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Mechanisms and challenges of renewable energy cooperation in Northeast Asia

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Abstract

In recent decades, sustainable economic growth has caused an increase in energy consumption in North Asia, especially in China, Japan and South Korea. However, internal supply cannot meet energy demand, bringing two related consequences: First, the enlargement of the gap between production and consumption leads to dependence on external energy sources. Second, forcing the government to map its energy policy. However, unlike other regions such as the European Union and the Association of Southeast Asian nations, the dependence of the Energy of Northeast Asia has not caused the closest intra-regional cooperation. Conversely, in some cases, it damages cooperation and worsens non -constructive competition. Therefore, in this study, we aim to highlight the problematic relationship between energy securitization and regional energy cooperation in Northeast Asia and provide an analysis of the reasons, mechanisms and challenges for regional cooperation led by energy. In this case, we think that, by exploiting regional compatibility in the generation of renewable energy and in the consumer model, building a mechanism of integration and multimodal communication will promote greater integration and contribute to filling the gap between securitization and energy cooperation in the east and work the same in the east and working with Asia.

Keywords: renewable energy; Northeast Asia; energy securitization; belt initiatives; clean energy; NEA; energy policy; economic growth; energy corporation

Introductions

The energy landscape of Northeast Asia (NEA) offers some compatibility in terms of generation and consumption patterns, level of development in energy-related technologies, industrial capacity, and geographical proximity (Shen et al., 2022). Indeed, the overall picture of the demand-supply structure in the region suggests that while countries such as Russia and Mongolia have high (real and potential) energy production and low consumption, China, Japan,

and South Korea require energy supplies from abroad because their energy generation is far from meeting demand (Du et al., 2022). Northeast Asian countries also differ concerning advances in energy-related technologies, especially in alternative (or, renewable) energy (RE) where China, Japan, and Korea can be considered more advanced in investment and innovation in advanced technologies than Russia and Mongolia (Lee et al., 2022). In terms of industrial capacity, too, a similar pattern is seen with China standing out as the more capable player in large-scale infrastructure development, including energy communication systems and networks. Finally, geographic proximity facilitates cross-border connectivity although existing geopolitical conflicts on the Korean Peninsula still interfere with potential gains in land-based integration (Otsuka & Cheng, 2022).

Favorable conditions for cooperation in the energy sector, however, have largely failed to create meaningful and results-oriented momentum towards energy integration in the NEA as individual state actors remain reluctant to dedicate major political and economic resources to achieving better connectivity and communications better. Paradoxically, while supply dependence (China, Japan, and Korea) and demand-side (Russia and, potentially, Mongolia) drive energy securitization as a key aspect of high-level politics, securitization is not leading to a visible boost in the long term. , formal and binding energy dialogue (R. Wang et al., 2022)c. Although, as will be outlined below, some progress has been made, energy securitization has sometimes discouraged stakeholders from engaging in constructive communication. Thus, in the NEA, the existing asymmetrical forces do not help overcome geopolitical distrust and unconstructive competition between actors (Popov, 2022).

Given the growing importance of the NEA as a major global economic actor and the high level of energy securitization, energy policy in the region remains a topic of interest in both academic and policy circles (W. Liu et al., 2022). An overview of the existing debate on this issue reveals a great deal of work on barriers to regional energy cooperation (political and technical) and measures to improve energy coordination across the region. However, existing scholarship is primarily concerned with traditional fossil fuels and research on renewable energy cooperation in the NEA appears to be inadequate. Therefore, this article aims to contribute to the nascent but growing literature by bringing renewable energy to the fore and analyzing the impetus for deeper energy cooperation (Zhao et al., 2022).

Literature Review

Challenges in traditional energy: Prerequisites for clean energy cooperation in the NEA

Northeast Asia is one of the world's most dynamic economic regions, standing out for its industrial capacity, innovation, wealth of natural resources, and human capital, although it is not evenly distributed across the region (X. Zhang et al., 2022). Indeed, the NEA is the second largest trading area after the European Union (EU) and commands a higher percentage of global trade than North America (USA, Canada, and Mexico) and ASEAN. Despite being poor in natural wealth (except China), the region's three largest economies (Mainland China, Japan, and South Korea) account for 21% of the global population, 23% of the global GDP, nearly 18% of global trade volume and more than 59% of the global population (İnal et al., 2022). %

global patent applications (Hachem-Vermette & Singh, 2022). Russia, on the other hand, is one of the world's largest producers of crude oil and natural gas whereas Mongolia is rich in renewable energy resources such as wind, solar, and water although the country currently uses only a fraction of its existing capacity(You & Kakinaka, 2022).

Economic dynamics remain the driving force for increasing energy demand in the NEA (Ge et al., 2022). However, the suitability of economic fundamentals in general, and the endowment of energy and resource utilization patterns, in particular, are still unable to become a meaningful catalyst for integration and connectivity in the region. Under optimal conditions, inter alia, complementarity in terms of industry size and power, fossil fuel reserves, and the basic structure of the economy in general (especially export- and import-driven growth patterns) should contribute to greater intra-regional energy cooperation (Dervishi et al., 2022). However, despite the complementarity and many underlying benefits that cooperation in traditional energy has the potential to offer for all actors facing supply- or demand-side challenges, energy policy in the NEA remains to be securitized and is a subject of high-level politics as such in such a way as to hinder meaningful and sustainable coordination and cooperation among regional actors (T. Zhang et al., 2022). Concerning traditional energy resources, geopolitically driven competition, questions of availability, and unfavorable prices in international energy markets are some of the fundamental challenges that must be overcome (Chai & Li, 2022).

Energy as a subject for high politics

Since the 1973 oil crisis, energy has been put into high politics and energy security has become one of the strategic priorities for most countries. Thus, economic development in the post-World War II era (albeit at different levels and in a non-uniform way) has forced regional countries, especially China, Japan, and South Korea, to consider energy security as an integral part of their national security and develop appropriate political strategies. Because fossil fuels are limited, pose major security risks, and can be depleted over time, intra-regional relations in traditional energy resources are often seen as a zero-sum game, hindering broad-based and sustainable cooperation (Doğan et al., 2022).

Indeed, the competition between China, Japan, and South Korea often results in the three doing worse. For example, in 2003, the Chinese government signed an agreement with Russia to build an oil pipeline from Angarsk in Russia's far east to Daqing in northeastern China. Later, Japan stepped in and offered $7 billion to build an alternative route from Angarsk to Nakhodka (Szabo, 2022). Finally, Russia supports a third route that crosses from Taishet which is considered the most profitable for the country. The fragmentation of national energy policies and the lack of coordination comes at a higher cost for the two actors (Gürzel Aka et al., 2022). Thus, within the NEA, the mercantilist approach to energy has so far hindered the establishment of a viable institutional framework for collective action. The lack of cooperation has made “regional resource markets less open, transparent and efficient”, thereby “undermining the effectiveness of these markets in providing resource security for all consumer economies” (İpek & Gür, 2022).

Geopolitical competition and distrust

In addition, political distrust and the existence of intra-regional competition undermine the collective bargaining power of individual countries, further worsening their prospects for energy security(Allan et al., 2022). Therefore, Asian countries have no choice but to agree to pay more when buying crude oil and natural gas from major producers and exporters. Due to a lack of collective action, for example, the increased demand for energy in China, Japan, and South Korea did not bring significant benefits because a favorable demand position has not been converted into a more favorable bargaining position. The three Northeast Asian countries, despite their high energy consumption mostly from imports, have so far failed to take a collective stance in their interactions with energy-exporting countries or blocs. Thus, in international energy markets, these countries usually pay a higher price due to a lack of coordination (Jang & Yi, 2022).

High dependence on imports

With unmet energy needs within the region, energy-importing countries are turning abroad, especially the Middle East, to meet their energy needs, causing two more problems (Sovacool et al., 2022). The first is the high dependence on energy imports from regions that are geopolitically and economically unstable. Indeed, uncertainty and instability in the Middle East and North Africa have worsened the prospects for economic security with energy-intensive industries. In addition, because of the important sea lanes (particularly the Malacca Strait) through which the majority of imported energy resources are heavily controlled by the US Navy, access to energy resources remains a potential security risk for major economies in East Asia (Krüger, 2022). Relying on other parties for the safety of energy transportation is highly undesirable, especially during a time of major strategic divisions between rival powers, such as China and the US. Therefore, for an energy-importing economy, factors such as resource depletion, potential disruption of energy production in resource-rich areas, foreign military hegemony over critical maritime communication lines (SLOC), and the possibility of energy being used as a political bargaining chip by exporting countries cause availability problems (Gordon et al., 2022).

Research Method

In this research, we argue that there are opportunities in the NEA for greater cooperation in the energy sector. In this respect, in contrast to the highly geopolitical nature of traditional sources, especially crude oil and natural gas, cooperation and integration in clean energy-based electricity in the NEA is more likely due to its relatively weak competitive nature, inherent comparative advantage, and abundance. Thus, our aim in this paper is to offer an analysis of the reasons, mechanisms, and challenges for clean energy-based cooperation in the NEA, highlighting energy as an appropriate starting point in promoting closer ties in the NEA. To this end, in the following pages, we first provide a brief overview of the existing problems in regional energy cooperation, validating the need for more effective communication and integration. We, then, examine incentives for renewable energy cooperation owing to their positive effects on enhancing energy security and non-geopolitical features. In what follows, we explore practical mechanisms for more feasible interactions among regional actors, arguing,

in this case, crystallizing clean energy cooperation in combination with the Belt and Road Initiative (BRI) may be a viable way to more comprehensive energy integration. We conclude by investigating the challenges and prospects for clean energy cooperation that exist in the NEA.

Result and Discussion

Incentives for RE cooperation in NEA

Historically, NEA countries have generally remained reluctant to deepen regional cooperation in traditional energy (bilateral cooperation such as that between China and Russia (Lowery et al., 2022), meanwhile, appears to be more developed than multilateral interaction in energy policy) (Ramey et al., 2022). We believe that, although actors may seek ways to achieve better regional connectivity and cooperation in traditional energy incrementally, renewables provide broader opportunities for relatively quicker, broad-based, and formal multilateral action due to several features which makes it less amenable to high securitization and allows concerted action. As we describe in the following pages, these features provide an effective response to the four main challenges inherent in traditional energy and securitization. In other words, we argue that renewable energy does not require, at least for now, the same geopolitical implications that involve traditional energy, thereby offering practical tools for all regional stakeholders to leverage and strengthen regional energy communication and development (Chauhan et al., 2022).

Although there is no consensus on the concept of energy security, the generally accepted definition includes the four A's, namely availability, accessibility, acceptability, and affordability (Demina, 2021). Viewed from the perspective of established energy security theory, the NEA has the requirements for securitization in the traditional sense. However, renewable energy, as we mentioned above, offers certain advantages that help to ameliorate all four challenges. However, it should be noted that these advantages are only potential and not absolute or inherent, so they still require efforts from the relevant actors. However, in the NEA where the economy remains hot while politics remain cold, they may be more needed and useful than in other regions (Chauhan et al., 2022).

The huge potential of clean energy

The first dimension that leads to traditional energy securitization is the issue of availability (Mehr et al., 2021). It involves aspects of supply and demand for resources from the point of view of importers and exporters. China, Japan, and South Korea, three manufacturing-oriented highly industrialized economies in Northeast Asia, represent a typical case of a vulnerability in terms of supply-side availability (Momete, 2018). However, when approached from a renewable energy perspective, it appears that Northeast Asia, which is generally considered oil and natural gas poor (except Russia), offers rich clean energy prospects, including the three developed economies of China, Japan, and South Korea (Y. Zhu et al., 2021). The potential for water, wind, and solar energy in this region is projected to reach 54.5 GW, 430 GW, and 510 GW respectively (Asmare, 2019), although only a small portion

is currently being exploited. For example, the potential for hydropower in Russia reaches 1.67 TW per year, but only less than 10% is utilized. It is also estimated that, if fully utilized, renewable energy in Mongolia can meet China's total energy demand by 2030. However, given that clean energy depends on the presence of favorable natural conditions such as sunlight and wind, its supply may be unstable and intermittent (Indrajayanthan & Mohanty, 2022). Thus, storing, transmitting, and distributing the generated electricity throughout the region through a network of power grids following the conditions of generation, demand, and supply is a must to reduce inherent shortfalls and ensure uninterrupted economic development for all stakeholders (Kumar et al., 2015).

Cheaper alternative

The second dimension, affordability, denotes the capacity of buyers to purchase energy resources at reasonable prices. One important aspect of affordability from the supply side involves collective bargaining power. If clean energy accounts for a greater proportion of energy demand in the NEA, its dependence on external sources of fossil fuels will decrease (Gavrikova et al., 2019). More coordination among regional actors and a higher level of self-sufficiency would result in more favorable prices for all participating countries. It is worth noting that recent technological advances have helped to reduce energy infrastructure-related costs significantly, as evidenced by the fact that total investment in the renewable energy industry has fallen by half worldwide whereas installed capacity in clean energy-based electricity has doubled. Projections suggest that "most mainstream renewables will be significantly cheaper than fossil generation by 2050" (Messay et al., 2021).

As such, the substantial gains from reduced initial investment and energy costs will provide a strong impetus for deeper energy cooperation, involving resource-exporting and importing countries. Although, from the perspective of countries rich in traditional energy resources such as Russia and Mongolia, switching to renewables may at first glance seem counter-intuitive as such a move could undermine their established advantageous position, in the long run they will have more advantages (Bello & Solarin, 2022). Exporting electricity based on clean energy along with fossil fuels will allow these countries to earn more revenue at fewer resource costs. In addition, the cooperation will help them improve national infrastructure and strengthen related industrial development. Lastly, leveraging renewable energy will meet domestic energy needs in an environmentally friendly way in areas that still lack access to sustainable electricity (Sherif et al., 2022).

More Accessible

Accessibility, on the other hand, denotes unhindered access to energy resources. Despite the advances made in exploration and exploitation technology (Ren & Lucey, 2022)v, there is still a long way to go before fully exploiting hydrocarbon resources located in hard-to-reach areas such as frigid locations with deep concentrations of fossil fuels. Indeed, the need to exploit previously inaccessible areas has become more pressing in recent years as easily accessible resources are depleted and most known reserves are located in the "very deep sea or arctic regions," requiring the utilization of advanced technology and more expensive extraction technologies (Xu et al., 2020). For example, most of Russia's fossil energy reserves are located

in the far east where climatic and geographical conditions make extrapolation more difficult. In Mongolia, fragile ecosystems and desertification hinder the development of potentially available energy resources. Therefore, technological barriers and high costs prevent national and private companies from seeking access to existing traditional energy resources (Tian & Chang, 2020). Renewable energy, meanwhile, does not pose the same challenges and constraints as it is spread more evenly across the region with each location having certain advantages and inaccessible sources. For example, while Mongolia boasts extensive water and wind energy capacities, Russia is rich in solar and geothermal energy generation potential. China, on the other hand, has huge water, wind, and solar energy potential (Hu et al., 2021).

Low environmental costs

The final dimension, acceptance, refers to the environmental implications and other social costs associated with energy generation and consumption. With global warming and climate change becoming important issues that cannot be ignored anymore, both the government and the general public are starting to pay more attention to the impact of energy on the environment and social welfare in general. In this regard, major energy-consuming countries such as China and Japan remain committed to existing climate change conventions and agreements, including full participation in the Paris Climate Agreement signed in 2015. According to a report released by the IEA, "nearly a quarter of global emissions in 2016 were generated in Asia from power and heat generation – an amount comparable to the total amount of European emissions, plus Russia, Africa, and Oceania combined" (Sharma & Banerjee, 2021).

This can be partly attributed to the fact that thermal power still dominates power generation in the NEA. However, renewable energy provides an effective response to acceptance questions that require traditional energy sources. As pointed out in the speech of the former president of State Grid Corporation of China, Liu Zhenya, "increasing the proportion of electricity in the final energy consumption can thoroughly solve problems such as the energy environment and climate change". Switching to clean electricity is sure to produce less pollution, thereby helping to achieve the goal of reducing global emissions. For developing, as well as developed, countries in the NEA, achieving sustainable economic growth while maintaining a more sustainable ecological environment can, therefore, be a strong incentive to cooperate on renewable energy by building a network of investment, generation, and infrastructure sharing electricity (Usman et al., 2020).

A unique feature of renewable energy

It is clear, however, that the benefits of adopting clean energy alone are not sufficient to induce the relevant state and private sector to take the necessary action by coordinating efforts on energy issues (Abbas et al., 2022), as evidenced by the lack of intra-regional cooperation and strong policy impetus within the NEA. Given the lack of higher authority on a regional (as well as international) basis, absolute advantage is not enough to convince countries to cooperate with others (X. Wang et al., 2022). Within a certain time, limited by exploration capabilities and other factors, the amount of fossil fuels available for sale is limited, so energy security is usually considered a zero-sum game among players in the region. The state has

asymmetric information about the beliefs of others; therefore, the existence of common interests is often insufficient to encourage and ensure cooperation. Fears of fraud and disobedience are further complicated by anarchy (real or perceived) in the international system (Sasmaz et al., 2020).

However, the different characteristics of renewable energy have the potential to reduce geopolitical concerns to some extent and inject new impetus into energy cooperation. Renewable energy-based regional communications can help allay security concerns, motivate cooperation on technological, financial, and physical infrastructure and policies, and bring all stakeholders together (Cheng et al., 2022). Opportunities for cooperation in the energy sector are not entirely lacking in the NEA and certain progress has been made especially in the renewable energy domain although a formal region-wide energy framework is still a long way off. As fossil fuels are limited and climate change caused in part by increasing energy consumption is receiving more and more attention, technological advances and environmental awareness continue to make clean energy a viable alternative to traditional energy in terms of providing greater co-benefits in various aspects such as economic, social, and environmental. Therefore, renewable energy is increasingly seen as more sustainable and capable of producing greater regional public goods, reducing unconstructive competition for fossil fuels to some extent and paving the way for more inclusive regional development (Ridha et al., 2022).

Clean energy-based regional cooperation mechanism

Several economic and political factors provide a stimulus for state actors to take concrete steps to increase energy interconnectivity and realize better energy security in the NEA. This section provides a brief discussion, exploring possible avenues to crystallize such cooperation (Rajan & Jeevananthan, 2022). We maintain, in effect, that because each country is dependent on the other for the demand or supply side of energy, strengthening ties among NEA countries will lead to a greater tendency to resolve differences and resolve disputes through consultation rather than confrontation or destructive competition. In addition, because clean energy cooperation requires coordination in other areas and involves more stakeholders (both state and non-state), certain spillover effects from multilateral interactions can serve as key factors in advancing and deepening energy integration. Clean energy serves as a potential catalyst for broader regional connectivity and communications. Given the complicated political landscape and the inherent weaknesses of the NEA, building a network of partnerships based on renewable energy could be a starting point. Such cooperation could also be considered in combination with other multilateral initiatives such as the Belt and Road Initiative (BRI) and the Eurasian Economic Union (EEU), helping to create a more favorable policy environment for infrastructure connectivity and formalization (Zeng et al., 2022).

Renewable energy-based partnership network

Since the end of the Cold War, various types of partnerships have replaced traditional alliances as the more desirable form of cooperation between countries, for the most part, in certain regional settings. In practice, partnerships offer greater flexibility, help avoid preventative wars, and encourage cooperation between competing nations (Moazzami et al., 2022). However, partnerships are primarily limited to the economic sector while their political

effectiveness remains to be tested. Energy, which involves political and economic aspects in international relations, is one of the main instruments for initiating, maintaining, and strengthening established regional partnership schemes. As outlined in the writings of the neo-institutionalism schools, the lack of information about each other's credibility and preferences is a major obstacle to cooperation. In that sense, seeking cooperation within the boundaries of formal, semi-formal, or informal regional institutions between partner countries is a practical way to achieve better energy integration (Yang et al., 2023).

Many countries have listed energy as a key area for cooperation in their official statements (Amoatey et al., 2022). For example, in the joint declaration between China and Russia on upgrading their relationship to a comprehensive strategic coordinating partnership for a new era, the two sides agreed to "continue to deepen all-inclusive energy cooperation in the upper, middle, and lower ranges". Similarly, in the 'Plan for Enhancing the Cooperation Strategic Partnership between China and the Republic of Korea', the two countries announced the enhancement of coordination in the development of renewable energy. With the experience of previous cooperation in energy and other fields, partner countries collect certain information about each other's preferred form of interaction and record of compliance with previously signed agreements. Therefore, establishing clean energy cooperation with partners in institutional arrangements will be relatively easy compared to non-partners (Gu et al., 2022).

According to network theory, networks of intense cooperative agreements can help overcome information and commitment problems (Wen et al., 2022). Triadic closure refers to the fact that countries are more likely to cooperate if they have signed agreements with the same third country. Cooperation provides related principals with evidence of mutual trust, helping to reduce reluctance to cooperate for fear of cheating or defecting. In addition, a country with a large number of agreements with other countries is more attractive to choose from because its agreements with other countries say a lot about its preferences and credibility. In a sense, renewable energy cooperation between partners in the NEA is more likely and has the potential to spread throughout the region (Aboagye et al., 2021).

Regional multilateral initiatives can complement each other in funding necessary infrastructure where they help pool and manage common resources through long-term planning, consultation, and consensus (Shahbaz et al., 2022). The Belt and Road Initiative, which places heavy emphasis on building and upgrading infrastructure along several land and sea routes in Asia, Africa, and Europe, may play an important role in promoting energy-based connectivity in Northeast Asia and beyond. Indeed, as part of the BRI, China established the Asian Infrastructure Investment Bank (AIIB) in 2015 to promote sustainable development in Asia through investments in infrastructure and other productive areas. According to the latest release of 'The Belt and Road Infrastructure Development Index Report 2019', capital from international multilateral banks and policy lenders is still far from sufficient, and commercial banks and special funds are showing greater willingness to invest more in infrastructure development (Olabi & Abdelkareem, 2022).

Meanwhile, with the growing great power competition in East Asia, the US has introduced its own Asia-Pacific strategy in competition and highlighted the provision of quality infrastructure investment to regional members. In 2018, US Secretary of State Mike Pompeo

pledged $113 million for three infrastructure initiatives, including Asia EDGE (Enhancing Development and Growth through Energy), while Japan offered to provide $10 billion under the Indo-Pacific Infrastructure partnership framework. Clean energy cooperation in the NEA can take full advantage of this effort to institutionalize infrastructure investments, including renewable energy. On the one hand, these efforts can coordinate infrastructure for the utilization, transmission, and storage of clean energy. On the other hand, the relevant members can avail it for funding (Q. Zhu et al., 2022).

Challenges of clean energy cooperation

However, there are several challenges to fully realizing clean energy-based interconnectivity communication and cooperation in Northeast Asia. Despite the benefits and prospects mentioned above, there is still a long way to go before regional-wide clean energy cooperation is achieved. First, due to technological constraints, intense competition for power, and lack of trust, clean energy accounts for only a small proportion of total energy consumption. Therefore, it may be too small a lever against the backdrop of the larger energy picture. Second, the infrastructure needed to develop clean energy is lacking or damaged. Third, while clean energy can help alleviate geopolitical concerns, it cannot eliminate them. As such, this challenge requires concerted and sustained efforts so that all relevant actors can make effective use of integration mechanisms (Kallio & Siroux, 2022).

Underdevelopment of the power grid

Lack of infrastructure risks derailing or undermining clean energy integration. Unlike fossil fuels which are transported via stationary ships or pipelines, electricity based on renewable energy relies on national and transnational power grids for storage, transmission, and distribution. However, in the NEA, the existing infrastructure is inadequate and, in some ways, underdeveloped. In Russia, for example, the electricity grid is "stuck, undersized, highly inefficient, slow to repair" (Amuakwa-Mensah & Näsström, 2022). A similar situation exists in Mongolia where only two out of nine power systems are connected to the grid. In China, non-parallel development and discrepancies between net electricity generation and transmission capacity have been major constraints. In Japan, the underdevelopment of transmission lines is associated with low demand in rural areas that have rich wind potential. In addition, power systems in northeastern and southwestern Japan (operating at 50 Hz and 60 Hz respectively) are not compatible with each other, making it more difficult to transfer excess power even within the country. South Korea is the only exception as it has a complete network of domestic networks. However, in South Korea too, independence in electricity (along with problems of ground-based connectivity due to the North-South divide) has so far kept the country from establishing a transnational power grid with its neighbors (Punt et al., 2022).

In addition, the need for large investments in the early stages of installing a renewable energy system discourages some actors from getting involved. Indeed, according to estimates, the NEA requires $2.7 trillion of investment in energy infrastructure by 2050, which only states can afford financially and politically willingly either singly or through various combinations such as public-private partnerships (Törnroth et al., 2022). Even though both Japan and China have abundant capital in the form of foreign exchange reserves, pouring money into facilities

located in foreign territories is still seen as financially risky – especially given the lack of political confidence. As a result, significant sunk costs in infrastructure coupled with geopolitical uncertainties result in capital-rich regional countries receiving far less than anticipated savings thanks to renewable energy development and connectivity (Calvo & Valero, 2022).

Small proportion of clean energy in the total energy mix

Although coordination in fully exploiting clean electricity is projected to grow, the reality is that renewable energy accounts for only a small proportion of total electricity generation and consumption in the NEA (Niu et al., 2022). In 2015, the proportion of renewable energy (excluding hydropower) of the total primary energy supply (TPES) in China, Japan, Mongolia, Russia, South Korea, and the DPRK was 5.5%, 4.4%, 3.4%, 1.1%, 2.43%, and 14.1%, respectively. Renewable energy (excluding hydropower) currently accounts for less than 1% of total electricity generation in Russia and is projected to increase to only 2% by 2040. In Mongolia, the share of renewable energy to total energy generation is only 1.96% in 2013 China and Japan also put more emphasis on nuclear energy and the latter emphasized hydrogen energy, which may reduce the attractiveness of multilateral clean energy development (Amjith & Bavanish, 2022).

Moreover, despite the advances that have been made in smart grid technology, it is currently unlikely that clean energy-based electricity production will keep pace with the surge in consumption in the NEA (Li et al., 2022). In general, the capacity to develop, store, and transfer generated electricity still lag behind the demand in each country. For this reason, with clean energy accounting for only a small fraction of the electricity generated, the three major consuming countries have no choice but to continue to rely primarily on fossil fuels. Thus, the positive impact that renewables can bring to alleviate mercantilist energy security structures will, in the short term, likely be partly offset by a more competitive relationship and continued insecurity in and external interventions (Haldar & Sethi, 2022).

The remaining historical problems continue to prevent the NEA countries from establishing further cooperation schemes in strategic areas, including energy (Sendstad et al., 2022). For example, the memory of Japanese colonialism continues to generate strong resentment in some of the neighboring countries in the region, forcing political actors to adopt policies that lack flexibility on sensitive issues such as territorial disputes, which hurts regional dialogue in policy areas that appear to be ineffective related. Even relations between close allies such as Japan and South Korea have not been spared, for that matter. A dearth of mutual trust is a significant obstacle to deeper cooperation on high political issues such as energy (Romero-Castro et al., 2022).

The track record of US engagement in NEA regional affairs is also significant in terms of negative geopolitical implications for regional energy cooperation (T. Liu et al., 2022). Since the NEA is of major strategic importance to the US, the reality of its relative decline in capacity (especially vis-à-vis China) and the subsequent strategic anxiety on the part of the political elite makes the US more desperate in its efforts to maintain its established position advantageous position in the region by seeking to prevent possible integration opportunities, including in the

energy sector. The US distaste for exclusive regional development will likely continue to negatively impact energy integration processes in the NEA as long as regional actors (especially Japan and South Korea) do not feel compelled to recalibrate their strong political and security attachments to the United States (Q. Wang et al., 2022).

Conclusion

With traditional fossil fuels at risk of depletion, more uncertainty and instability in key energy exporting regions, especially in the Middle East, and conditions of prolonged dependency (supply or demand side), energy continues to pose a serious policy challenge for states across the globe. NEA. Against this geopolitical backdrop, network integration on renewables offers a window of opportunity for cooperation and ensures greater connectivity and greater security. The unequal distribution of energy resources, differences in technological and financial capabilities, and the existence of major supply and demand centers provide powerful incentives for intra-regional energy cooperation. The progress that has been made in the generation, storage, and transmission of clean power, meanwhile, is facilitating the establishment of a comprehensive clean energy-based connectivity in the NEA.

The advantages of such cooperation abound. First and foremost, intra-regional energy cooperation will greatly reduce the risk of supply disruptions for energy-dependent countries. In addition, the potential for energy-related cost savings makes energy connectivity a useful tool for responding to security challenges, benefiting both resource importers and exporters. Apart from these technical and economic incentives, energy cooperation can contribute to easing geopolitical tensions such as the Korean Peninsula issue, as well as benefit from an improved situation. In this regard, warming inter-Korean relations and US-North Korean dialogue offer opportunities for strategic rapprochement across the region.

In the final analysis, the interdependence and expansion of functional clean energy cooperation have the potential to contribute to regional integration and community-building processes in Northeast Asia. Yet, for all the prospects for better connectivity and communications in the region, geopolitical uncertainty remains. Concerning clean energy-based connectivity, despite all existing incentives, technical, financial, and political challenges such as questions of initial investment costs, the small proportion of clean energy in the total energy mix, and the potential intervention by external actors, notably, the US, are real. Overall, it is clear that there is still a long way to go before achieving the renewable energy-based interconnections that will pave the way for the wider economic community in the NEA. Nevertheless, there is no doubt that the benefits of comprehensive communication and integration for the regional development of the NEA are worth all the effort.

Reference

Abbas, S. C., Lin, C., Hua, Z., Deng, Q., Huang, H., Ni, Y., Cao, S., & Ma, X. (2022). Bamboo-derived carbon material inherently doped with SiC and nitrogen for flexible supercapacitors. *Chemical Engineering Journal*, *433*.

https://doi.org/10.1016/j.cej.2021.133738

Aboagye, B., Gyamfi, S., Ofosu, E. A., & Djordjevic, S. (2021). Status of renewable energy resources for electricity supply in Ghana. In *Scientific African* (Vol. 11). https://doi.org/10.1016/j.sciaf.2020.e00660

Allan, J., Lemaadel, M., & Lakhal, H. (2022). Oppressive Energopolitics in Africa's Last Colony: Energy, Subjectivities, and Resistance. *Antipode*, *54*(1). https://doi.org/10.1111/anti.12765

Amjith, L. R., & Bavanish, B. (2022). A review on biomass and wind as renewable energy for sustainable environment. *Chemosphere*, *293*. https://doi.org/10.1016/j.chemosphere.2022.133579

Amoatey, P., Al-Hinai, A., Al-Mamun, A., & Said Baawain, M. (2022). A review of recent renewable energy status and potentials in Oman. *Sustainable Energy Technologies and Assessments*, *51*. https://doi.org/10.1016/j.seta.2021.101919

Amuakwa-Mensah, F., & Näsström, E. (2022). Role of banking sector performance in renewable energy consumption. *Applied Energy*, *306*. https://doi.org/10.1016/j.apenergy.2021.118023

Asmare, M. (2019). Bahir Dar City Municipal Solid Waste Potential Assessment for Clean Energy. *American Journal of Energy Engineering*, *7*(1). https://doi.org/10.11648/j.ajee.20190701.14

Bello, M. O., & Solarin, S. A. (2022). Searching for sustainable electricity generation: The possibility of substituting coal and natural gas with clean energy. *Energy and Environment*, *33*(1). https://doi.org/10.1177/0958305X20985253

Calvo, G., & Valero, A. (2022). Strategic mineral resources: Availability and future estimations for the renewable energy sector. *Environmental Development*, *41*. https://doi.org/10.1016/j.envdev.2021.100640

Chai, R., & Li, G. (2022). Renewable clean energy and clean utilization of traditional energy: An evolutionary game model of energy structure transformation of power enterprises. *Xitong Gongcheng Lilun Yu Shijian/System Engineering Theory and Practice*, *42*(1). https://doi.org/10.12011/SETP2021-0149

Chauhan, V., Beaton, D., Hamada, N., Wilkins, R., Burtt, J., Leblanc, J., Cool, D., Garnier-Laplace, J., Laurier, D., Le, Y., Yamada, Y., & Tollefsen, K. E. (2022). Adverse outcome pathway: a path toward better data consolidation and global co-ordination of radiation research. *International Journal of Radiation Biology*, *98*(12). https://doi.org/10.1080/09553002.2021.2020363

Cheng, Z., Wang, C., Zhu, Y., Wang, C., Jiang, X., Qian, Z., Chen, B., & Yang, J. (2022). Mesocarbon Microbeads Boost the Electrochemical Performances of LiFePO4||Li4Ti5O12 through Anion Intercalation. *ChemSusChem*, *15*(8). https://doi.org/10.1002/cssc.202102475

Demina, Y. V. (2021). Formats for Multilateral and Bilateral Economic Cooperation in Northeast Asia. *Regional Research of Russia*, *11*(2). https://doi.org/10.1134/S2079970521020040

Dervishi, S., Pashako, F., Dushaj, X., & Dervishi, I. O. (2022). Energy performance optimization of traditional housing in Mediterranean climate. *Journal of Building*

Engineering, *45*. https://doi.org/10.1016/j.jobe.2021.103423

Doğan, B., Chu, L. K., Ghosh, S., Diep Truong, H. H., & Balsalobre-Lorente, D. (2022). How environmental taxes and carbon emissions are related in the G7 economies? *Renewable Energy*, *187*. https://doi.org/10.1016/j.renene.2022.01.077

Du, M., Lei, J., Zhao, D., & Lu, H. (2022). Pn Anisotropic Tomography of Northeast Asia: New Insight Into Subduction Dynamics and Volcanism. *Journal of Geophysical Research: Solid Earth*, *127*(1). https://doi.org/10.1029/2021JB023080

Gavrikova, E., Burda, Y., Gavrikov, V., Sharafutdinov, R., Volkova, I., Rubleva, M., & Polosukhina, D. (2019). Clean energy sources: Insights from Russia. *Resources*, *8*(2). https://doi.org/10.3390/resources8020084

Ge, J., Lu, J., Wu, J., Luo, X., & Shen, F. (2022). Suitable and energy-saving retrofit technology research in traditional wooden houses in Jiangnan, South China. *Journal of Building Engineering*, *45*. https://doi.org/10.1016/j.jobe.2021.103550

Gordon, R., Harada, T., & Spotswood, F. (2022). The body politics of successful ageing in the nexus of health, well-being and energy consumption practices. *Social Science and Medicine*, *294*. https://doi.org/10.1016/j.socscimed.2022.114717

Gu, X., Pang, N., Qiu, Y., Fu, X., Yao, Y., & Chen, S. (2022). Systematic evaluation of fractionation and valorization of lignocellulose via two-stage hydrothermal liquefaction. *Fuel*, *310*. https://doi.org/10.1016/j.fuel.2021.122358

Gürzel Aka, A. G., Engin Bozoglu, A., Hashimov, I., & Pulhan, A. (2022). The 'new great game' in the Eastern Mediterranean. *Israel Affairs*, *28*(1). https://doi.org/10.1080/13537121.2022.2017133

Hachem-Vermette, C., & Singh, K. (2022). Energy Systems and Energy Sharing in Traditional and Sustainable Archetypes of Urban Developments. *Sustainability (Switzerland)*, *14*(3). https://doi.org/10.3390/su14031356

Haldar, A., & Sethi, N. (2022). Environmental effects of Information and Communication Technology - Exploring the roles of renewable energy, innovation, trade and financial development. *Renewable and Sustainable Energy Reviews*, *153*. https://doi.org/10.1016/j.rser.2021.111754

Hu, C., Dai, Q., & Dai, L. (2021). Multifunctional carbon-based metal-free catalysts for advanced energy conversion and storage. In *Cell Reports Physical Science* (Vol. 2, Issue 2). https://doi.org/10.1016/j.xcrp.2021.100328

İnal, V., Addi, H. M., Çakmak, E. E., Torusdağ, M., & Çalışkan, M. (2022). The nexus between renewable energy, CO2 emissions, and economic growth: Empirical evidence from African oil-producing countries. *Energy Reports*, *8*. https://doi.org/10.1016/j.egyr.2021.12.051

Indrajayanthan, V., & Mohanty, N. K. (2022). Assessment of Clean Energy Transition Potential in Major Power-Producing States of India Using Multi-Criteria Decision Analysis. *Sustainability (Switzerland)*, *14*(3). https://doi.org/10.3390/su14031166

İpek, P., & Gür, V. T. (2022). Turkey's Isolation from the Eastern Mediterranean Gas Forum: ideational mechanisms and material interests in Energy Politics. *Turkish Studies*, *23*(1). https://doi.org/10.1080/14683849.2021.1925884

Jang, S., & Yi, H. (2022). Organized elite power and clean energy: A study of negative policy experimentations with renewable portfolio standards. *Review of Policy Research*, *39*(1). https://doi.org/10.1111/ropr.12449

Kallio, S., & Siroux, M. (2022). Hybrid renewable energy systems based on micro-cogeneration. *Energy Reports*, *8*. https://doi.org/10.1016/j.egyr.2021.11.158

Krüger, T. (2022). The German energy transition and the eroding consensus on ecological modernization: A radical democratic perspective on conflicts over competing justice claims and energy visions. *Futures*, *136*. https://doi.org/10.1016/j.futures.2021.102899

Kumar, V., Shrivastava, R. L., & Untawale, S. P. (2015). Solar Energy: Review of Potential Green & Clean Energy for Coastal and Offshore Applications. *Aquatic Procedia*, *4*. https://doi.org/10.1016/j.aqpro.2015.02.062

Lee, Y., Ahn, M. H., & Lee, S. J. (2022). Incremental Learning with Neural Network Algorithm for the Monitoring Pre-Convective Environments Using Geostationary Imager. *Remote Sensing*, *14*(2). https://doi.org/10.3390/rs14020387

Li, D., Heimeriks, G., & Alkemade, F. (2022). Knowledge flows in global renewable energy innovation systems: the role of technological and geographical distance. *Technology Analysis and Strategic Management*, *34*(4). https://doi.org/10.1080/09537325.2021.1903416

Liu, T., Nakajima, T., & Hamori, S. (2022). The impact of economic uncertainty caused by COVID-19 on renewable energy stocks. *Empirical Economics*, *62*(4). https://doi.org/10.1007/s00181-021-02087-3

Liu, W., Dong, J., Du, G., Zhang, G., Hao, Z., You, N., Zhao, G., Flynn, K. C., Yang, T., & Zhou, Y. (2022). Biophysical effects of paddy rice expansion on land surface temperature in Northeastern Asia. *Agricultural and Forest Meteorology*, *315*. https://doi.org/10.1016/j.agrformet.2022.108820

Lowery, B. R., Hanson, M. K., Garrett, G. R., Miller, D. J., Almudhhi, T., Cheung, F., Bajorek, S. M., Tien, K., & Hoxie, C. L. (2022). BENCHMARK DATA ON REFLOOD TRANSIENTS MEASURED USING THE NRC-PSU ROD BUNDLE HEAT TRANSFER (RBHT) TEST. *NURETH-19*, *35963*.

Mehr, V., Kahrobaee, S., & Avendano, M. (2021). Harnessing the Full Potential of Clean Energy: The Role of Southern California's Utility Distributed Energy Resource Pilots. *IEEE Power and Energy Magazine*, *19*(4). https://doi.org/10.1109/MPE.2021.3072816

Messay, E. G., Birhanu, A. A., Mulissa, J. M., Genet, T. A., Endale, W. A., & Gutema, B. F. (2021). Briquette production from sugar cane bagasse and its potential as clean source of energy. *African Journal of Environmental Science and Technology*, *15*(8). https://doi.org/10.5897/ajest2021.3006

Moazzami, N., Khadempir, S., Karimi-Maleh, H., Karimi, F., & Karaman, C. (2022). Enhanced methanol electrooxidation by electroactivated Pd/Ni(OH)2/N-rGO catalyst. *International Journal of Hydrogen Energy*. https://doi.org/10.1016/j.ijhydene.2022.01.248

Momete, D. C. (2018). Analysis of the Potential of Clean Energy Deployment in the European Union. *IEEE Access*, *6*. https://doi.org/10.1109/ACCESS.2018.2872786

Niu, S., Zhang, Z., Ke, X., Zhang, G., Huo, C., & Qin, B. (2022). Impact of renewable energy

penetration rate on power system transient voltage stability. *Energy Reports*, *8*. https://doi.org/10.1016/j.egyr.2021.11.160

Olabi, A. G., & Abdelkareem, M. A. (2022). Renewable energy and climate change. *Renewable and Sustainable Energy Reviews*, *158*. https://doi.org/10.1016/j.rser.2022.112111

Otsuka, K., & Cheng, F. T. (2022). Embryonic forms of private environmental governance in Northeast Asia. *Pacific Review*, *35*(1). https://doi.org/10.1080/09512748.2020.1811372

Popov, S. P. (2022). Methodological approach to the study of the electro-hydrogen system in Northeast Asia. *International Journal of Hydrogen Energy*, *47*(28). https://doi.org/10.1016/j.ijhydene.2022.02.191

Punt, M. B., Bauwens, T., Frenken, K., & Holstenkamp, L. (2022). Institutional relatedness and the emergence of renewable energy cooperatives in German districts. *Regional Studies*, *56*(4). https://doi.org/10.1080/00343404.2021.1890708

Rajan, P., & Jeevananthan, S. (2022). A new partially isolated hybrid output of multiport multilevel converter for photovoltaic based power supplies. *Journal of Energy Storage*, *45*. https://doi.org/10.1016/j.est.2021.103436

Ramey, K. M., Margulis, M., Read, N., Shwageraus, E., & Petrovic, B. (2022). Impact of molybdenum cross sections on FHR analysis. *Nuclear Engineering and Technology*, *54*(3). https://doi.org/10.1016/j.net.2021.09.021

Ren, B., & Lucey, B. (2022). A clean, green haven?—Examining the relationship between clean energy, clean and dirty cryptocurrencies. *Energy Economics*, *109*. https://doi.org/10.1016/j.eneco.2022.105951

Ridha, H. M., Hizam, H., Mirjalili, S., Othman, M. L., Ya'acob, M. E., & Abualigah, L. (2022). A Novel Theoretical and Practical Methodology for Extracting the Parameters of the Single and Double Diode Photovoltaic Models. *IEEE Access*, *10*. https://doi.org/10.1109/ACCESS.2022.3142779

Romero-Castro, N., Miramontes-Viña, V., & López-Cabarcos, M. Á. (2022). Understanding the Antecedents of Entrepreneurship and Renewable Energies to Promote the Development of Community Renewable Energy in Rural Areas. *Sustainability (Switzerland)*, *14*(3). https://doi.org/10.3390/su14031234

Sasmaz, M. U., Sakar, E., Yayla, Y. E., & Akkucuk, U. (2020). The relationship between renewable energy and human development in OECD countries: A panel data analysis. *Sustainability (Switzerland)*, *12*(18). https://doi.org/10.3390/SU12187450

Sendstad, L. H., Hagspiel, V., Mikkelsen, W. J., Ravndal, R., & Tveitstøl, M. (2022). The impact of subsidy retraction on European renewable energy investments. *Energy Policy*, *160*. https://doi.org/10.1016/j.enpol.2021.112675

Shahbaz, M., Sinha, A., Raghutla, C., & Vo, X. V. (2022). Decomposing scale and technique effects of financial development and foreign direct investment on renewable energy consumption. *Energy*, *238*. https://doi.org/10.1016/j.energy.2021.121758

Sharma, A., & Banerjee, R. (2021). Framework to analyze the spatial distribution of the labor impacts of clean energy transitions. *Energy Policy*, *150*. https://doi.org/10.1016/j.enpol.2021.112158

Shen, J., Li, K., Cui, Z., zhang, F., Yang, K., & Wang, C. (2022). Improvement of summer

precipitation simulation in China by assimilating spring soil moisture over the Tibetan Plateau. *Theoretical and Applied Climatology*, *147*(1–2). https://doi.org/10.1007/s00704-021-03840-5

Sherif, M., Ibrahiem, D. M., & El-Aasar, K. M. (2022). Investigating the potential role of innovation and clean energy in mitigating the ecological footprint in N11 countries. *Environmental Science and Pollution Research*, *29*(22). https://doi.org/10.1007/s11356-021-18477-0

Sovacool, B. K., Hess, D. J., Cantoni, R., Lee, D., Claire Brisbois, M., Jakob Walnum, H., Freng Dale, R., Johnsen Rygg, B., Korsnes, M., Goswami, A., Kedia, S., & Goel, S. (2022). Conflicted transitions: Exploring the actors, tactics, and outcomes of social opposition against energy infrastructure. *Global Environmental Change*, *73*. https://doi.org/10.1016/j.gloenvcha.2022.102473

Szabo, J. (2022). Energy transition or transformation? Power and politics in the European natural gas industry's trasformismo. *Energy Research and Social Science*, *84*. https://doi.org/10.1016/j.erss.2021.102391

Tian, S., & Chang, S. (2020). An agent-based model of household energy consumption. *Journal of Cleaner Production*, *242*. https://doi.org/10.1016/j.jclepro.2019.118378

Törnroth, S., Wikberg Nilsson, Å., & Luciani, A. (2022). Design thinking for the everyday aestheticisation of urban renewable energy. *Design Studies*, *79*. https://doi.org/10.1016/j.destud.2022.101096

Usman, A., Ullah, S., Ozturk, I., Chishti, M. Z., & Zafar, S. M. (2020). Analysis of asymmetries in the nexus among clean energy and environmental quality in Pakistan. *Environmental Science and Pollution Research*, *27*(17). https://doi.org/10.1007/s11356-020-08372-5

Wang, Q., Dong, Z., Li, R., & Wang, L. (2022). Renewable energy and economic growth: New insight from country risks. *Energy*, *238*. https://doi.org/10.1016/j.energy.2021.122018

Wang, R., Gentine, P., Li, L., Chen, J., Ning, L., Yuan, L., & Lü, G. (2022). Observational Evidence of Regional Increasing Hot Extreme Accelerated by Surface Energy Partitioning. *Journal of Hydrometeorology*, *23*(3). https://doi.org/10.1175/JHM-D-21-0114.1

Wang, X., Zhao, Y., Wang, L., Peng, W., Feng, J., Li, D., Su, B. J., Juang, J. Y., Ma, Y., Chen, Y., Hou, F., Zhou, S., Liu, H. K., Dou, S. X., Liu, J., & Liang, J. (2022). Regulating the Electronic Configuration of Supported Iron Nanoparticles for Electrochemical Catalytic Nitrogen Fixation. *Advanced Functional Materials*, *32*(21). https://doi.org/10.1002/adfm.202111733

Wen, J., Okolo, C. V., Ugwuoke, I. C., & Kolani, K. (2022). Research on influencing factors of renewable energy, energy efficiency, on technological innovation. Does trade, investment and human capital development matter? *Energy Policy*, *160*. https://doi.org/10.1016/j.enpol.2021.112718

Xu, J., Xi, R., Xu, X., Zhang, Y., Feng, X., Fang, X., & Wang, X. (2020). A2B2O7 pyrochlore compounds: A category of potential materials for clean energy and environment protection catalysis. In *Journal of Rare Earths* (Vol. 38, Issue 8). https://doi.org/10.1016/j.jre.2020.01.002

Yang, Z., Zhang, Q., Liao, W., Bak, C. L., & Chen, Z. (2023). Harmonic Injection Based

Distance Protection for Line With Converter-Interfaced Sources. *IEEE Transactions on Industrial Electronics*, *70*(2). https://doi.org/10.1109/TIE.2022.3159971

You, V., & Kakinaka, M. (2022). Modern and traditional renewable energy sources and CO2 emissions in emerging countries. *Environmental Science and Pollution Research*, *29*(12). https://doi.org/10.1007/s11356-021-16669-2

Zeng, L., He, H., Chen, H., Luo, D., He, J., & Zhang, C. (2022). 3D Printing Architecting Reservoir-Integrated Anode for Dendrite-Free, Safe, and Durable Zn Batteries. *Advanced Energy Materials*, *12*(12). https://doi.org/10.1002/aenm.202103708

Zhang, T., Qu, Y., & He, G. (2022). Pricing Strategy for Green Products Based on Disparities in Energy Consumption. *IEEE Transactions on Engineering Management*, *69*(3). https://doi.org/10.1109/TEM.2019.2907872

Zhang, X., Zhang, S., & Lu, L. (2022). The banking instability and climate change: Evidence from China. *Energy Economics*, *106*. https://doi.org/10.1016/j.eneco.2021.105787

Zhao, Y., Chen, R., Zang, P., Huang, L., Ma, S., & Wang, S. (2022). Spatiotemporal patterns of global carbon intensities and their driving forces. *Science of the Total Environment*, *818*. https://doi.org/10.1016/j.scitotenv.2021.151690

Zhu, Q., Chen, X., Song, M., Li, X., & Shen, Z. (2022). Impacts of renewable electricity standard and Renewable Energy Certificates on renewable energy investments and carbon emissions. *Journal of Environmental Management*, *306*. https://doi.org/10.1016/j.jenvman.2022.114495

Zhu, Y., Shen, W., Zhang, C., Ge, Y., & Cai, D. (2021). Forecasting method of clean energy development potential considering sector coupling. *E3S Web of Conferences*, *329*. https://doi.org/10.1051/e3sconf/202132901024