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RESEARCH ARTICLE

Clean energy transition and energy security in metropolises: A case study of Beijing under the "coal-to-gas" movement

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The transition to clean energy is one of the most important trends of development in the contemporary world, and ensuring energy security during the energy transition has naturally become an issue that urgently needs to be studied. Unlike most studies that analyze this issue at the global and sovereign national levels, this article delves back to the subnational level. It focuses on exploring energy security guarantees in metropolitan areas while considering differences in urban hierarchies. Considering that Beijing is not only the most influential metropolis in China but also a pioneer in promoting clean energy transition globally, this article analyzes the energy security issues in Beijing through the framework of Energy Security and Sustainable Development and explores the policy actions taken during the 2017 "coal-to-gas" movement by the city. Our research shows that the transition to clean energy may reduce the energy security of metropolitan areas. However, the big cities can receive prioritized protection from the central government and state-owned enterprises due to their prominent political status. However, the cost of ensuring energy security in urban areas may be passed on to their surrounding areas, where their energy security may be additionally impacted. These findings indicate that it is necessary to distinguish and examine the energy security of the metropolitan areas and surrounding regions. Only when energy justice is protected can urban areas truly achieve energy security.

Keywords: Energy security, Energy transformation, Energy justice, Metropolis, Political priority

1. Introduction

Energy issues are vital to modern nations, representing a crucial aspect of their economies and security concerns. Thus, energy security has long been recognized as a prominent component of national security, receiving significant attention from countries worldwide. Due to its significance, energy security has been a focal point in security research, resulting in countless studies. However, there does not appear to be a unified approach to the definition of "energy security," and such differences in understanding the concept are a significant obstacle in energy security research.

According to an incomplete count, there are at least 45 different conceptual frameworks for defining "energy security" (Sovacool, 2011). Asia Pacific Energy Research Center (APERC) defines energy security as "the ability of an economy to guarantee the ability of energy resource supply in a sustainable and timely manner with the energy price being at a level that will not adversely affect the economic performance of the economy" (APERC, 2007). Sovacool (2009) contends that energy security has 4 interconnected dimensions: availability, affordability, efficiency, and stewardship. Some other studies also believe energy security can be condensed as the "low vulnerability of vital energy systems" (Nkundabanyanga et al., 2020). Due to the broad scope of energy security, which is shaped by different regions and historical periods, there is no precise and universally applicable concept of energy security (Chester, 2010). Despite this, the overall focus remains on the security of the energy supply, with availability, affordability, and stability of energy supply being consistent themes in the energy security agenda. Because modern industrial societies rely on fossil fuels, "energy security" is often assumed to refer to the security of fossil fuels. With increasing global demands for carbon reduction, the environmental impact of energy has also become an integral part of "energy security."

This disparity has been exemplified in the discussion on the relationship between energy security and climate–environmental issues. In earlier years, many scholars and policymakers advocated for separating energy and

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climate–environmental problems, focusing solely on specific directly related issues (Pasqualetti, 2011). However, against the backdrop of global energy transformation, energy sustainability has gained unprecedented importance, putting low-carbon energy transition on the energy agenda (Carleton and Hsiang, 2016). Fossil fuel consumption has been a significant source of carbon emissions, and the transition from fossil fuels to clean energy is essential in addressing climate change. The lowered cost and improved efficiency due to the rapid development of renewable energy technology further make the low-carbon transition more than an ethical issue to control global warming. It has become a political-economic problem related to the competition among nations' future energy systems. Worldwide economies have increasingly incorporated climate issues into the energy security agenda (Vogler, 2013). Within the context of energy security encompassing the demand for low-carbon transition, decision-makers must often balance energy supply security and low-carbon transformation. A policy that promotes low-carbon energy transition may potentially exacerbate the vulnerability of the energy system (Brown and Huntington, 2008). Addressing the different facets of energy security while considering its compatibility with climate benefits poses a significant challenge.

Metropolises have the highest concentration of population and economic activities, making them the epicenter of energy consumption. Each metropolitan municipality faces extremely complex energy security challenges. As many metropolises in developing countries expand, their future energy security issues will be even more complex and challenging. The world is undergoing a new wave of energy transformation: from high-carbon energy sources like coal and oil to low-carbon energy sources, primarily renewable ones. The decarbonization of megacities is of utmost importance in this clean energy transition. Thus, this trend brings new questions and challenges to the energy security issues in such areas: How can metropolises meet their current and future substantial energy demands against the clean energy transition? What are the advantages and challenges of clean energy transition in megacities compared to other areas? Also, can clean energy transition in big cities enhance equity, bridge divides, and alleviate poverty in the energy systems? These are all crucial questions that must be addressed during the process of clean energy transition in metropolises and should be considered in energy security research.

The main contributions of this article can be summarized in the following aspects. First, unlike most studies focusing on a global or specific regional/national perspective, this article examines metropolitan areas as the primary subject of energy security. It takes a relatively microlevel approach to investigating the energy security challenges faced by megacities, emphasizing the differentiation among different regions within a single country when confronted with similar energy security issues. Second, we seek to shed light on the influence of political priorities on energy security within the framework of state ownership. Through comparative research, it explores characteristics that arise in megacities' energy security under the logic of political priorities. It also analyzes the implications of such characteristics and their impacts on megacities. Finally, this article also acknowledges that low-carbon energy transition does not necessarily guarantee higher energy justice, contrary to what most studies assume. Instead, the transition may negatively impact energy equity, and the differences in political priorities can lead to varying levels of energy security across different regions during the transition period.

This article will discuss the energy security challenges in metropolises during the clean energy transition by fulfilling the following sections. The next section briefly reviews and analyzes important issues such as energy supply security during the energy transition, urban energy security, and energy justice. The third section focuses on the political divide in energy security. It proposes that political priorities influence urban energy security through the actions of state-owned enterprises driven by political motivations. The fourth section uses the Energy Security and Sustainable Development (ESSD) framework to interpret and summarize Beijing's current energy security situation and problems. The fifth section analyzes the case of Beijing's "coal-to-gas" campaign in 2017 as an example to demonstrate how political logic influences energy security in different regions under the background of the low-carbon transition. The sixth section discusses the path to energy security for metropolises, based on Beijing. It seeks a transitional pathway to better balance and meet broader energy security needs. The last section concludes this article.

2. Literature review

Existing research on clean energy transition and metropolitan energy security has primarily focused on the following 3 areas: security of the energy supply during the energy transition, problems of urban energy security, and energy justice issues. Existing research in these areas provides essential foundational knowledge that serves as the basis and inspiration for this article.

Ensuring the security of the energy supply during the global energy transition has become one of the main directions of energy research in recent years. In the earlier stages, due to insufficient and unaccumulated alternative energy technologies and relatively high costs, energy transition was often seen as a threat to the safety of the energy supply. Concerns included exacerbated energy vulnerability, reduced energy reliability, and an increased reliance on unreliable energy sources (Luft et al., 2010). However, this viewpoint has gradually diminished with the increasing urgency of climate and environmental issues and the sophistication of alternative energy technologies. The positive role of energy transition in energy security has become a mainstream perspective. Constructing a sustainable energy system is one of the primary objectives of energy transition, as it can provide significant public benefits. It prompts energy efficiency, reduces dependence on high-carbon energy sources, and increases the use of renewable energy, thereby offering noncompetitive and nonexclusive benefits to future generations (Karlsson et al., 2012). It also brings greater flexibility to the energy sector,

mitigating the adverse impacts of climate change and ensuring a reliable and timely energy supply (Ellabban et al., 2014). Diversifying energy sources for environmental concerns, reducing overall energy consumption, and increasing the share of renewable energy are key strategies to achieving energy security in the energy transition process (Rabbi et al., 2022). However, while energy policies aimed at mitigating climate change have the potential to reduce carbon emissions and contribute to global warming mitigation significantly, they may potentially have an adverse impact on energy security. This includes exacerbating energy poverty, impeding the development of nontraditional fossil fuel industries, and destabilizing the power system (Luft et al., 2010). Many other studies adopt a relatively optimistic view, arguing that prioritizing energy sustainability and integrating low-carbon transition into the energy security agenda can help achieve energy supply policy goals. These studies generally suggest that long-term decarbonization offers significant benefits to energy security, and low-carbon energy transition implies lower trade volumes and higher diversity in the energy system (Jewell et al., 2014). If one can fully integrate energy, environment, and climate concerns, a proactive climate policy can help alleviate environmental pollution and energy supply issues (McCollum et al., 2013). The energy transition can reduce the demand for fossil fuels. For countries with high energy import dependency, in particular, the energy transition can substantially improve energy security (Gillessen et al., 2019). As long as the potential synergies are leveraged effectively, even more significant benefits can be realized (Bollen et al., 2010).

The energy security issues in cities are closely related to their large population and highly concentrated economic activities. Therefore, improving urban energy security is essential in energy security research. Suppose one continuously integrates urban energy transition with the ever-changing and interdependent aspects of energy security issues. In that case, one will gain a clearer perspective on the transition's extent, types, and impact (Rutherford and Coutard, 2014). The energy consumption of large cities has a significant impact on national carbon emissions and hence warrants greater attention in the carbon reduction process so as to obtain better technologies and more investments. Such factors will prioritize enhancing and improving energy systems in these cities (Dhakal, 2009). Some research has observed that international cities have high energy demand due to their large areas but need more production capacity. Their energy supply often depends heavily on other regions, and the coordination and negotiations involved in cross-regional low-carbon energy transition may increase energy costs (Holley and Lecavalier, 2017). Thus, enhancing energy resilience is considered one of the key ways to achieve urban energy security. Building more resilient urban energy systems helps address various challenges, including climate change, while meeting traditional energy security needs (Sharifi and Yamagata, 2015). Many studies have also recognized that urban energy security and policy issues cannot be considered isolated energy or economic matters. Path and context dependencies arising from historical evolution and the political nature of energy policy significantly shape urban energy issues (Moss, 2014). Despite having a broad consensus on "energy transition," the diverse cultural and political characteristics of different cities can engender pressure from different directions, which would lead to divergent energy policy orientations (Bulkeley et al., 2014; Emelianoff, 2014; Rohracher and Späth, 2014).

"Energy Justice" as a new term first emerged in 2010 as part of the sustainable development discourse (Guruswamy, 2010). Benjamin K. Sovacool defines it as the equitable distribution of the benefits and costs of energy services, along with inclusive and fair decision-making processes in the global energy system (Sovacool and Dworkin, 2015). It typically encompasses 3 main components: distributive justice, procedural justice, and recognition justice (Walker and Day, 2012). Energy issues were once considered value-neutral topics, as different stages of the energy supply chain did not involve ideological judgments. However, with the expansion of energy systems worldwide and the acceleration of energy transient, energy issues as ideological value have become an integral part of energy research. Discussing the global energy system based on energy justice principles has become a shared choice among countries (Jenkins et al., 2021). Ensuring access to energy consumption is a prerequisite for a dignified life in modern society. This inevitably raises issues of fairness in energy distribution and the allocation of public burdens, highlighting the value dimension of energy (Melin et al., 2021). Addressing "energy poverty" is a crucial objective in achieving energy justice. Energy transition contributes to the redistribution of energy benefits by selecting appropriate energy combinations from a broader range of energy sources—beyond just a few fossil fuels—to meet different regions' and populations' specific energy needs (Jenkins et al., 2016). From a broader perspective, energy transition is also a necessary requirement for inclusive development, helpful to fulfill the dual values of growth and equality, thereby achieving the goals of energy justice (Rauniyar and Kanbur, 2010). Furthermore, the climate and environmental benefits resulting from energy transition can generate global advantages. Controlling global climate change itself is an issue of significant ethical importance (Hayward, 2012). Therefore, fundamentally changing the existing energy order by transitioning from fossil fuels to low-carbon energy is a foundational pathway to achieving energy justice (Healy and Barry, 2017).

The research findings from the 3 perspectives above demonstrate that the relationship between energy transition and energy security has received extensive scholarly attention. The role of energy transition in promoting energy security, the peculiarities of urban energy security, and the requirements for "energy justice" have formed the basic consensus in research. However, there are still several shortcomings in the current research of urban energy security issues during the energy transition.

First, most energy security research focuses on the macrolevel at the global, regional, or national scale, where countries are often treated as homogeneous units.

However, viewing countries as such entities is a joint research fallacy in political science (Peters, 1998). The energy situation within a country can vary significantly, and a homogenized approach neglects the heterogeneity within a nation, leading to research biases. While there is a considerable body of research on specific cities or regions, most remain descriptive or purely technical, often overlooking these cases' natural and political contexts. As a result, relevant studies tend to be overly broad. The urban energy transition is neither a singular, universal, nor linear path toward achieving a "zero-carbon" city. It exhibits context-specific characteristics that vary by location and time, which can profoundly influence cities' low-carbon transition pathways and energy security (Rutherford and Coutard, 2014).

Furthermore, while some studies have started to address the political implications of energy security, most research has not treated political factors as primary variables in the study of energy security. Existing research has demonstrated that cities' historical and cultural characteristics and their host countries' political attributes significantly influence their pathways to urban energy security. In studies related to large cities, spatial inequalities between the "core" metropolitan areas and the "periphery" have been growing (MacLeod and Jones, 2011). This heterogeneity highlights the influence of the "center-periphery" divide issue on urban research. The dynamics of local political discourse and power relations have significant implications for urban energy issues (Huang and Broto, 2017). Therefore, it is crucial not to overlook political variables when examining energy security. Furthermore, it is necessary to understand how political factors shape urban energy security policies. Important questions to consider include how political environments influence urban energy security policies and which factors influence the energy security policies of cities in different political contexts. Only by addressing these issues can we gain a deeper understanding of urban energy security.

Finally, while there is abundant research on urban energy security, the focus has been predominantly on developed countries, with relatively less attention given to cities in developing countries. Even within the limited samples of research on cities, the research concentrates on a few world-class and Western metropolitan cities. This tendency overlooks the energy security issues that most developing countries and peripheral regions face. It also neglects the roles of nongovernmental entities outside city governments (Verdeil, 2014). Ignoring the regional disparities within a country and the varying policy treatments weakens the persuasiveness of the research. Comparative studies with other regions become neglected by focusing on densely populated central cities with well-developed infrastructure and a higher priority. This approach fails to represent a country's entire energy security landscape. It overlooks the unique energy security issues stemming from the political status and policy treatment of metropolitan areas compared to other regions.

To address these issues in the current literature on energy security and transition, this study adopts the ESSD framework, which analyzes energy security in 3 dimensions: social, economic, and environmental. It examines the availability, accessibility, affordability, acceptability, and governance of energy. Compared to the traditional energy security framework, ESSD not only focuses on the short-term material benefits of energy security but also considers the inter-temporal and inter-generational distribution of existing resources, thereby accommodating longer term and more extensive energy security issues (Indriyanto et al., 2010). Overall, such a framework sufficiently considers the environmental impacts on energy security, balances short-term and long-term goals, and emphasizes the benefits of sustainable energy development. It aligns with this article's focus within the energy transition context.

3. The political divide in energy security: Urban energy transition and energy security

As some of the most concentrated areas of energy consumption, the energy system transformation of cities is a key target, as well as a crucial "tool" for the energy transition (Rutherford and Coutard, 2014). Urban energy systems have aspects that are both relatively advanced and highly vulnerable. The energy transition is inevitable in enhancing the sustainability of energy systems. However, energy transition itself is an iterative energy consumption process, and its primary objective is improving energy systems' sustainability. Nevertheless, the notion of a perfect seamless iteration does not exist in reality, and energy transition is bound to have varying impacts on the energy supply security of metropolises during specific periods.

Based on the ESSD framework adopted in this article, potential threats to urban energy security from energy transition include energy supply disruptions, rising prices, and inadequate governance. When these risks become a reality, they can have severe consequences for cities and, subsequently, the entire nation. For example, skyrocketing electricity prices in certain countries can increase energy costs, while frequent power outages due to aging power systems can cause substantial economic losses. "Energy transition" is a concept that encompasses multiple dimensions and diverse needs. Aiming to enhance the sustainability of energy systems by executing the energy transition brings benefits and new risks. Even when only considering the requirements of energy transition and sustainability, many policies exhibit dualities. For instance, policy biases favoring domestic renewable energy products can undermine market competition and delay the deployment of renewable energy infrastructure. Similarly, measures to replace coal with relatively cleaner natural gas can deepen a nation's dependence on specific natural gas exporters.

When addressing energy security issues against the backdrop of the energy transition, it is evident that the policies of different countries, regions, and cities are not driven solely by rational economic thinking. They are influenced by various political and cultural factors, resulting in significant differences even within the same overarching direction of the energy transition. Large cities often hold a higher political status and priority, allowing them to transcend the constraints of pure market logic. Even during periods in which there are national energy

supply disruptions, they can secure prioritized energy resources to avoid catastrophic consequences. To explain the energy security issues in large cities, it is necessary to consider relevant political variables, including the political logic of state-owned enterprises and cities' hierarchical and political statuses. This article argues that governments prioritize energy security concerns across different regions, expecting that state-owned energy enterprises should first meet the higher-priority energy demands of certain regions, according to the rational logic of decision-making. This prioritization is the leading cause of the political divide in energy security.

Specifically, this article argues that state-owned energy enterprises prioritize the needs of the government over profit objectives when facing energy security issues. As shown in **Figure 1**, the varying political priorities across different regions are the leading cause of the energy security prioritization problem.

State-owned enterprises are crucial pillars of many countries' economies, where the government acts as both the main shareholder and regulator, holding real control over these enterprises. Legal governance and political governance coexist in the operation of state-owned enterprises (Wang, 2014). These enterprises have multiple objectives, including profit maximization and political, social, cultural, and income distribution goals (Zif, 1981). Their role in transferring welfare to specific groups is crucial, known as "social welfare contributions" (Avsar et al., 2013). While profitability remains a natural objective for enterprises, the additional responsibility imposed by their state ownership often leads to conflicting demands. Regarding significant strategic issues like energy supply security, profit-oriented goals are often subordinated to political requirements because state-owned enterprises are subject to the government's soft budget constraints. The government utilizes these constraints to incentivize and reward state-owned enterprises for behavior that aligns with national requirements (Chow et al., 2010).

For the government, state-owned enterprises are essential to the state's economic intervention and participation. The government can utilize them to address market failures and implement public interest policies (Huang and Jing, 2006). Therefore, the behavior of state-owned enterprises in the energy sector often reflects the government's will, sacrificing the short-term economic interests of specific enterprises to achieve policy objectives in other areas. This is particularly evident in many developing countries, where large state-owned enterprises are established to manage the national energy system, driven by objectives such as increasing tax revenue, promoting energy development and exports, and anti-imperialism and anti-colonialism (Song and Zou, 2020). In these countries, the logic and behavior of state-owned enterprises are more pronounced.

As mentioned earlier, other aspects of energy security may be negatively affected during the energy transition. In countries where state-owned enterprises dominate the energy system, political logic tends to prevail when faced with the dilemma of energy security. The government will

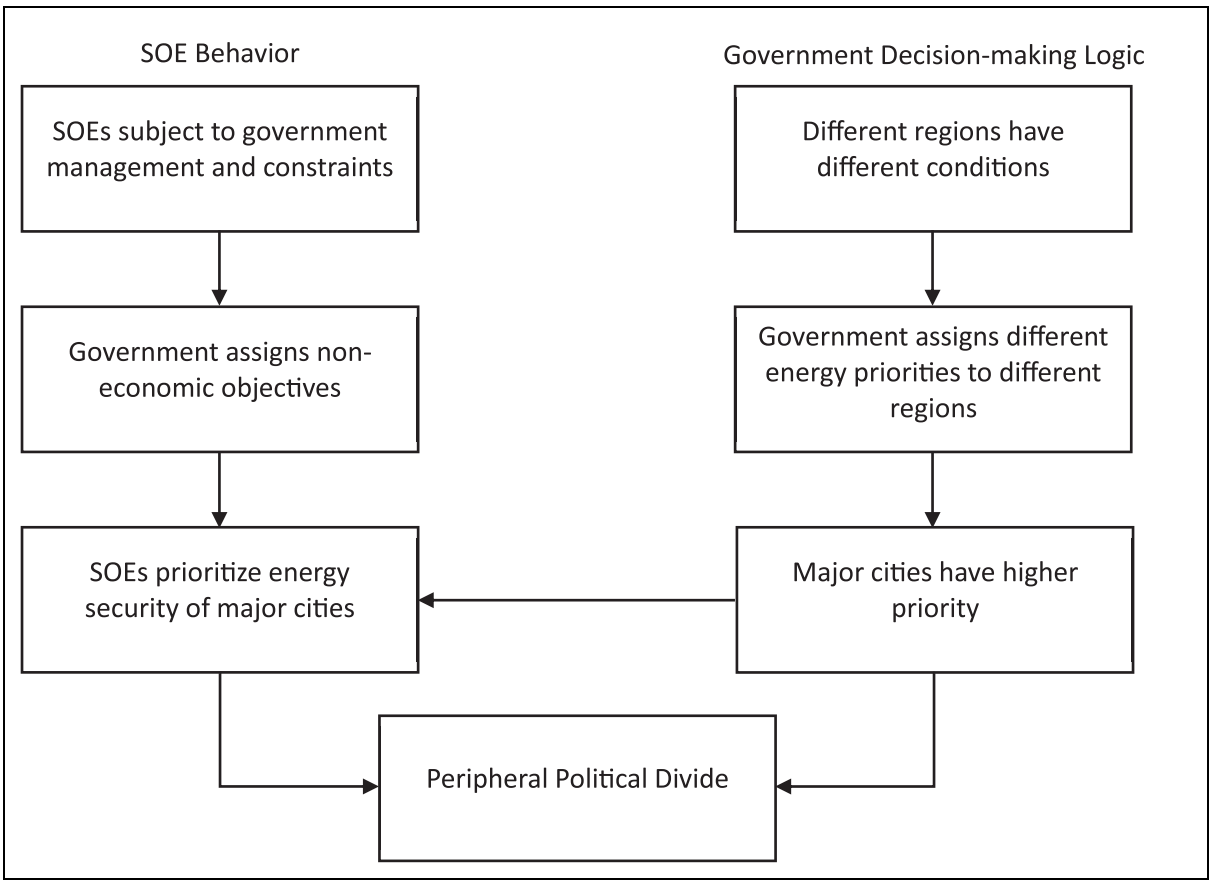

Figure 1. The causal mechanism and hypothesized logic of the political divide in energy security.

require state-owned enterprises to make politically, rather than economically, rational decisions based on the overarching political agenda. Major cities, benefiting from their political advantages, often become the priority for protection when energy becomes scarce. State-owned enterprises must focus more on these strategically important areas, even at the expense of profitability.

Influenced by the government's political calculations, state-owned enterprises will often shoulder higher energy supply costs and prioritize metropolises' energy demands with lower prices. Although this can indeed allow the major cities to have a higher level of energy security, the energy availability and affordability in peripheral regions will be negatively impacted. In terms of availability, even if the surrounding areas are willing to pay higher prices or have higher energy demands, they still need to adhere to the political logic of "major cities first." In terms of affordability, major cities that have higher concentrated energy consumption often only need to pay lower costs for higher levels of energy security, resulting in significant economic losses for state-owned enterprises in those areas. From the perspective of enterprises or local regions, the behavior of state-owned energy enterprises indeed appears to violate the requirement of economic rationality, leading to a decline in profits. Behind these decisions that contradict local economic rationality is the government's comprehensive consideration of political, economic, and social demands, with the conclusion that prioritizing the interests of major cities is more conducive to the overall national interests. Therefore, in such countries, careful consideration of energy security issues during the energy transition cannot ignore the influence of political logic on the behavior of state-owned enterprises. Especially when the energy transition process has exposed energy security issues, the influence of political logic far outweighs direct economic rationality.

Almost all governments claim to treat all regions and citizens with equal standards. However, objective differences in political priority between regions exist in realistic political agenda settings and significantly influence regional energy security. Every country's major cities serve as political and economic centers, with high energy consumption and well-developed energy systems. Thus, they are a significant source of carbon emissions in modern nations (Dodman, 2011). In contrast, other regions have relatively more dispersed populations and economic activities. The wealth generated by a few major cities and their role in political and social stability far outweigh that of the other regions. This privilege bestowed upon these central cities often grants them "special rights" in energy matters, allowing them to have prioritized access to advanced energy technologies and sufficient energy supply under similar conditions.

At the same time, the energy security issues of other regions, particularly rural areas with lower priority, are relatively neglected. This is reflected in lower power reliability and a higher probability of power interruptions than in major cities, lower prioritization for energy system upgrades and iterations, and relatively lower energy efficiency. Especially when the country's energy security is compromised, and difficult choices must be made, prioritizing the energy security needs of a few significant cities aligns with economic and political requirements. Economically, this choice can reduce the loss of economic benefits, while politically, it can mitigate the political and social risks associated with energy security issues. In this scenario, a political divide arises in energy security, where the limited overall resources of the country lead to prioritizing and accommodating the energy security needs of major cities.

Even though such decisions based on political priority may align with the requirements of rational decision-making, they may impact the achievement of energy justice. From a fairness perspective, the energy transition inevitably affects the energy supply security of many regions, and placing significant security risks on peripheral regions may lead to energy poverty in these areas. Energy poverty refers to the lack of access to sufficient, affordable, reliable, high-quality, safe, and ecologically friendly energy services, which hinders economic and human development (Reddy, 2000). The energy transition can potentially reduce the energy supply security in certain regions. From the government's point of view, prioritizing energy security for metropolitan areas can indeed bring more wealth, reduce political and social risks, and subsequently offset the losses in noncore areas region through the benefits brought by urban energy security, such as providing subsidies and improving energy acquisition channels. However, this idealized scenario also needs to be realized through practice measures. Therefore, it is necessary to find a path that, while prioritizing the energy security needs of major cities due to their political significance, maximizes the consideration given to the other regions while minimizing the impact on their energy security within the broader environment of the energy transition. This has become a part of the energy security agenda in the context of urban energy security within the broader environment of energy transition.

In summary, major cities' energy security issues are economic and political. Merely examining economic factors is insufficient to explain a series of energy security phenomena that deviate from economic rationality, such as major cities constantly receiving higher energy security priorities at lower prices. It is also necessary to consider it from the perspective of political logic and give full attention to the specific status of major cities in the national energy security agenda, especially their unique role in national political stability and economic development. Only then can we truly understand the various characteristics of energy security in major cities; only then can we also discover more realistic and compelling insights into energy security in major cities during the energy transition. Although this political divide may facilitate the simultaneous achievement of clean energy transition and energy supply security goals in major cities, it would inevitably affect the energy security of other regions. From the viewpoint of the central government, such trade-offs align with the economically rational requirement of maximizing the overall national interests, that is, at the expense of energy security in noncore areas, prioritizing the energy demands of core areas. And the benefits to the core areas

will outweigh the damage suffered by noncore areas. However, striving to eliminate the adverse impacts on other disadvantaged regions is still necessary to achieve the goal of "energy justice." To grapple more fully with the energy security in major cities, it is essential to examine major cities together with the surrounding regions that suffer from compromised energy security.

4. Energy security issues in Beijing in the context of clean energy transition

The CPC Central Committee and the State Council have designated Beijing as China's political, cultural, international exchange, and technological innovation center (State Council, 2017a). As of the end of 2022, Beijing had a permanent resident population of 21.843 million. It is a classic metropolis and indisputably holds the highest priority among regions in China. To achieve the energy security goals outlined by the ESSD framework, it is necessary to comprehensively consider energy supply security, carbon reduction, green energy usage expansion, reduction of traditional fossil fuels, and air quality improvement. Specifically, in the ESSD framework, energy security issues in Beijing can be analyzed from the following 5 perspectives.

4.1. The availability of energy resources in Beijing

In terms of the composition of energy consumption, based on 2022 statistics, Beijing's total energy consumption amounted to 68,968,900 tons of standard coal. Among these, as shown in **Figure 2**, natural gas had the highest proportion at 38.92%, followed by electricity at 32.65% and petroleum at 23.06%. Coal accounted for only 1.02% of the energy consumption, indicating a significant decline in its share. With the implementation of government-driven projects to reduce pollution and carbon emissions, such as the energy conversion program known as the "coal-to-gas," the demand for natural gas in Beijing has rapidly increased.

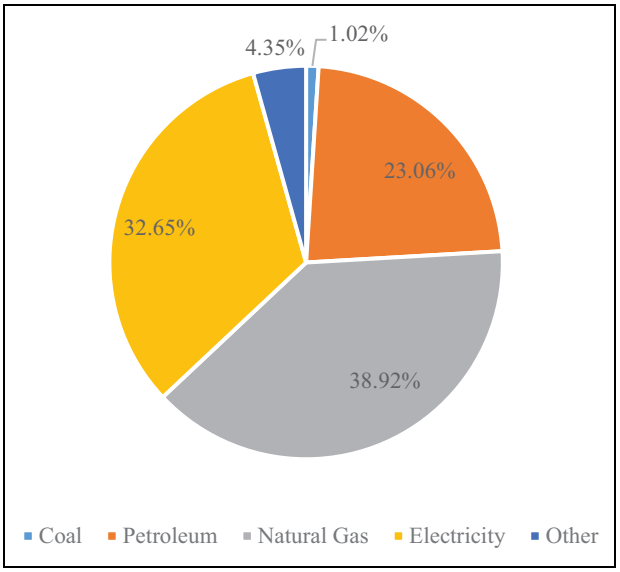

Figure 2. Composition of Beijing's 2022 energy consumption. Graphed according to the data published by the Beijing Bureau of Statistics (http://www.bjstats.gov.cn/), accessed March 31, 2024.

It has become the primary energy source for heating in Beijing. As displayed by **Figure 3**, in 2022, the city's natural gas consumption reached approximately 19.911 billion cubic meters and became the top source of the city's energy consumption. The number of gas users in residential areas reached 9.73 million households, with a nearly 100% residential gas penetration rate. These positive measures have significantly diversified Beijing's energy system and reduced overreliance on a single energy source.

As China's capital city, Beijing has a well-developed energy infrastructure and abundant investment. As a result, its energy supply stability is kept at a high level. In 2023, the reliability rate of power supply in Beijing is as high as 99.997%, a leading level domestically. The supply of other energy products, such as natural gas and refined oil, is also very consistent. Beijing is experiencing almost no foreseeable risk of power supply interruption.

Beijing's accessibility issues concentrate on environmental availability. Although Beijing has shut down all thermal power plants and moved out many energy-intensive enterprises from within the city limits, this improvement is more of a geographical transfer of environmental costs. Beijing's electricity supply is still highly dependent on thermal power generation in other regions, and its overreliance on coal has not been fundamentally resolved, either. For this reason, *Beijing's Energy Development Plan for the 14th Five-Year Plan Period* has clearly defined the direction of energy transformation as "reducing coal, stabilizing gas, reducing oil, strengthening electricity, and increasing green." It strives to increase the proportion of renewable energy to over 14.4%. By 2025, Beijing's local newly installed capacity of renewable energy will increase to about 2.17 million kilowatts (kW), reaching a total of about 4.35 million kW, accounting for about 28% of the city's installed power generation capacity (Beijing Municipal People's Government, 2022). This policy also reflects Beijing's pursuit of diversity in its energy mix.

4.2. The accessibility of energy in Beijing

Beijing is not rich in terms of natural resources. It mainly relies on imports and cross-regional allocation of resources to maintain essential supplies. All the natural gas and oil resources and 70% of electricity come from other regions. Beijing's energy productivity itself is meager, far from meeting consumer demands. The city's primary energy sources are coal transported from major coal-producing provinces such as Shanxi and Inner Mongolia, crude oil deployed from oil fields in Northern China, or imported through ports such as Tianjin. Even its problem of urban water supply is mitigated by the "South-to-North Water Diversion" project. This severe imbalance between output and supply directly leads to Beijing's extremely high dependence on foreign energy. With the support of high policy priorities, Beijing's energy security can always be prioritized, even during energy security disruptions. Even so, Beijing has prioritized energy transition in its energy policy, especially when the renewable energy transition can enhance local energy production capacity.

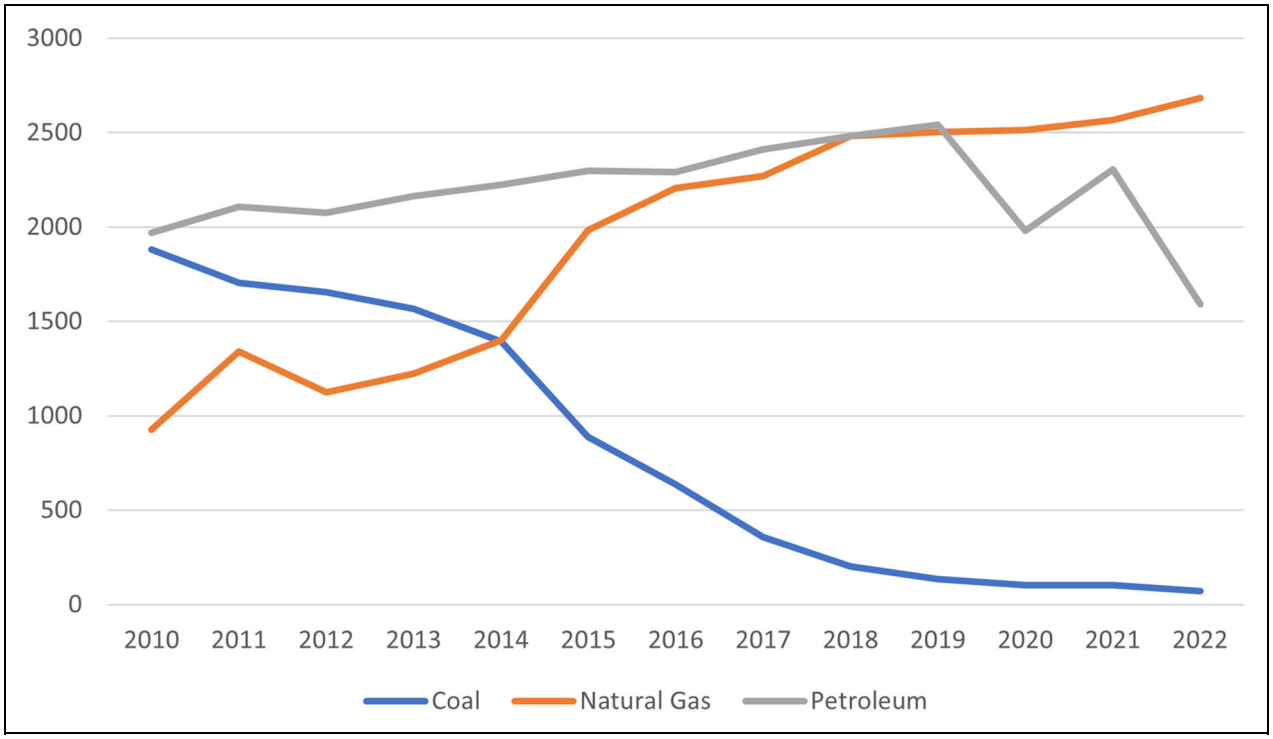

Figure 3. Beijing's coal and natural gas consumption 2010–2022. (Unit: 10,000 tons standard coal.) Graphed according to the data published by the Beijing Bureau of Statistics (http://www.bjstats.gov.cn/), accessed March 31, 2024.

Historically, Beijing has been a coal-producing area. However, due to concerns such as air quality and environmental protection, the city's coal production has declined to zero by 2020. At the same time, Beijing has been actively expanding its sources of natural gas as its dependence on natural gas has increased. Beijing mainly supplies the required natural gas through the Shaanxi-Beijing First, Second, and Third Pipelines, Datang Coal-to-Gas Pipeline, Tangshan Liquified Natural Gas (LNG) Pipeline, and the Russian Natural Gas Pipeline. Meanwhile, the Dagang gas storage group also provides natural gas resources for Beijing. Thus, Beijing's energy access channels have become quite diverse with these different channels. As Beijing's power generation capacity is increasingly dependent on natural gas and global warming leads to higher temperatures in summer, the traditional winter peak season for natural gas demand has also changed. In contrast, the demand for natural gas in summer continues to increase.

By 2023, Beijing's energy availability was relatively well guaranteed. The country's substantial policy preference for Beijing has made Beijing a vital destination for major energy transportation channels. In addition, there have been no severe natural disasters in and around Beijing in recent years, which has mostly allowed Beijing to keep its energy supply channels open. The threat to Beijing's energy availability mainly comes from the following aspects. On the one hand, the surrounding areas of Beijing are quite mountainous and located in the North Chinese earthquake zone, so the risk of geological disasters remains relatively high. Too much reliance on the external natural gas supply may aggravate Beijing's energy resources when such disasters occur. On the other hand, while Russia is one of Beijing's primary sources of natural gas, the outbreak of the Russia-Ukraine conflict has intensified Russia's geopolitical risks, and its ability to maintain natural gas infrastructure has declined.

4.3. The affordability of energy in Beijing

Both natural gas and heating prices in Beijing are at the intermediate level of the country. In July 2023, the first tier (less than 350 cubic meters) of progressive residential gas prices in Beijing was 2.63 yuan per cubic meter, the second tier was 2.85 yuan, and the third was 4.25. In terms of heating, in 2022, the price of civil heating supplied by Beijing's extensive network amounts to 24 yuan per square meter of building per heating season. The price of civil heating supplied by an independent network is 30 yuan per square meter of building per heating season for oil, gas, or electric boilers. The price of nonresidential heating is 40.5–45 yuan per cubic meter of building. The proportion of energy consumption costs in residents' daily lives remains relatively low. For example, with government subsidies on rural and urban natural gas usage, the average annual heating costs in 2018 accounted for 1.3% of Beijing citizens' average disposable income (Liu, 2017).

In terms of traffic regulation, to encourage the purchase of alternative energy vehicles, Beijing provides a subsidy of 8,000–10,000 yuan for car owners who wish to replace their old cars with alternative energy ones. In addition, unlike the lottery system used to register for traditional gasoline vehicles, Beijing's alternative energy vehicles adopt a "queueing" approach. Although the latter

has a long waiting cycle—as of March 2023, more than 400,000 individuals and 170,000 families are in queue—compared to the 0.03% success rate of the lottery system, the queueing system helps to encourage Beijing citizens to buy alternative energy vehicles. These policies ensure residents' energy costs remain lower and promote Beijing's low-carbon transformation process.

It should be noted that the guarantee of Beijing's energy affordability still relies on a supply structure dominated by fossil fuels and government-subsidized energy consumption. Because of these subsidies, the Beijing municipal government can complete the "coal-to-gas smoothly" initiative, allowing citizens to switch to higher-priced natural gas. Even so, due to China's high dependence on foreign natural gas of 40.5% (based on 2022 data) and the continuous increase in global natural gas consumption, Beijing's energy cost remains in an upward trend. The natural gas price in July 2023 was the result of an increase of 0.35 yuan per cubic meter. If Beijing hopes to achieve greater environmental benefits of energy in order to achieve the goal of low-carbon transformation of its energy system, such as replacing natural gas with more renewable energy sources, then its costs may also further increase, reducing the affordability of Beijing's energy.

4.4. The acceptability of Beijing's energy

Beijing's energy acceptability has gone through a long process of improvement. As an ancient city with lots of history, Beijing has a large area of dated constructions, represented by "hutongs (胡同)," and many old residential areas with outdated infrastructure. After several rounds of citywide renovation, the energy acceptability goal in the urban areas of Beijing has been achieved, with centralized heating systems widely used in different sectors. By 2021, the area of centralized heating exceeded 98%, eliminating the usage of small coal stoves for heating. To improve residential electricity conditions, Beijing has done multiple periodical refurbishments to the power equipment in old residential areas to improve the power system's safety and efficiency. As of the beginning of 2023, most regions in Beijing have established relatively cleaner and more efficient energy systems, and as a result, even the most vulnerable demographic groups in the city can enjoy good benefits. In addition, to improve Beijing's energy and environmental conditions, the city repeatedly forced the relocation or closure of heavily polluting enterprises. For example, the Capital Steel Corporation (首钢; Shougang) was moved to Tangshan, and many inner-city thermal power plants were closed. These efforts have significantly improved the environment of Beijing.

However, there are still many challenges to Beijing's energy acceptability. First, excessive clustering of high energy consumption and pollutive industries in the Beijing–Tianjin region still exists. With severe air pollution and multiple other sources of contamination prevalent in its surrounding areas, Beijing can hardly remain immune. Second, motor vehicle exhaust emissions have become the primary source of PM2.5. In 2022, the number of motor vehicles in Beijing has reached 53 per 100 households and is still rising. Motor vehicle exhaust remains a major challenge for Beijing in addressing energy acceptability. Third, the high proportion of fossil fuels remains a significant energy security issue in Beijing, especially with limited local renewable energy potential. Furthermore, there is limited room for further improvement in fossil energy efficiency, which limits Beijing's capacity to continue to improve energy efficiency.

4.5. The governance of Beijing's energy

In terms of institutional arrangements for energy transformation and security, Beijing has always been in a leading position in China with solid energy governance capabilities, allowing Beijing to balance the needs of clean energy transformation and energy security. During the 13th Five-Year Plan period, the reduction rate of carbon dioxide emissions intensity in Beijing reached over 23%, dropping to 0.42 tons per 10,000 yuan of GDP. This is among the top level of success across the provincial-level regions in China, exceeding the nationally planned goal of reducing by 20.5%.

After China proposed the "Dual Carbon (双碳; Peak Carbon Dioxide Emissions and Carbon Neutrality)" goal, Beijing responded to the national policy and proposed the *14th Five-Year Plan for Energy Development in Beijing.* The document comprehensively summarized the energy transformation issues during Beijing's 14th Five-Year Plan period, emphasizing that "enhancing energy security capabilities and accelerating green and low-carbon transformation are equally important, with the construction of a strong, resilient, green, low-carbon, smart capital energy system as the main line of development throughout" (Beijing Municipal People's Government, 2022). Beijing has also proposed more specific plans for each industry, such as *the Implementation Plan for Peak Carbon Dioxide Emissions in Beijing*, *the Action Plan for Green and Low Carbon Development of Manufacturing Industry during the 14th Five-Year Plan Period in Beijing*, and *the Low Carbon Pilot Work Plan for the 14th Five-Year Plan Period in Beijing.*

To achieve the "Dual Carbon" goal, Beijing has established a task force, led by the Deputy Secretary of the Municipal Party Committee and the Mayor, to drive relevant departments to coordinate the "Dual Carbon" work. By forming a leadership group, Beijing's clean energy transformation initiative will not be easily constrained by hierarchy and leadership authority and can better integrate multiple forces to achieve the same goal to the maximum extent, thereby significantly improving administrative efficiency. This is a common organizational approach in China's political life when addressing significant issues. It has also been proven that this approach is practical and has successfully driven comprehensive participation from the government, enterprises, social groups, and individuals. It is an important reason for Beijing's good governance performance.

By examining various dimensions of the ESSD framework, it can be found that Beijing has effectively ensured local energy security issues during clean energy transformation, achieving both environmental benefits and energy supply security, as well as the sustainable development goals in energy issues. This is undoubtedly a remarkable achievement for a metropolis like Beijing. Thus, it is worth asking why Beijing can balance so many goals

simultaneously. At the same time, the cost of achieving Beijing's energy security goals also needs to be included in the scope of examination: Beijing is the city with the highest political priority and the most abundant political resources in China, and Beijing's achievements also benefit from this preferential treatment. Therefore, in assessing Beijing's clean energy transformation and security issues, it is necessary to consider other regions that bear the costs to outline a complete picture of Beijing's energy security.

5. Ensuring Beijing's energy security under the 2017 "coal-to-gas" plan

Although Beijing is committed to consolidating its energy security while promoting the clean energy transition, its consolidation effect can only be thoroughly examined when an energy crisis occurs. Just as the 1973 oil crisis brought serious energy security threats to the United States and Western European countries, the natural gas crisis in northern China at the end of 2017 would be the most severe energy disruption to Beijing and even the whole of China in recent years. In 2017, 37.94% of China's natural gas depended on external sources. While this number is far lower than that of petroleum (69.95%), the long-term contractual requirement of natural gas trade, a severe shortage of oceanic shipping capacity, and seasonal surge in usage demand all indicate that China's main battlefield for maintaining energy security is in the natural gas sector rather than the oil sector (British Petrol, 2018).

Since September 2017, the "coal-to-gas" movement pushed by Chinese local governments and the instability of Turkmenistan's natural gas supply have led to a severe large-scale supply shortage of natural gas, which was already in a "tight balance" of supply and demand. On the demand side, to fulfill the requirements outlined in the *Action Plan for Air Pollution Prevention and Control*, the *Action Plan for Comprehensive Control of Air Pollution in the Beijing–Tianjin–Hebei and Surrounding Areas*, and other documents, local governments made unprecedented efforts to promote the "coal-to-gas" project in 2017. Under this effort, they completed the replacement of coal-fired boilers for over 3 million households in rural areas. While effectively reducing loose coal combustion and pollutant emissions, it significantly increased the demand pressure for natural gas (State Council, 2013; Ministry of Ecology and Environment, 2017). It is worth noting that "coal-to-gas," as a top priority in the transformation of clean energy, has been placed on the prioritized agenda of the governments of Beijing and the neighboring Tianjin–Hebei area. Although the "coal-to-gas" movement has caused a shortfall in demand for natural gas heating, its impact on China's energy security is relatively limited (Song, 2018).[1] In fact, the more significant threat to China's energy security does not lie in the growth of demand caused by internal policy incentives but in the sudden drop in supply caused by external supply instability.

On the supply side, Turkmenistan's unstable natural gas supply and a sudden drop in gas supply have rapidly imposed risks on the energy security situation in China. Turkmenistan's natural gas has always been regarded as the "ballast stone" of China's natural gas security. Statistics show that in 2017, Turkmenistan's natural gas accounted for 80.47% of China's imports through pipelines and 34.46% of China's total natural gas imports. It can be said that it is of great significance to China's natural gas security (British Petrol, 2018). However, since November 2017, Turkmenistan's natural gas has been disrupted due to multiple equipment failures in Turkmenistan's National Konzen, and the Central Asian natural gas pipeline, known as the "artery of China's natural gas imports," has seen its gas transmission volume plummet by nearly 50%. PetroChina, responsible for the pipeline operation, even warned that the pipeline network was in danger of collapse, and the situation remained unchanged until February 2018. This significant decline in natural gas supply in Turkmenistan has caused an irreparable supply and demand gap. Taking December 2017 as an example, the daily average supply gap of natural gas for that month was as high as 6.4%, with the highest exceeding 14.1%. After this sudden drop, the price of liquified natural gas in China doubled within a week; natural-gas-powered taxis and buses were extensively shut down; some cities in the Northwest cut off heating during noontime to save energy; factories that use natural gas as a fuel or raw material were required to limit or even completely shut down production; and the total domestic natural gas reserves had also fallen below its lowest level in history (Song, 2018). It can be said that the situation caused by the instability of the natural gas supply from Turkmenistan is exceptionally severe, and the shortage of natural gas poses a serious threat to China's energy security.

This threat is even more daunting and urgent for Beijing and Hebei Province, which vigorously promotes the "coal-to-gas" movement. The energy security of Beijing and Hebei Province in all dimensions under the ESSD analytical framework has been severely threatened. In terms of availability, physical supply interruptions due to the reduction of natural gas supply have become an imminent threat; in terms of availability and affordability, the risk of rising gas prices is more prominent due to the imbalance between supply and demand. The governance of energy security has also been made difficult as both national and local governments are facing their first significant challenge after the comprehensive implementation of the "coal-to-gas" policy. It is necessary to shift the governance model that was oriented to the reliance of residents on domestic coal and gas for their heating needs, toward a reliance on imported natural gas.

Faced with the increasingly severe natural gas supply and demand situation, the Chinese government and major energy companies have jointly taken multiple response measures, with the latter playing a very positive role. Since October 2017, the National Development and Reform

1. The reason is that on the one hand, the "coal-to-gas" movement mainly affects household heating in rural areas of Northern China, and the affected areas and industries are relatively limited. On the other hand, the negative effects brought about by the "coal-to-gas" movement can be alleviated to a certain extent through policy adjustments (Song, 2018).

Commission (NDRC) and the National Energy Administration (NEA) have entered an emergency duty state to ensure natural gas supply, issuing a series of important notices and documents such as the *Notice on Safeguarding the 2017 Winter Season Natural Gas Peak* to mobilize and guide local governments to reverse the "coal-to-gas" actions (NDRC, 2017). However, a pullback or suspension of the movement can only suppress the growth of natural gas demand, and the local governments lack effective policy tools to cope with natural gas shortages.

In contrast, expanding the scale of natural gas supply by major energy companies has been proven to be a feasible and effective measure to address the shortage. To this end, the NDRC convened the heads of 3 major Chinese energy companies—China National Petroleum Corporation (CNPC), China Petrochemical Corporation (Sinopec), and China National Offshore Oil Corporation (CNOOC)—and required them to make every effort to "tap into the potential to increase production, implement spot procurement of liquified natural gas (LNG), achieve resource mutual assistance and the south-to-north gas transfer, as well as leveraging the peak shaping role of large nonresidential users" (Li, 2017; State Council, 2017b). China's major energy companies responded quickly to the government's call to ensure natural gas supply. They took the main responsibility of handling the shortage of natural gas according to the outlined instructions.

Under the coordination of the NDRC and the NEA, PetroChina, Sinopec, and CNOOC have taken several actions to address the natural gas shortage. For example, they supplied natural gas to downstream companies beyond the agreed scale of their existing contracts; they prioritized the residential natural gas supplies to protect residents' needs over nonresidents (State Council, 2017b; Sinopec, 2018); they purchased spot natural gas from the international markets at high prices and sold it to downstream gas companies at lower prices (State Council, 2017b; CNPC, 2018); they ensured the supply of northern China through mutual assistance and protection. Overall, in response to the natural gas supply shortage at the end of 2017, primary energy companies in China have taken on important responsibility for maintaining energy security and played a positive role as a mainstay. When summarizing the experience of success in responding to the natural gas shortage of 2017, the director of NDRC pointed out: "A very important thing is the sense of duty of state-owned enterprises at critical moments…several major gas suppliers have demonstrated the overall situation consciousness and responsibility consciousness in the process of guaranteeing supply," which can ensure that China is "safe and sound" in dealing with the surging natural gas shortage (State Council, 2018a).

While the northern regions of China eventually weathered the gas crisis, the costs borne by different cities were very different. As the capital and the most crucial metropolis in northern China, Beijing was undisputedly included at the center of the energy security and safety initiatives. Li Yalan, President of the International Gas Union and the Chairman of Beijing Gas Group, pointed out that Beijing's natural gas consumption jumped to 16.4 billion cubic meters in 2017, raising its share of natural gas in its primary energy consumption to about 32%. Beijing's annual gas consumption ranks second among the world's cities, after Moscow. It can even be said that natural gas has become the "lifeline" of Beijing's energy sources. Beijing's natural gas consumption approached 95 million cubic meters per day during the cold snap in November 2017, and it has since stabilized at 82–86 million cubic meters per day. Most of this consumed gas is for heating (State Council, 2018b). Despite the unstable supply of natural gas from Turkmenistan and the apparent increase in the demand for heating in Beijing, Beijing Gas Group still confidently declared that "the supply of natural gas in Beijing is still sufficient." From the public's perspective, the residents of Beijing had not felt the negative impact of the gas crisis on their lives.

However, the natural gas crisis affects the provinces and cities surrounding Beijing due to the objective "political divide" that exists. On the one hand, rural areas in northern China cannot afford the high cost of heating their homes with natural gas as opposed to cheaper bulk coal. Even though local governments have provided subsidies, the price of subsidized natural gas is still much higher than coal. A resident pointed out that "my house has an area of more than 150 square meters, and if I burn coal for heating, I use about 2.5 tons of coal, which according to last year's prices, costs about 1500 yuan after subsidy. After switching from coal to gas, the average daily cost is more than 40 yuan, which is about 5000 yuan for a heating period. Even with the subsidies, you must pay about 4000 yuan" (Qi, 2017). The high cost of natural gas makes people around Beijing choose not to use it for heating even if they are freezing. On the other hand, tight natural gas supplies are prioritized for delivery to Beijing by major state-owned enterprises such as PetroChina. Critical studies have found that Beijing is the central "gas-sucking vortex" in northern China. To ensure the stability of their supply, gas from the West-to-East pipeline and Bohai Bay LNG imports must be prioritized for Beijing. At the same time, the rest of the small- and medium-sized cities are forced to make painful sacrifices. According to incomplete statistics, Baoding, Shijiazhuang, Luanchuan, and Qingyun have all suffered complete gas shutoffs in the industrial sector and limited-time gas supplies in the residential sector (Qi, 2017).

In summary, Beijing minimized the impact of the 2017 gas crisis with a massive boost from major state-owned energy companies prioritizing gas supply. The gas crisis did not significantly impact Beijing, which has been pushing its "coal-to-gas" campaign and leapfrogging its clean energy transition goals. In a sense, Beijing is an excellent case of ensuring energy security during its clean energy transition. However, when looking at Beijing's neighboring provinces and cities, it is easy to see that Beijing's achievements have come at the expense of neighboring towns and provinces, which have not been prioritized for supply by the major state-owned energy companies due to the underlying "political divide."

After the 2017 natural gas shortage, the central government of China and state-owned energy enterprises have recognized that the areas surrounding Beijing were greatly

affected by the "political divide," leading to difficulties in providing energy for those areas. This has accelerated efforts to enhance energy security levels and promote energy transition in surrounding areas such as Hebei Province, advancing the process of "inclusive development." The guiding ideology of the "coal-to-gas" project has shifted from "quick and aggressive" to "steady and gradual," with an emphasis on the driving role of natural gas. Hebei Province also actively seeks out richer gas sources both domestically and internationally while continuously improving the construction of natural gas infrastructure. Meanwhile, local governments and gas companies in the province have signed supply guarantee agreements to ensure uninterrupted gas supply. Objectively, however, the increase in natural gas supply is slower than the growing consumption rate, and the inadequacy of market mechanisms persists, leading to still occasional gas shortages in Northern China.

Under the ESSD framework, it is evident that the energy security situation in Hebei Province falls far short of that of Beijing, particularly in terms of accessibility and affordability. From the perspective of accessibility, Hebei's energy consumption structure has undergone certain changes following the "coal-to-gas" initiative. Natural gas consumption in the region increased from 12.64 million tons in 2017 to 24.74 million tons in 2021, with the proportion of natural gas in total consumption rising from 3.94% to 7.59% (Hebei Bureau of Statistics, 2023). However, as of 2021, coal still accounts for a high proportion of 76.58% of the energy consumption structure of Hebei Province, indicating extremely limited progress in the transformation of the energy structure. It is difficult to argue that Hebei has shown a significant improvement in the accessibility of natural gas. On the contrary, the accessibility of natural gas in Hebei has been inadequate, particularly under the joint effects of the political logic of "prioritizing supply to major cities" and "ensuring supply at all costs." At times of natural gas insufficiency, supplies must be redirected to Beijing, making it difficult for Hebei to meet the rising demand for consumption. Consequently, the province must resort to large-scale price adjustments to meet demands for natural gas, leading to serious affordability problems. The natural gas supply in Hebei Province heavily relies on government subsidies to be sustained, imposing an onerous burden on local governments and gas companies. Particularly during the period of global price hikes in 2022–2023, gas companies experienced widespread "price inversion," where they were required to purchase natural gas at market prices but sell it at a guaranteed lower price. Such actions resulted in huge financial losses. The unfavorable economic situation also led to delays in government subsidy payments, which triggered a new round of gas shortages. Meanwhile, Hebei has to bear higher natural gas prices despite its lower level of economic development. For example, in 2023–2024, the residential natural gas price in Beijing was 2.61 yuan per cubic meter; while in Langfang and Tangshan cities of Hebei, prices were 2.93 and 3.13 yuan per cubic meter, respectively.

The differences in energy security and energy transition between Beijing and Hebei since the "coal-to-gas" initiative in 2017 highlight that, even if the government recognizes that energy security decisions under a political logic may harm the principle of "energy justice" and lead to energy poverty in the surrounding areas of major cities, there is also a conscious effort to bridge the gap between regions in order to achieve energy security and justice. However, for a country like China with massive and constantly rising energy consumption and also with high external energy dependency, the contradiction between energy security and energy transition is hard to be fully resolved. Under the influence of political logic, once the fragile supply–demand balance is broken due to external factors such as supply shortages, surging demands, or high gas prices, it remains a norm for the government to make decisions based on comprehensive considerations, much similar to the trade-offs between Beijing and its surrounding areas during the 2017 "coal-to-gas" initiative. Even though the government can sustain basic needs through substantial subsidies, the enormous cost of ensuring supply cannot be overlooked. This further illustrates that overly aggressive energy transition policies will inevitably jeopardize energy supply security, and the government and state-owned enterprises will repeatedly allocate limited energy supplies based on political logic. Therefore, after 2017, the pace of "coal-to-gas" initiatives in the northern regions of China started to slow down, while more gradual energy transition policies could actually provide some assistance to energy security in Beijing and its surrounding areas.

The case of Beijing's energy security in the context of the 2017 coal-to-gas transition has given us valuable lessons. First, it is easy to overlook the huge differences within countries when discussing clean energy transition and energy security at the level of sovereign states. In reality, this variability is even more pronounced than that between countries. Therefore, it is even more necessary to discuss the differences in clean energy transition and energy security between cities, especially between metropolises and their neighboring areas. Second, the objective "political divide" between metropolises and other cities only becomes apparent when energy security is threatened. In other cases, the "political divide" tends to be hardly noticeable. Third, the issue of "energy justice" in the process of clean energy transition needs to be given considerable attention, and "energy justice" will be realized only when energy security is guaranteed for all entities.

6. Discussion: Beijing's path to energy security in the context of clean energy transition

Against the backdrop of the accelerating global clean energy transition and the emergence of a low-carbon economy as a new point of growth for the national economy, the question of how to ensure Beijing's energy security while considering the energy security of neighboring provinces and municipalities has become an essential issue of the contemporary time. The solution to this problem depends not only on Beijing's individual efforts within its administrative boundaries but also on its strategies and actions embedded at the national level.

Through examining Beijing under the ESSD model framework, it is evident that Beijing has maintained

a strong level of energy security while experiencing continuous growth in consumption. Beijing has also successfully balanced a series of objectives within its energy system, such as carbon reduction, improvement in energy efficiency and air quality, affordability of energy, and reduced dependence on traditional fossil fuels. Whether in terms of low-carbon transformation or energy supply security, Beijing has achieved notable success. This outcome is the result of both local efforts of the municipality and the overarching political logic at the central government level prioritizing the major cities.

In terms of the individual efforts undertaken by Beijing as an administrative zone, first, Beijing has fully leveraged its role as a metropolis for resource aggregation by expanding cooperation with Beijing municipal and other central energy enterprises. Technological advances, corporate scale-up, and capital deepening contribute to improving Beijing's overall energy efficiency and supply stability, thereby maintaining its energy security, all of which depend on cooperation with energy enterprises (Wang et al., 2017). At the same time, maintaining good relationships with said enterprises is a mandatory step to maximize Beijing's energy security in the event of energy supply problems. These relationships can also drive the entire energy industrial chain and improve the energy security of other regions, through large-scale, orderly, and uniformly coordinated supply activities.

Second, Beijing is gradually changing its energy status quo of excessive reliance on fossil energy. Specifically, Beijing is vigorously promoting energy conservation and environmental protection, including actively developing low-carbon energy industries such as wind and solar power in accordance with local conditions. This effort does not simply reduce Beijing's carbon emissions through carbon emission transfers and interregional power supply but rather reduces carbon emissions in the entire energy production process and improves energy efficiency through active transformation (Zhang et al., 2018). In order to achieve these goals, Beijing actively promotes the appropriate combination of energy utilization and emission reduction tasks. On the one hand, the city has improved the efficiency of fossil energy sources such as coal, oil, and gas through technological optimization. On the other hand, Beijing's renewable energy production has been increasing annually, and Beijing's universities, corporations, and research institutes have carried out some forward-looking research to resolve the contradiction between energy security and carbon emission reduction in China.

Third, as China's capital city and an international metropolis, Beijing has continued to explore various effective governance innovation paths, offering other regions and the world the "Beijing experience" of balancing energy security and carbon reduction needs. Since 2013 Beijing has become one of the first pilot cities for national carbon emissions trading. In 2022, its carbon dioxide emissions per 10,000 yuan of GDP and energy consumption per 10,000 yuan of GDP have decreased by 50% and 46%, respectively, compared to 2012. Beijing has also established a National Voluntary Emissions Reduction and Trading Center in 2022 to prepare for the launch of the national carbon market. In addition, relying on an international metropolis's rich political and economic resources, Beijing has made active exploratory attempts in many related areas, such as green financial products and other necessary policy measures, to promote low-carbon innovations across more industries and regions, as well as to facilitate a systematic low-carbon transition across the country (Liu et al., 2022). These efforts will not only help promote Beijing's energy transition and safeguard its energy security but will also leverage its advantages as a metropolis in supporting the national energy transition and security efforts.

In terms of Beijing's strategies and actions at the national level, on the one hand, Beijing is cooperating with the Chinese central government to accelerate the construction of an international oil and gas trading center, an international futures market for oil and gas, and China's oil pricing benchmark based on the Beijing Petroleum Exchange established in 2010. Through these measures, Beijing seeks to enhance its international influence and support the construction of a non-dollar oil settlement system. These measures will help break the monopoly of Europe and the United States over the entire international oil market, diversify systemic risks in the global energy market, and prevent unexpected damage to the worldwide energy market arising from the fluctuation of the U.S. dollar. In addition, Beijing is building a new platform for global energy security governance, based on the "Belt and Road" Initiative (BRI). Beijing is the seat of the core institutions of the BRI, such as the Asian Infrastructure Investment Bank (AIIB), and also the place where the BRI energy cooperation partnership was established. Beijing has become the center of the BRI's energy governance, contributing to the overall level of energy security.

On the other hand, in response to the "political divide" between Beijing and its neighboring regions, Beijing has also been enhancing energy policy coordination with those regions. At the end of 2017, when the "coal-to-gas" campaign posed a threat to their energy supply, Beijing, Tianjin, and Hebei jointly released the *Beijing–Tianjin–Hebei Energy Cooperative Development Action Plan (2017–2020)*, based on the *Beijing Tianjin Hebei Energy Collaborative Development Plan (2016–2025)*. The plan puts forward "eight major synergies" on energy strategy, energy facility, energy governance, green development, energy operation, energy innovation, energy market, and energy policy, with a safeguard mechanism. These synergies seek to achieve the division of labor, coordination, and integrated development among the 3 regions.

Beijing is the central city of the Beijing–Tianjin–Hebei region, and it needs to play to the dual advantages of capital and regional central city to have a leading role in the regional and even national energy development and transformation process. Beijing should fully recognize its position as the capital, break free from provincial or local limitations, and must coordinate with the central government's implementation of the national energy security strategy. It should be fully recognized that Beijing's energy security level ultimately depends on the energy security

level of the whole country. Only with the smooth implementation of China's energy security strategy and the improvement of the energy security level of its surrounding areas, can Beijing' energy security be fundamentally guaranteed. This is a critical relationship between "mother and child" and "trunk and branch."

7. Conclusion

By examining the classic metropolis of Beijing and its energy transition and energy security under the 2017 "coal-to-gas" campaign under the ESSD framework, it can be found that the government's political prioritization and the political logic in the management of state-owned enterprises have profoundly impacted the energy security of the metropolis and its surrounding areas, allowing some metropolises, including Beijing, to obtain a much higher level of energy security at a much lower price than their neighbors. This is achieved as the 2-fold benefits of carbon transformation and energy supply security. However, based on examinations of the areas surrounding Beijing under the ESSD framework, it is evident that although these areas have also made progress in low-carbon transformation and energy supply security after the "coal-to-gas" initiative, their progress has been much slower compared to Beijing. Moreover, it has brought about direct issues of reduced energy affordability and accessibility. This is the norm in countries where state-owned enterprises dominate the energy sector. In addition to the inherent geographic and capital differences between metropolises and other regions, this political divide, caused by political factors, may adversely affect the energy security of the surrounding neighborhoods of metropolises, if not addressed effectively. However, this political divide is not absolute and can be bridged through a series of strong policy coordination as well as the conscious reverse compensation by state-owned enterprises. Metropolises can also capitalize on their strengths in providing high-quality public goods for energy governance in terms of technological upgrading and innovative governance.

It is common and long-standing for governments to place different political priorities on different regions out of rational considerations, and the nature of state-owned enterprises also dictates that their political logic will always exist. Combining the two will result in a long-lasting political divide when there is a "dilemma" in energy security. Given the current energy consumption environment dominated by fossil energy, energy security has been relatively scarce, leading to zero-sum logic prevailing (Bridge, 2015). This also highlights the importance of energy transition. In addition to the economic and environmental benefits, the energy transition can also bring significant political benefits: only through a comprehensive energy transition can energy security become less scarce, thus eliminating the ground for political divides. The only way to truly achieve the energy justice goal is to eliminate the need for shifting the costs of achieving energy security in metropolises to other lower-priority regions. In other words, metropolitan energy security can only be achieved through an effective energy transition that takes into account the energy security needs of other regions.

Under the trend of global energy transition, ensuring energy security in metropolises is an arduous task. It is not only a technical issue but also a political one: The energy security of the metropolitan areas is inextricably linked to the energy security of neighboring regions and even the nation. Although metropolises can objectively enjoy better energy security through the political divide and ease the "pain" of the energy transition, they will still need to maximize their own advantages to enhance the energy security level of the surrounding areas and the country through effective governance and coordination, so as to achieve a more comprehensive energy security goal, and ultimately fill the political divide in energy security. With the continuous advancement of clean energy transition processes, further research and exploration are needed in the future to maintain energy security with lower costs and higher efficiency and improve the fairness of the energy system.

Data accessibility statement

Beijing Energy data are available from Beijing Municipal Bureau of Statistics Website: http://www.bjstats.gov.cn/. Hebei Energy data are available from Hebei Municipal Bureau of Statistics Website: http://tjj.hebei.gov.cn/.

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Author contributions

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