization of Iran, 2023).

9. Conclusion

The findings of this study indicate that the current natural gas pricing structure in Iran faces several challenges in terms of economic efficiency, investment sustainability, and the competitiveness of energy-intensive industries. The linkage of industrial feedstock and fuel prices to a pricing formula that is partially based on European gas hubs has resulted in geopolitical fluctuations beyond the control of the Iranian economy directly affecting industrial energy costs. This issue became particularly evident following the Russia–Ukraine conflict, during which natural gas prices for Iranian industries exceeded gas prices in certain North American production hubs.

Furthermore, an examination of the country's gas tariff structure reveals that the relationship between fuel prices for different industries and petrochemical feedstock prices lacks a transparent economic rationale. The existing coefficients have largely evolved over time under the influence of fiscal considerations and negotiations among stakeholders rather than being based on criteria such as value added, energy intensity, productivity, or international competitiveness. Consequently, the current structure fails to provide effective price signals for improving energy efficiency and achieving an optimal allocation of resources.

Unlike previous studies that have primarily examined gas imbalance as an energy-sector issue, this research demonstrates that natural gas imbalance in Iran is fundamentally an industrial and trade policy challenge that directly affects the competitive advantage of energy-intensive industries, non-oil exports, and the country's industrial development trajectory. To evaluate potential reform options, three alternative scenarios for revising the natural gas pricing formula were assessed. The results indicate that eliminating European gas hubs from the pricing formula would have the greatest impact on reducing the average feedstock price, lowering it from approximately 12.6 cents to 9.6 cents per cubic meter. However, such an approach could lead to a substantial reduction in government revenues and increase the formula's dependence on North American market conditions.

The scenario based exclusively on the Henry Hub benchmark also reduces the average gas price to approximately 11.7 cents per cubic meter by eliminating distortions associated with infrastructure constraints and excess supply in the Alberta market. Although this approach offers advantages in terms of simplicity and transparency, it remains vulnerable to fluctuations in international gas markets.

In contrast, the scenario involving the application of a price cap linked to Henry Hub preserves the existing pricing structure while limiting excessive price volatility. The findings suggest that imposing a cap equivalent to 1.5 times the Henry Hub price maintains the average feedstock price at a level close to the current situation while preventing severe price shocks

arising from geopolitical crises. Therefore, this scenario appears to provide the most balanced solution in terms of safeguarding government revenues, preserving industrial competitiveness, and maintaining a stable investment environment. Based on the findings of this study, reforming Iran's natural gas pricing system should be guided by the following principles:

- Enhancing transparency in determining fuel prices for different industries and replacing existing coefficients with indicators based on value added, energy intensity, and productivity.
- Reducing the sensitivity of the pricing formula to external geopolitical shocks through the introduction of price ceilings and floors or by revising the weighting of benchmark gas hubs.
- Establishing a stronger linkage between pricing and energy supply security, whereby industries paying higher prices receive a greater degree of assurance regarding gas supply during peak-demand periods.
- Developing incentive mechanisms to improve energy efficiency and allocating a portion of revenues generated from pricing reforms to energy-efficiency projects in energy-intensive industries.
- Adopting pricing methodologies based on the economic value of final products, such as the Netback approach, as an alternative to the direct linkage between industrial fuel prices and petrochemical feedstock prices.

Overall, the results of this study suggest that reforming the natural gas pricing formula should simultaneously pursue three key objectives: ensuring the sustainability of government revenues, preserving industrial competitiveness, and creating incentives for improving energy efficiency. Within this framework, implementing a Henry Hub-based price cap in conjunction with revising the mechanism for determining fuel prices in mineral-based industries may serve as a balanced and practical option for the gradual reform of Iran's natural gas pricing system.

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