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Energy socialization: The Northeast Asia energy grid and the emergence of regional energy cooperation framework

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ABSTRACT

Over the past decade, global energy generation via clean resources has grown considerably. An energy dependent region, Northeast Asia (NEA), in this regard, has made significant progress in clean energy development. However, a region-wide energy cooperation is still far from being realized due, in large part, to a lack of viable framework which helps coordinate, among others, infrastructure development, institution build-up, market connectivity and regulation, and financing. In this paper, through an examination of the potential role of an energy grid interconnection, we aim to explore the causal links between clean energy development in NEA and the emergence of a regional energy cooperation framework. We observe that the energy complementarities and complexities in NEA both facilitate and require the establishment of a regional energy grid, which would have far-reaching economic and political implications. Economically, grid development may encourage energy-related investment, innovation, efficiency and environmental protection. Geopolitically, regional grid networking may contribute to confidence building, institutionalization and de-securitization. Thus, we argue, as a process of energy socialization, the formation of a comprehensive and institutionalized cooperation framework in NEA would lead to broad implications for regional development, security and community build up.

1. Introduction

Utilization of clean energy resources for power generation and the transmission and distribution of the generated electricity efficiently has gradually become an important development agenda for Northeast Asian (NEA) states. However, the region lacks a unified approach to clean energy (CE) [1] as a networked commodity since each actor stands at disparate stages of progress in their energy policy formulation, infrastructure development, technological capacity, and financial strength. In addition to internal factors, external geopolitical issues also impact negatively the potential of the creation of a regional energy network. Nevertheless, as with other regions such as Europe, Central Asia and Latin America, in NEA, too, there has been a growing interest on part of the business communities, governments, track two institutions, academia, and the general public toward the question of capitalization on clean resources and systems for power generation, transmission and distribution in a way that is sustainable, acceptable and affordable [2].

While each of the above actors has their own priorities, in general, sustainability refers to long term interest generation through clean energy development, which calls for careful and integrative planning of energy infrastructure and systems. Acceptability requires that these resources be exploited with minimum impact on the environment, which calls for, among others, continued innovation in clean energy-related technologies and services. Affordability, on the other hand, refers to cost effectiveness of clean energy for the manufacturers, governments, service providers and consumers. Affordability, therefore, requires innovation and other policy related strategies such as incentives and subsidies. Meeting the above three criteria is more challenging under new energy than it is under traditional energy. Needless to say, the specific nature of clean energy resources (especially renewables such as photo-voltaic and wind) necessitate concrete cooperative action at the state, inter-state, and regional levels as well cooperation among non-state actors because of the innate complexity that involves technology and innovation, financing, and pricing to ensure sustainable, acceptable and affordable power generation, transmission and distribution.

The build-up of a grid connected new energy infrastructure in NEA provides the required linkage between CE and a more institutionalized regional energy cooperation. A viable national grid network is the prerequisite to construct cross-border connections that would over time lead to a web of region-wide interconnectivity. Therefore, in addition to

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economic incentives that regional grid connectivity offer, national conditions such as the existing energy and distribution infrastructures, financial and technological capabilities, and environmental awareness are significant to kick-start CE development in NEA. When the national conditions are in place at the minimum, then standardization and interoperability of country-based grid systems for cross-boundary connections would be the next major task. The associated challenges (such as financing the costs of transmission lines and converter stations, setting up pricing mechanisms, adjusting seasonal fluctuations in the availability of generation and electricity generation capacity, etc.) [3] to ensure national, cross-national and region-wide grid connectivity would only be met through communicative and cooperative action. Hence, grid development may serve as a catalyst for coordinated regional action and the emergence of an institutionalized energy regime in NEA, which may eventually transform into an economic community of which energy cooperation an integral part. This process, accordingly, can be characterizes as socialization in which grid interconnection acts as a nexus for a broader and deeper cooperation.

CE-related grid development in NEA has been a relatively recent phenomenon, hence, research on the issue small (albeit growing) compared to literature on traditional energy resources and cooperation within the Northeast Asian context [for a summary, see Refs. [4–8]]. In one of the pioneering studies, Streets discusses extensively the question of the impact of electricity grid in NEA, analyzing a number of environmental benefits at the local, regional and global levels that a regionwide grid network would offer [9]. However, the paper does not address the political, technical and economic feasibility of such a cooperation, a question which is tackled by Choo [10], Lee [11] and Hippel et al. [12] in their respective studies. For example, whereas Choo's article does not specifically debate challenges related to grid connectivity, it nonetheless presents a comprehensive comparative analysis along the two major conceptual lines of “general energy cooperation” and “energy security cooperation” [[13], p. 93]. In another early study on the feasibility of grid connectivity in NEA, Kanagawa and Nakata look at Korea and Japan [14]. The authors develop an energy interconnection model for electricity systems of the two countries, concluding that the positive economic outcomes achieved through in the modelling could also be generated across the region. Finally, in a much recent study, Tuballa and Abundo introduces an overview of smart grid in terms of its functions as well as related technologies and policies in a number of country-based case studies [15]. Thus, although the paper does not include in its scope inter-state or intra-regional grid connectivity issues, the research nonetheless offers a broad overview and rich bibliography.

Research on clean-energy driven regionwide grid development generally approaches the issue from three main aspects: economic, technical and political. In this regard, while economic and technical aspects are stressed in the literature, geopolitical underpinnings of intra-regional grid connectivity are less emphasized. In one of the most comprehensive studies on renewable energy (RE) generation, storage and transmission via sub-regional and regional grids, Breyer *at al.* examine a Northeast Asian super grid based on a simulation in which solar and wind resources from the Gobi Desert are transmitted along 14 sub-regions in NEA [16]. The findings provide a strong case for renewable energy-based grid network development, which is also voiced in another study where the authors indicate that the cost advantage of a RE-based grid system would help decrease costs of electricity regardless of installation costs and differences in electricity prices in related countries [17].

Findings from several other studies, however, approach the question more cautiously. Otsuki, for instance, states that the initial high investment costs and route uncertainties (especially with respect to the DPRK in the case of NEA) would render across border grid interconnections economically less viable although considerable environmental benefits could be accrued provided that strong policy impetus were present [18]. Another major issue debated in a case study by Zeng et al. is the question of lagging in grid build-up following speedy RE development, which has led to management and efficiency problems in China [19]. Other studies also point out similar transmission problems of the generated wind energy [20]. In any case, most of the studies on electricity grids fall short of offering a more comprehensive approach in which political, technical and economic dimensions of CE-based grid development are analyzed in terms of risks, challenges and prospects.

Accordingly, the present research represents an attempt to address the perceived gap by contributing to the existing CE-based electricity grid literature by theorizing a clean energy-regional cooperation nexus in which regionwide grid networking acts as an essential link between the two. It aims to explore the status of clean energy development in NEA by looking at the individual actor's particular conditions, including their domestic policies, technological innovation capacities and regional integration strategies, in an effort to draw a detailed picture of the progress (or lack thereof) toward achieving an energy community in the NEA sub-region. For this end, it examines the progress made so far with respect to national, inter-state and intra-regional grid development, economic advantages of a regional clean energy framework, existing political challenges for energy cooperation, and prospects for future. It analyzes the role of clean energy in NEA and introduces the concept of “energy socialization” to account for the larger economic and political implications of energy cooperation for the regionalization process.

In this paper, we treat clean energy development as the independent variable that has an impact on the potential emergence of a common energy framework in NEA. We identify the development of an energy grid system as the linking agent to facilitate the transition from disparate and uncoordinated clean energy infrastructures to a regionally-unified electricity interconnection, involving generation, transmission, distribution, pricing and trading. In the long run, we maintain, through a process of socialization, clean energy-driven grid networking may lead to a NEA-wide energy framework with all political, economic and social actors represented in an institutionalized setting [21]. This energy framework, in the long run, may act as one of the integral components of NEA economic community.

In the ensuing pages, we first analyze clean energy development in NEA, taking into account and examining China, Japan, South Korea [22], Russia and Mongolia, with the aim of drawing a general picture of energy policy and security in NEA and investigating country-specific energy patterns such as national policies, available clean energy resources, and electricity investment, production and consumption rates. Also, in this chapter, we pay particular attention to the issue of compatibility between those actors with abundant electricity production via clean resources (including potential) and low consumption, and those with less clean resource endowments and high consumption (or, as in the case of China, high production but even higher consumption).

In the following section, we investigate in detail the critical role of an electricity grid in a “clean energy-regional economic integration” nexus in NEA. To this end, we analyze the domestic and regional (economic, technical, and political) dimensions of NEA energy grid. A more in-depth look at the potential energy community build up is provided in the last chapter. Here, we first examine the role of grid networking for the emergence of a regional energy framework which would involve a high degree of institutionalization, coordinated management of systems and platforms, and technical and financial cooperation. Then we look at the potential challenges for and obstacles to (domestic and regional) electricity grid interconnectivity in NEA. We end our discussion with a note on the future course of energy cooperation in NEA.

2. Clean energy development in Northeast Asia

Energy security situation in NEA offers a complex but complementary picture. Complexity arises from disparate degrees of industrial development and financial condition, and varying levels of investment in research and development of clean energy technologies. It appears that each actor in the region has certain strengths and weaknesses. For instance, China enjoys a growing consumption market, command huge financial reserves for scientific research and development, and has a quality pool of human capital; however, its energy rich regions and consumption centers are distributed unevenly. Japan, on the other hand, is an advanced industrial economy with high per capita income and a technologically advanced industrial fundament while it suffers from a declining population and consumption base. As for Russia, although it still enjoys high status in certain critical sectors such as metallurgy, rocketry and advanced engines, and is a middle-income economy, it lacks behind other NEA neighbors mentioned in this study except Mongolia in new technology investment and research, including clean energy. Thus, the scope of financial investment in energy, infrastructure development, potential market size and innovation capability varies considerably among the five nations. The existence of a heterogenous energy structure and differences in the levels of economic development, therefore, slow down energy cooperation, including cross border grid development.

Complementarity, on the other hand, encourages further cooperation due to obvious, if not matching, mutual benefits from cooperation [23]. In this respect, NEA can be grouped into three sets of states: The first is those with rich (real and potential) CE capacity (and overall electricity generation from traditional and hydro resources) in the excess of domestic demand. For instance, both Russia and Mongolia have considerable clean energy capacity and Russia is a net electricity exporter. The second group of states are those that lack considerable CE production capacity but command high consumption of energy generated mostly through conventional means such as fossil fuel-fired and nuclear. Japan and South Korea fit in this category. These states' total electricity consumption is high but its growth potential is moderate. And finally, in the third category is China, a major CE producing country but also world's largest consumer of electricity with a sizable and growing demand potential. Accordingly, strong complementarities encourage cooperation between (existing and potential) producers of electricity with low consumption and consumers of electricity with inadequate production but high consumption.

Stressing complementarities and the ensuing benefits may create the required momentum for cooperation on tackling the complexities of CE development that involve not only technologies related to generation platforms such as solar, wind or tidal energy, but also issues related to market arrangements and pricing, power system characteristics (such as load curves and generation dispatches) alignment, and grid networking, which require advanced and expensive technologies such as smart grids to streamline energy generation, transmission and distribution (such as wide area network management technologies, or WAMs) by utilizing advanced information and communication technologies, and ultra-high voltage DC (UHVDC) installation for large geographical (cross border and regional) transmission. The benefits include revenue creation through peak share and power transaction, regulation and management of power supply and demand in the region, and "joint utilization of … mutually supplementary seasonal excessive capacities" [24].

2.1. Russia

Among the five countries analyzed in this paper, the one with the most expansive energy production capacity is Russia. World's fourth largest producer and sixth largest consumer of primary energy in 2013, Russia accounted for 10% of global energy production and 5% of energy consumption. The difference between the two indicators in favor of production demonstrates Russia's energy export capacity. For example, in 2013, Russia's electricity production (1000 billion kilowatt-hours (BkWh)) was considerably higher than its consumption (878 BkWh), allowing the country to export 18 BkWh of electricity [25] even though, at times, Russia also imports electricity (e.g., from Nordic countries, although fluctuating over the years) due to import cost-effectiveness [26]. For instance, in 2014, Russia imported 570 thousand tons of oil equivalent electricity while exporting 1262 thousand tons of oil equivalent electricity via numerous cross-border connections. In 2014, 23.6% of Russia's electricity export went to China, followed by Lithuania, Finland, Kazakhstan and Belarus (23.1%, 17.4%, 11.9% and 10.6% of the total exports, respectively). Mongolia, on the other hand, received 3.9% of Russian electricity export [27]. Thermal power (oil, natural gas, and coal) dominates nearly 70% of Russia's electricity production. In 2014, natural gas accounted for 50.2% of total electricity production, followed by nuclear (17.0%), hydro (16.5%), and coal (14.9%) [28]. Renewable energy (RE) other than hydroelectric plants accounted for less than 1% of total power generation capacity [29].

Due to the diverse natural resources in a vast landmass, Russia's energy capacity is spread across the country. However, installed RE capacity other than hydro is still negligible. In 2012, CE including hydro constituted about 3% of total primary energy supply (TPES). According to Global and Russian Energy Outlook to 2040, the share of RE resources will reach only 2% of total production by 2040 [30]. Nonetheless, Russia has considerable clean energy potential, including hydro, wind, solar and biomass. The coastal regions along the Pacific and Arctic Oceans, the Caspian, Azov and Black Seas provide economically viable potential wind resources although they are currently underutilized. Indeed, as of 2016, only four wind farms were operating in the country [31]. Photovoltaic energy potential is high in the regions such as the Black Sea and the Caspian [32]. One significant obstacle to RE development is that majority of the RE resources are located far from large population centers, therefore, a viable grid network is required to ensure transmission.

Whereas Russia's solar and geothermal energy production has achieved moderate grown over the past few years, power grid development in the country has been rather stunted due to limited investment and innovation. Indeed, RE connectivity to the grid has remained a major challenge in Russia because the grid network is "congested, undersized, monstrously inefficient, slow to repair, and in need of $750 billion of investment in the next two decades" [33]. The Russian energy grid needs investment to ensure interconnections between regional energy systems. Furthermore, the country's power generation installations such as thermal and hydro are old and in need of major renovation and upgrade [34]. However, the Western sanctions on the country in the aftermath of the annexation of Crimea in 2014 have further undermined grid build up and maintenance to a certain degree although the void is likely to be filled by other countries, especially by China.

2.2. Mongolia

Mongolia is considered a resource rich country, including CE such as wind, solar and hydro. However, currently, the country's electricity production relies heavily on coal (92.3%) and oil (4.5%). Solar energy generation started in 2007 and reached 5 megawatt (MW) by 2014 whereas wind energy production grew from 0.6 MW in 2007 to 51.1 MW in 2014. In 2013, the share of RE in total electricity generation reached 1.96% and percentage of TPES stood at 3.77% [35]. According to estimates, the country's total energy potential from variable resources is big enough to meet China's total energy demand in 2030 [36]. In recent years, Mongolian energy industry has witnessed moderate growth in CE's share in total production, especially with the inclusion of new wind and solar power stations into national grid. However, most of the deployed energy remained limited to small grid distribution. Of the nine solar power systems that have been built in the country as of 2016, only two were connected to the grid [37].

Mongolia has comprehensive RE targets to account for 20% of the country's power generation capacity by the mid-2020s since most of the potential energy sources have not been fully explored. Therefore, the country imports energy from neighboring states, especially from China and Russia, to meet the electricity demand. Mongolia's electricity imports have increased over the years while its exports declined. In 2013, 75.7% of Mongolia's total electricity imports was sourced from China, the remaining 24.3% coming from Russia. In the same year, Russia was the only destination for Mongolian electricity exports [38]. Currently, coal is the primary source of energy in the country, followed by hydropower, oil, biomass and imports.

An important drawback that Mongolian energy sector experiences is the underdeveloped grid system [39]. In fact, Mongolian grid is far from meeting the national demand and some regions have no generation capacity, relying entirely on imports from Russia. Currently, in addition to two cross-country interconnectors through which Mongolia imports electricity from Russia, there are five cross-border grid connections across Mongolia-China border [40]. There has been investment in energy infrastructure over the years to connect off-grid areas, which includes plans for building 7000 km of power lines and increasing the share of renewable sources to 20% of the total generated electricity [41].

2.3. Japan

Japan is the third largest energy consumer in Asia and is entirely self-reliant in terms of electric production even though its electricity generation has been decreasing since 2007 due to declining consumption and increasing efficiency [42]. Hydrocarbon resources for energy generation are imported as the country's indigenous capacity is minimal. While nuclear-generated power accounted for one-third of the country's electricity capacity in the past, after the 2011 earthquake and the Fukushima disaster, the share of nuclear power plants in total electricity production has been reduced significantly with natural gas and coal replacing the lost capacity (In 2014, electricity from nuclear power halted entirely) [43]. In 2015, fossil fuels (natural gas 39.2%; coal 34%; oil 9%) represented more than 80% of Japan's total generation while hydro power added more than 8% to the total power generation and nuclear power accounted for less than 1%. The share of clean energy has grown over the years (16.9% in 2015), hydro, solid biofuel and solar accounting for most of it. In 2015, hydro power's share was 8.4% in total power generation, followed by biofuels (4.1%), solar (3.6%), wind (0.5%), and geo-thermal (0.3%) [44].

Japan is only behind China and Germany in installed photovoltaic capacity and among the top seven countries in bioenergy capacity [45]. However, Japan is still considered to be lacking in clean energy development, which is largely ascribed to inadequate grid capacity [46]. For example, Japan's onshore wind energy potential is located in rural areas where demand is lower; hence, the existing grid is insufficient to transmit the generated energy [47]. The Japanese government plans further investment in the electric transmission and distribution networks to increase efficiency, to manage supply and demand differences between regions by reinforcing connectivity, and to better integrate renewable energy into the national grid. Japan does not have any grid connectivity with neighboring countries, hence, it does not import or export electricity.

2.4. South Korea

Like Japan, Korea is self-sufficient in terms of electricity production and consumption without any import or export [48]. In 2015, about 95% of Korean electricity generation came from hydrocarbons and nuclear. Coal accounted for 40% of generation mix, followed by nuclear power, natural gas and oil at 31%, 19%, and 6%, respectively. Clean energy resources, on the other hand, took up 4% of total generation while hydropower accounted for 1% [49]. In 2011, Korea had the lowest share of energy from CE among International Energy Agency (IEA) member states, with 1.5% of total energy generation coming from renewable resources. However, the share rose to 5% by 2015. In 2012, the Korean government adopted Renewable Portfolio Standards, requiring power suppliers to raise the obligatory share of renewables in their portfolio to 10% by 2022 [50]. In 2014, waste, bio, and hydro energy constituted 90.6% of total CE generation while photovoltaic and others accounted for the remaining 9.4% [51]. Korea plans to generate 13.4% of its electricity from renewables by 2035 with a greater focus on solar and wind in place of waste energy [52].

Although there has been robust growth over the past five years, Korea's renewable energy capacity is considered low as compared to the four other NEA nations. However, the country's grid development has been successful and is considered one of the most efficient in the world as the government continues to emphasize research and development in energy infrastructure. For instance, Seoul initiated a smart grid program, which has been pilot tested on Jeju Island since 2009, creating one of the world's largest smart grid communities in which various smart renewables technologies such as solar and wind energy are put into use. Thus, Korea plans to achieve nationwide smart grid by 2030 [53]. However, Korea does not have any cross-border transmission even though a number of proposals have been made to connect its grid with neighboring countries. Among others, the unfavorable geopolitical situation on the Korean Peninsula has slowed down such efforts although the energy landscape may eventually change if the ongoing political rapprochement between the two Koreas registers tangible success.

2.5. China

China is the largest producer and consumer of electricity in the world (surpassing the US on both categories in 2011) and accounts for more than 50% of production and consumption in Asia. China's electricity consumption is much higher than its production, hence the country is a net importer. According to Enerdata, in 2015, China's electricity trade had a deficit of 9 TWh and has demonstrated deep fluctuations over the past 15 years [54]. In 2014, China imported electricity from Russia (48.7% of the total imports), Myanmar (14.2%), DPRK (2.5%), while the remaining was sourced from Hong Kong province (34.6%). The same year, major foreign destinations for exports were Vietnam (9.9%), Mongolia (8.0%), Myanmar and Laos (each 1.2%), and DPRK (0.4%). The bulk of the exports (79.4%), however, went to Hong Kong and Macao provinces [55].

China's energy generation relies heavily on hydrocarbons. In 2013, thermal power generation accounted for more than 78% of total generation with coal as the primary fuel for electricity. Although coal's share in total electricity production has declined over the past few years from the peak of 80%, it still accounted for more than 70% of national production in 2014, according to data from Asia-Pacific Energy Portal. The share of natural gas, on the other hand rose to 2.2% of the total, followed by oil at a declining rate of 0.1%. In the same year, nuclear energy accounted for 2.3% [56].

The weight of CE resources in China's electricity production has grown over the past decade with immense government support through favorable policies and market regulation [57]. The country now leads the world in both installed renewable energy capacity and production. In 2015, CE represented nearly one fourth (24.7%) of the nation's entire production with hydro power holding the largest share at about 20%. Wind energy accounted for 3.3%; biomass, 0.9%; and solar, 0.7% [58]. The explosive growth in renewable energy generation, however, has encountered setbacks as power grid development lagged behind generated renewable energy capacity [59]. For example, in 2010, about 30% of the country's installed wind power capacity did not have access to grid [60]. In response to this setback, China has laid out extensive plans to update the national grid and add new transmission and distribution capacity, such as the planned $31 billion investment in smart grid infrastructure in Xinjiang province between 2015 and 2020 [61]. Other than the national grid, China also plans to reinforce grid interconnectivity with neighboring countries, including Russia, Mongolia, Vietnam, Myanmar, Kazakhstan and Laos, which is considered important given the fact that the country partly depends on imports for electricity as its domestic production cannot meet the ever-growing demand [62].

3. Electricity grid as a linkage for energy cooperation in Northeast Asia

It is understood from the brief introduction above that the NEA region's CE landscape is diverse and uneven, indicating both complexities and complementarities. Russia is the primary energy actor, trading electricity with eleven neighboring countries [63]. Russia's domestic electricity is transmitted and distributed via seven power systems as well as an independent power system (IPS) in the east of the country. Similarly, seven power grid systems are functional across China and new UHV lines are being built in response to the diverse location of the country's electricity distribution and load centers [64]. In Mongolia, four independent electricity grid systems provide the country's power supply, achieving 95% electricity access rate [65]. As for Japan and Korea, both nations have well-developed national grid systems as compared to their developing NEA neighbors. In Japan, ten grid systems are installed (two HVDC lines) along the island-state with frequency differing between the East (50 Hz) and West (60 Hz) of the country [66]. In Korea, a 750 kV UHV transmission line traverses between from the west to the east of the nation.

NEA lags behind in creating electricity interconnection via a regional super grid in which large scale power is transmitted over very long distances. The regional response to the challenges (sorting out complexities and capitalizing on complementarities) has been less promising as compared to other economic regions such as the European Union (especially with respect to the Nord Pool) [67] and the Commonwealth of Independent States (CIS) [68]. However, recently, in NEA, too, there has been a growing momentum toward the creation of a regional CE cooperation framework, involving both public and private actors. The primary focus of the debate on the issue is infrastructure which includes technologies related to CE generation, transmission and distribution. The question of distribution to ensure cross border energy sharing, naturally, raises the issue of energy grid build up.

We hold that development of an energy grid provides the vital linkage between CE energy generation and regional energy regime buildup as it encourages investment in CE technologies to lay out a cross-borders grid network in NEA. Recent proposals for greater energy integration by various regional stakeholders indicate the genesis of such momentum. As will be detailed in the ensuing paragraphs, what has been achieved so far may be viewed as less than satisfactory, however, considering the enormity of the geopolitical stumbling blocks and the common yet complex history in the region, the initial steps are nonetheless encouraging. As much significant, in this case, as the actual work carried out on the ground is the emergence and sustenance of a debate and recognition by the involved parties of a need for a serious upgrade in the region's connected and streamlined energy infrastructure. Considering the Asian way of incremental and consensus-based policy adjustment and institutionalization, the existing debate and gradual process of socialization is very significant.

Currently, there is not a unified grid network connecting the five nations in NEA. However, there have been numerous cross-country grids between Mongolia, China, and Russia as well as a number of connections between Russia, China and other neighboring states in Central and Southeast Asia. According to a 2017 report by Global Energy Interconnection Development and Cooperation Organization (GEIDCO), the existing transnational interconnections connect China, Russia and Mongolia although the scale of transmission is relatively small. Via 12 transnational transmission lines, the three states conduct energy trade. China's State Grid Company imports electricity from Russia and exports to Mongolia. Russia also provides electricity to Mongolia (see Table 1).

The anticipated outcome of national grid development in NEA is the formation of a regional interconnectivity structure, which is being increasingly recognized by the primary actors. For example, at the UN Sustainable Development Summit in September 2015, Chinese President Xi Jinping put forward the idea of a global energy interconnection to promote clean energy and international collaboration [69]. The plan involves three geographically-defined stages in the order of domestic, intracontinental, and inter-continental grid connectivity. Obviously, for intracontinental grid to become feasible in NEA, individual states need to achieve a certain level of national grid infrastructure development. At the moment, NEA does not present an even picture even though significant steps are being taken to upgrade electricity infrastructure in individual countries, including investment in CE technologies, UHV AC/DC transmission lines and smart grid systems. Thus, along with developments in energy infrastructure at the national scale, intraregional interconnections would improve. Currently, however, interconnections in NEA are still limited to cross-border bilateral energy trade as a unified electricity network and market does not exist in the region.

Table 1
The existing transnational power interconnection lines in Northeast Asia.
Source: Data collected by authors from "Technology and Prospects for Cross-Regional Power Networks, GEIDCO, 2017, p. 34 and Liu Chenya, *Global Energy Interconnection,* China Electric Power Press: Beijing, 2015, p. 315 (In Chinese).

Interconnection projects	Voltage (kV)
Gusinoozerskaya (Russia)–Dahl Khan (Mongolia)	220
Kharanorskay GRES(Russia)–Choba Hill (Mongolia)	110
Chadan (Russia)—Khandagaity—Ulanngom (Mongolia)	110
Braque Vesnsk (Russia)—Heihe (China)	500/220/110
Sivakian (Russia)—Sirius/Ai Hui (China)	110
Braque Vesnsk (Russia)– Sirius/Ai Hui (China)	2*220
Amur (Russia)—Heihe (China)	500
Mongolia–China	2*220
Habibiga (Mongolia)– Hulunbeier (China)	10
Baiyinhushuo (Mongolia)– Hulunbeier (China)	10
Songbell (Mongolia)– Aershan City (China)	10
Cobbdo province (Mongolia)– Altai Qinghe County (China)	35

Since the 1990s, various NEA countries have made proposals regarding a comprehensive regional electricity connectivity. Whereas domestic, regional and wider international conditions prevented the realization of any of these plans, the continuing regional energy interconnectivity debate has reinforced the emergence of a discourse. One of the earliest proposals in this respect was made by Energy Systems Institute of Siberian Branch of the Russian Academy of Science (ESIS-BRAS), which, under the concept of Northeast Asian Electrical System Ties (NEARST), suggested working on investment and enhancing the reliability of power systems in the region. The Russian plan included two phases: The first included launching an energy bridge with Japan, and, the second, establishing an electricity market with Mongolia, China and South Korea. Thus, as an energy rich nation spanning across Eurasia, Russia continued to support grid networking in NEA and beyond.

Similarly, Mongolian government, too, places major importance to grid development, especially to the question of upgrading and integrating its wind and hydro power capacity with, first and foremost, China, and the rest of NEA countries via a regional transmission network. In fact, the deepening cross-border energy cooperation between China and Mongolia serves as a demonstration of practical benefits of trans-border energy communication [70]. Similarly, Japan, which consumes the most expensive electricity among the five NEA nations, and South Korea, which hopes to serve as an electricity grid bridge between China and Japan, have shown interest in the idea of a NEA energy grid. Although still not officially endorsed and supported via concrete legislative action by the respective governments [[71], p. 43], business and academic communities in both countries have shown interest in grid connectivity (albeit with certain security reservations [72,73]), and taken certain steps towards the idea of adding the continental NEA electricity from wind, solar and hydro into their national power grid to ensure energy security by better responding to problems such as electricity supply and demand imbalances and transmission obstructions [74].

Accordingly, advances in clean energy production, storage and transmission technologies as well as growing awareness regarding ecological protection have facilitated more concrete action. Especially from the 2010 onward, several major proposals were put forward by various governmental and non-governmental agencies. The concepts proposed for power connectivity vary in terms of their primary purpose and geographical scope. For instance, the focus of the three proposals, namely, Asia Super Grid (ASG), Asia Pacific Power Grid (APPG), and Gobitec and Asian Super Grid (Gobitec), have been clean energy interconnection. Pan-Asian Energy Infrastructure concept, on the other hand, suggests increased connectivity and a transition to clean-burning fuel, including natural gas, whereas the focus of the Northeast Asia Super Grid is renewable and thermal sources.

These plans also differ in terms of their suggested geographic scope. In this regard, Japan Renewable Energy Foundation (JREF)'s ASG and Japan Policy Council's APPG are the most comprehensive plans in terms of their proposed geographic scope, suggesting coverage across Northeast, Southeast and South Asia. NEASG (proposed separately by KEPCO and Skoltech) and Gobitec are more conservative in their geographic scope, covering exclusively China, Japan, Korea, Russia, and Mongolia [75]. Finally, the report prepared by GEIDCO in 2016 proposes two connectivity routes for NEA in which power flows from Mongolia, Western China and Russia to the Korean Peninsula and Japan. The first planned route connects East Shenyang in China with Pyongyang, Seoul and Tokyo while the second route connects Yantai city in China's Shandong Province with South Korea and Japan. Both projects include submarine UHV (as well as overland) cables [76]. In fact, China has already begun to construct an undersea UHV transmission line for domestic connection, which is important to later expand the acquired experience and technology to connect NEA island states such as Japan, and in light of the present geopolitical situation on the Korean Peninsula, South Korea (see Table 2).

As important as the number of proposals over the years is the incremental rise of them in popularity and acceptance. The progress of these concepts lends support to the central theme of this paper, that is, energy socialization. Ever since the first proposal made in the late 1990s, a norm making process appears to be in effect. Especially in the case of China, which, while remaining a major component in each proposal, was initially not directly involved in any of them, the growing interest and participation by both state and non-state actors indicate a degree of endorsement, adaptation, and quest for a stakeholder status. For example, together with Korea Electric Power Corporation and Russia's PSJC Rosseti, China's State Grid Corporation joined the Asia Super Grid idea proposed by Japan's SoftBank. In September 2016, the four sides signed a Northeast Asia Power Network Cooperation Memorandum to pursue regional interconnectivity [77]. The conference also led to the establishment of the Global Energy Interconnection Development and Cooperation Organization (GEIDCO) with, Liu Zhenya, chairman of the State Grid of China, serving as the first president of the organization. In October 26, 2016, GEIDCO held a Northeast Asia Power Networking and Cooperation Forum in Beijing.

The energy socialization process via clean energy generation and increased grid-enabled connectivity involves both domestic and regional dimensions. In this regard, we identify a number of potential advantages that can be classified under the two general dimensions that help facilitate the realization of a NEA energy framework. The domestic dimension includes investment, innovation, efficiency and environment. First and foremost, CE-driven grid development encourages investment in a variety of technologies and infrastructure. In this realm, NEA energy landscape is uneven: there are developed and developing states as well as those with better financial, technological and industrial capacity and those without. In most cases, countries with greater CE potential and much less consumption (Mongolia and Russia) and the ones with greater investment potential but much less resource endowments (such as Japan and South Korea) are not the same. Eastern Siberia and Far East regions of Russia have rich hydro, coal and natural gas potential. Also, Russian Arctic and Mongolia offer considerable solar wind energy potential. Once connected to a regional grid, these resources can be transmitted to demand centers in Northeast China, Korea and Japan. China, for its part, represents a special case due to its relatively rich CE resource potential, financial strength and industrial capacity. For instance, in 2015, among the leading RE (excluding large hydro) investor countries in the world, only China and Japan featured in the top ten [78].

In NEA, CE development and grid connectivity may encourage coordinated investment, following the global trend in which spending on RE (especially in wind power and increasingly in solar) has gradually shifted from developed to developing countries [79]. The changing landscape brings together various public and private institutions. Coordinated and common investment schemes would mean that a more even distribution of energy-related innovation in the region is eventually ensured, helping expand human capital base and distribute innovation and efficiency by integrating energy infrastructure, markets, standards and systems among countries with diverse technological capabilities. Transfer and share of technology would not only encourage further innovation in various industries such as electricity generation, storage as well as electric mass and private transportation, and smart city solutions, but also help streamline energy infrastructure and systems, and prevent grid idleness due to shortage in electricity, helping increase efficiency.

One critical advantage of grid connectivity is the diverse peak load seasons in NEA which enables "greater advantage of generating options with relatively low costs according to peak load differences among

Table 2
Major Northeast Asia grid interconnection proposals.
Source: Asia Pacific Energy Research Centre (APERC), Electric Power Grid Interconnections in Northeast Asia, 2015 (http://aperc.ieej.or.jp/) and the authors.

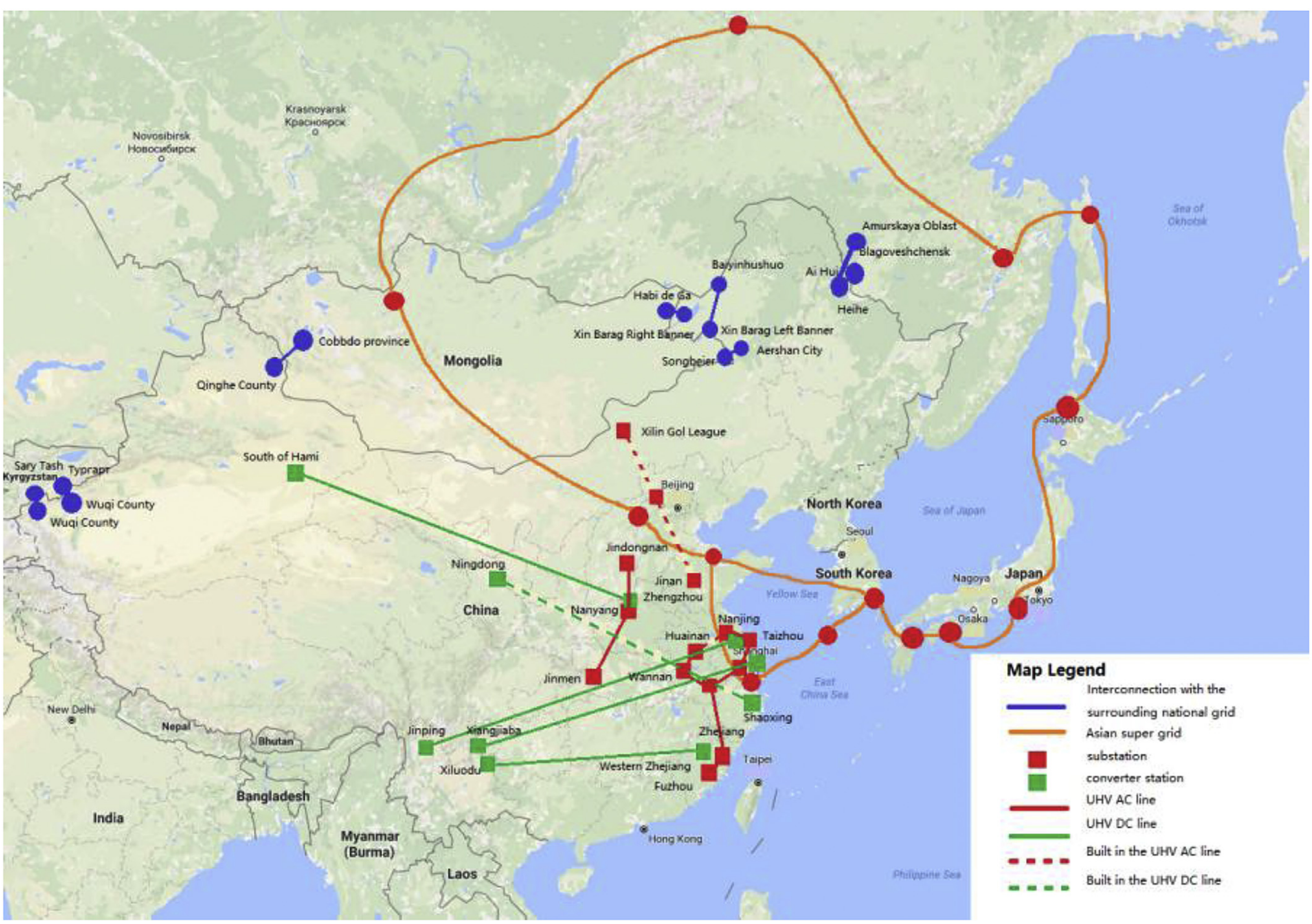
Year	Grid Name	Proposing Institute(s)/Country(ies)	Geographical Scope
1998	NEAREST (Northeast Asian Electrical System Ties)	Melentiev Energy System Institute, Siberian Branch of the Russian Academy of Science	China, Japan, Korea, Mongolia and Russia
2010	GRENATEC (Pan-Asian Energy Infrastructure)	GRENATEC	ASEAN nations, Australia, China, Japan, Korea and Chinese Taipei.
2011	Asia Super Grid	Japan Renewable Energy Foundation	Bangladesh, Bhutan, China, India, Japan, Korea, Malaysia, Philippines, Singapore, Chinese Taipei, Thailand and Russia
2011	Asia Pacific Power Grid	Japan Policy Council	ASEAN power grid region, Australia, Japan, Korea and Chinese Taipei.
2014	NEA Super Grid	Korea Electric Power Corporation	China, Japan, Korea, Mongolia and Russia
2014	Gobitec and Asian Super Grid	Energy Charter Secretariat Korea Energy Economics Institute	China, Japan, Korea, Mongolia and Russia.
2014	Northeast Asia Super Grid	Skolkovo Institute of Science and Technology (Skoltech) Melentiev Energy Systems Institute	China, Japan, Korea, Mongolia and Russia.
2016	Asian Super Grid	State Grid of China, Korea Electric Power Co. (Kepco), Rosseti (Russia) and Softbank (Japan)	China, Japan, Korea, Mongolia and Russia.

countries" [80]. Roughly speaking, in Japan, peak load is in summer; in Korea, in winter (it should be noted that, since 2009, due to preference to use electricity for heating; however, summer peak is nearly as high as winter. Therefore, if the peak load seasons continue to match, sharing peak may not be significantly beneficial for these two countries); and in Russia, in winter [81]. A multi-nation grid would enable the transmission of generated electricity by allowing effective utilization of supplementary seasonal excessive capacity. Admittedly, the benefits from peak share would vary among countries depending on their grid scale, peak seasons, and energy generation and consumption capacities. Nevertheless, the aggregated gains accrued from such transactions would be instrumental as driving forces in the larger regional energy integration process. Furthermore, peak share and power transaction would also assist the member economies indirectly by preventing power outages and ensuring affordable and accessible energy for industries. However, so far, other than a few number of bilateral cooperation schemes such as the one established between China and Russia, the five NEA countries lacks a common technology sharing framework [82]. Finally, by reinforcing RE development through extensive geographic access and transmission by means of super grid and smart grid technologies, regional grid interconnection facilitates the ongoing shift from coal and other hydrocarbon energy resources for electricity generation and help improve natural environment in the region [83] (See Map 1).

We believe that greater electric energy connectivity would also have regional political implications, leading to de-securitization, confidence building and comprehensive institutionalization. Energy cooperation "as the entry point of economic integration" requires a high level of communication between various levels of public and private actors responsible for policy making, interoperability, technology, finance, and crisis management [84]. If the economical, political and environmental aspects of energy security facilitate such integration, then, the anticipated result would be, first and foremost, a less securitized regional environment. An increased sense of security would, in turn, reinforce the confidence building process by bringing diverse actors together. The ongoing negotiations on a regional grid, therefore, may be considered as both the cause and result of a greater sense of trust and confidence among the related parties. Eventually, an institutionalized regional energy framework may be built upon the material and normative realities on the ground. Institutionalization is significant to ensure that regional crises and disputes would not easily derail the progress that has already been made and drive it into regression. It follows that, the ongoing developments with respect to economic, technological and political aspects of CE are indicative of an incremental progress in NEA even though numerous challenges do also exist.

4. The emergence of a regional energy cooperation framework

It is understood that the realization of CE-driven grid connectivity in NEA is not a far-fetched possibility although pessimism regarding the potential of comprehensive energy cooperation in general continues to prevail to some degree, leading some to even argue that "the Northeast Asian states actually care little about the prospects for energy cooperation" [85]. However, there are now more indicators to become cautiously optimistic. For instance, technically, constructing an



Map 1. Proposed NEA energy grid network.
Source: Prepared by the authors with reference to "Technology and Prospects for Cross-Regional Power Networks," GEIDCO, 2017, p. 32 and p.34 (In Chinese). Please note that the transmission lines may not indicate exact locations, but drawn for reference only.

electricity super grid in NEA is now more feasible. Advanced technologies such as UHV, smart grid, WAMs, and storage systems are available in advanced industrial nations such as Japan, China and South Korea. China, on its part, has already experimented on UHVDC/AC connectivity by investing heavily on long distance, high voltage, large capacity transmission technologies. Furthermore, China's 18 trans-border transmission lines with neighboring countries offer valuable insights in terms of project financing, national electricity market structures and pricing, electric power industries and political differences [86]. Especially considering that, in general, grid extension lags power generation capacity build-up in many (developing) countries, the physical integration of energy after it is generated via conventional but increasingly new sources may further encourage region wide connectivity [87]. The experience gained from what has been accomplished bilaterally so far in NEA may provide a valuable road map for more comprehensive regional electricity networking.

It appears that political drive toward an energy community trails the technological capabilities and breakthroughs that leading NEA economies have accomplished over the past decade. Then, to move from bilateral energy cooperation into a multilateral pattern, institutionalization is a must. Although there are a number of energy cooperation schemes of which most NEA states are a member such as the APEC Energy Working Group and East Asian Summit (EAS) Energy Cooperation Task Force, a more exclusive and dense institution that is specifically geared toward the NEA region would be instrumental for a goal-oriented energy regionalization [88]. Thus, aside from the ongoing efforts to reinforce energy infrastructure connectivity, there is a growing need for the establishment of a powerful Northeast Asian energy institution to regulate and supervise such critical issues as technology transfers, electricity market structures and pricing, power stream characteristics (load curves, generation dispatch etc.) streamlining and project financing. Only under an institutionalized structure would NEA energy cooperation move beyond its present form and assume a true regional characteristic. For this end, desecuritization of relations between China, Japan and South Korea via energy socialization is of greatest importance. Otherwise, the capability of market forces would not be able to overcome geopolitical distrust and rivalry.

In any case, although in its nascent stage, the drive toward region-wide electricity interconnection via market-oriented initiatives, political dialogue and epistemic community interaction indicate the presence of a growing energy discourse in NEA. The reason why setting up of an energy connectivity network is now more likely than before can be explained by the existence of domestic and regional factors that altogether facilitate energy socialization. Yet, these factors by themselves may not be enough to overcome the existing obstacles and challenges; therefore, further steps need to be taken to capitalize on the regional compatibilities and sort out complexities related to state-specific differences in energy market structures, technological and industrial capacities, and incompatible geopolitical interests. The momentum now appears to be growing toward a connected electricity infrastructure in NEA with various social segments inside each state actor showing interest and providing feedback.

The construction of an electricity grid spanning across the five NEA nations is significant not only due to the potential material gains such as peak load sharing, technology transfer and investment, energy efficiency, and environmental protection [89], but also due to positive political implications such as growing mutual trust and confidence that accompany an institutionalized energy communication and cooperation mechanism. However, challenges do exist on both technical and political levels of grid connectivity in NEA. Technically, streamlining electricity market structures and power system characteristics, providing finance for CE generation and transmission infrastructure such as solar and wind power units, UHV lines, smart grid systems, and computer-aided services for energy trade between producers and consumers in a large geography across several national borders are among the major challenges to tackle.

However, the major challenge, we believe, is of political nature. NEA, in spite of the long peace ever since the end of the Korean War, has been strife with adverse historical sentiments, territorial disputes and geopolitical rivalries in which strong external actors such as the US are deeply involved. To be sure, even though historical feelings are mutually healed to a certain degree and overlapping sovereignty claims are shelved, geopolitics is difficult to overcome. The US military presence in Japan and Korea, the apparent role of Tokyo and Seoul to materialize the “Rebalance to East Asia” scheme (especially the military aspect of it), which Beijing perceives as an explicit effort by the US to contain China, and the implicit competition for regional leadership between China and Japan are challenges that energy-driven interest convergence would not easily be able to respond. Another sticking point, currently, is the division in the Korean Peninsula, although recently there has been a momentum toward a political solution to the crisis. Currently, even though the geographic division itself may not slow down the construction of a regional energy infrastructure (as seen in many proposals which by-pass North Korea), the negative implications of a unified response to the DPRK's nuclearization by the US, South Korea and Japan (such as the deployment of the THAAD system in Korea) for China and Russia's national security appears to be a major roadblock. Obviously, under present geopolitical conditions in the Korean Peninsula, even in the absence of a major war, moving on with electricity grid connectivity is still unrealistic.

Then, against the backdrop of the existing geopolitical reality in NEA, what would be the optimum strategy for the regional actors to pursue a more advanced state of electricity connectivity? This question brings the debate back to the point we made above: The response to political challenges needs to involve more institutionalization and institutionalized multilogue. If a viable (and relatively autonomous) institution built around a binding energy charter with substantial public and private support from each actor is established, then, multi-actor conservation on electricity cooperation would continue even when the political environment becomes more contentious due to conjectural tensions [90]. An institution composed of branches with clearly-defined responsibilities would facilitate the energy socialization process among the related agencies of the member governments and help achieve incremental but continuous progress. The imminent task, therefore, is to unify the existing multitude of CE development and electricity grid proposals into one regional master plan and channel the combined financial, technical and political efforts into a common goal in an institutionalized setting.

A viable level of electricity infrastructure connectivity and communication would constitute a major breakthrough in the process of community making in NEA. The accumulated experience and trust gained from such a successful energy institutionalization would strengthen the economy-driven characteristic of East Asian regionalism and regionalization that have been in effect for more than half a century now. Energy would indeed constitute the very linkage between the nation state and region in NEA due to its often-securitized features which require more than political rhetoric to be interlinked across national boundaries via a grid ecosystem. NEA may in fact act as the nucleus of a larger community of energy in East Asia and beyond in its advanced stages. Starting from NEA and then gradually expanding into adjacent regions appears to be the optimum strategy because of the high level of energy compatibility in NEA, advanced technological and financial capabilities and advantageous geographic proximity. In the later stages, a belt and road of electricity connectivity may bring together a larger geography, extending into Southeast, South and Central Asia. Considering that both ASEAN and Commonwealth of Independent States (CIS) are working on their own regional grid infrastructure, the multitude of sub-regional grid connectivity would indeed not be out of reach.

5. Conclusions

In this study, we have theorized a causal relationship between CE development in NEA and the emergence of a regional energy framework. Grid development, in this regard, was singled out as an essential link that may help connect national-based energy strategies with a cross-borders electricity network due, mainly, to the presence of strong energy complexities (which require cooperation) and energy complementarities (which facilitate cooperation). We also explored domestic and regional (both economic and political) implications of grid-connected electricity cooperation in NEA, stressing, on the domestic realm, the aspects of efficiency, investment, innovation and environment and, on the regional realm, confidence building, de-securitization and regional peace. Thus, we argued that a CE-driven electricity grid network spanning across five NEA states is an essential stage for the creation of a regional energy framework. In the long run, socialization through energy infrastructure connectivity would contribute immensely in the community making in East Asia.

We also pointed out a number of challenges of economic, technical and political nature to be tackled with to realize a feasible regional electricity grid in NEA. On the economic plane, we highlighted disparate levels of financial capacity among the state and non-state stakeholders to maintain capital-intensive RE and grid related investment as one of the major impediments. In the same vein, we stressed the importance of sorting out existing technological disparities and energy system incompatibilities to facilitate and sustain RE generation and grid connectivity. Finally, we underlined the question of politics as the most persistent and consequential issue to be dealt with by the regional actors due to the strategic, historical and sovereignty-related nature of the disputes.

It is anticipated that, if major strategic differences remain unsolved, a certain amount of political resistance to the idea of a closely-integrated energy network in NEA will continue to linger, slowing down the progress of energy socialization, if not entirely derailing it. Thus, integrating diverse and often incompatible energy systems and markets across a large geography with varying political systems, (at times) incongruent strategic priorities and often irreconcilable historical memories is a major task that requires a step-by-step approach. Obviously, the most difficult undertaking of all is the issue of overcoming geopolitical interest divergencies and historically-informed disputes. All in all, sorting out these economic, technological and political challenges is indeed daunting. Yet, the very fact that the challenges are of immense scale also signifies the scale of potential gains that a CE-driven grid networking in NEA would bring about in terms of regional economic community making.

There are now more reasons to be optimistic about the prospects of an electricity grid in NEA than before as the related state and non-state actors appear to be interested and have launched a number of initiatives ever since the late 1990s. Russia, the country with the largest energy potential and huge landmass neighboring with both advanced and developing nations, has been the earliest proponent of a regional grid. Mongolia, the smallest economy among the five NEA states, also attaches great importance to a regional power grid, designating energy security as one of the fundamentals of national economic development. This provides the country a foundation for regional cooperation which, given Mongolia's geographic location, energy cooperation is a practical way to break through the country's physical isolation from the rest of the region. In Japan, especially the initiative promoted by Japanese IT company, SoftBank, has generated momentum in regards to research on the feasibility of a five-country grid connectivity. Similarly, South Korea has shown interest over the years, especially with the aim of acting as an energy bridge between China and Japan. Indeed, the existing national UHV power lines provide the initial base for Korea's role as a facilitator of a cross-sea network in NEA. China, thanks the size of its economy, infrastructure and technology capabilities, and consumption potential, is both a major energy producer and consumer. Therefore, despite a relatively belated actor in NEA electricity network debate, China, also, has worked to assume a more central, integrating role. In short, the work that has been carried out so far by NEA nations, although still with inadequate coordination, indicates that the groundwork on the economic and technical feasibility of a wider regional electricity networking is near completion.

NEA grid development can learn from the experience of other regions that are at relatively more advanced stages of interconnectivity – such as the European grid interconnection that covers 34 nations, the CIS grid network that includes Russia and former Soviet republics, and the North American transmission grid which currently include the US and Canada [91]. Admittedly, NEA has its own specific regionalization patterns, which appear to be at work with respect to grid connectivity, as well. The ongoing energy socialization is a positive indicator and will likely continue so that a certain level of institutional maturity is achieved. Unexpected geopolitical crises might derail or stall the progress, but, the higher the level of institutionalization gets, the more autonomous electric power interconnectivity will become, thereby having greater immunity from unexpected geopolitical shocks. The present stage, in this regard, is a critical one, especially considering the acceleration of the twin forces of electricity networking in NEA and the improving political conditions on the Korean Peninsula that involve almost all the actors covered by the Northeast Asia Super Grid project.

References

[1] Clean Energy Includes Renewable Energy Sources, Such as Hydro, Solar, Wind, Wave, Geothermal, Bio, Tidal as Well as Technologies Designed to Improve Energy Efficiency.
[2] We derive these components from the generally accepted definition of energy security. See for reference, Brenda Shaffer, Energy politics, University of Pennsylvania State 2009 and John V. Mitchell, A new political economy of oil, Q. Rev. Econ. Finance 42 (2002).
[3] David von Hippel, Ruslan Gulidov, Victor Kalashnikov, Peter Hayes, Northeast Asia regional energy infrastructure proposals, Energy Pol. 39 (2011) 6856.
[4] Bo Kong, Jae H. Ku (Eds.), Energy Security and Sustainability in Northeast Asia, Routledge, OX, 2015.
[5] Yu Sheng, Xunpeng Shi, Dandan Zhang, Economic development, energy market integration and energy demand: implications for East Asia, Energy Strat. Rev. 2 (2013) 146–152.
[6] Qi Wang, Ting Ting Xu, Xiao Li Guo, Analysis on the risk of Northeast Asia regional energy security cooperation, Energy Proc. 16 (2012) 341–345.
[7] David von Hippel, et al., Energy security and sustainability in Northeast Asia, Energy Pol. 39 (2011) 6719–6730.
[8] Jaewoo Choo, Energy cooperation problems in Northeast Asia: unfolding the reality, East Asia 23 (2006) 91–106.
[9] D.G. Streets, Environmental benefits of electricity grid interconnections in Northeast Asia, Energy 28 (2003) 789–807.
[10] Jaewoo Choo, Energy cooperation problems in Northeast Asia: unfolding the reality, East Asia 23 (2006) 91–106.
[11] Jae-Seung Lee, Energy security and cooperation in Northeast Asia, Kor. J. Defense Anal. 22 (2010) 217–233.
[12] David von Hippel, et al., Energy security and sustainability in Northeast Asia, Energy Pol. 39 (2011) 6719–6730.
[13] Jaewoo Choo, Energy cooperation problems in Northeast Asia: unfolding the reality, East Asia 23 (2006) 91–106.
[14] Makoto Kanagawa, Toshihiko Nakata, Analysis of the impact of electricity grid interconnection between Korea and Japan—feasibility study for energy network in Northeast Asia, Energy Pol. 34 (2006) 1015–1025.
[15] Maria Lorena Tuballa, Michael Lochinvar Abundo, A review of the development of Smart Grid technologies, Renew. Sustain. Energy Rev. 59 (2016) 710–725.
[16] Christian Breyer, et al., North-east Asian super grid: renewable energy mix and economics, Jpn. J. Appl. Phys. 54 (2015) 1–17.
[17] Dmitrii Bogdanov, Christian Breyer, North-East Asian Super Grid for 100% renewable energy supply: optimal mix of energy technologies for electricity, gas and heat supply options, Energy Convers. Manag. 112 (2016) 176–190.
[18] Takashi Otsuki, Costs and benefits of large-scale deployment of wind turbines and solar PV in Mongolia for international power exports, Renew. Energy 108 (2017) 321–335.
[19] Ming Zeng, Jinhui Duan, Liang Wang, Yingjie Zhang, Song Xue, Orderly grid connection of renewable energy generation in China: management mode, existing problems and solutions, Renew. Sustain. Energy Rev. 41 (2015) 14–28.
[20] Yuning Zhang, Ningning Tang, Yuguang Niu, Xiaoze Du, Wind energy rejection in China: current status, reasons and perspectives, Renew. Sustain. Energy Rev. 66 (2016) 322–344.
[21] We Define Energy Socialization as a Learning Process in Which Regional State Actors Develop Energy Community by Comprehensively Formalizing Institutionalized Multilateral Ties in Energy by Aligning Physical Infrastructures,

Systems, Markets and Regulations.
[22] In This Study, We Also Refer to South Korea as Korea. For the North of the Korean Peninsula, North Korea and the DPRK Are Used Interchangeably.
[23] Won-Cheol Yuna, Zhong Xiang Zhang, Electric power grid interconnection in Northeast Asia, Energy Pol. 34 (2006) 2299.
[24] Won-Cheol Yun, Zhong Xiang Zhang, Electric power grid interconnection in Northeast Asia, Energy Pol. 34 (2006) 2301.
[25] US Energy Information Administration, Russia Country Brief, (October 2016: 24) https://www.eia.gov/beta/international/analysis_includes/countries_long/Russia/russia.pdf.
[26] Russia imports electricity from Finland for first time, Russia Today (June 8, 2015), https://www.rt.com/business/265672-russia-finland-energy-electricity/ http://asiapacificenergy.org/#main/graph/1/type/0/sort/0/time/[1999,2014]/indicator/[3000:834]/geo/[RUS]/legend/1 also see, Asia-Pacific Energy Portal (APEC).
[27] Asia Pacific Energy Portal (APEP), http://asiapacificenergy.org/#main/graph/8/type/0/sort/0/time/[1999,2014]/indicator/[8525:7772]/geo/[RUS]/legend/1.
[28] Asia Pacific Energy Portal (APEP), http://asiapacificenergy.org/#main/graph/3/type/0/sort/0/time/[1999,2014]/indicator/[2983:3014]/geo/[RUS]/legend/1.
[29] Global Energy Network Institute, National Energy Grid Russia, (Date not indicated), http://www.geni.org/globalenergy/library/national_energy_grid/russia/index.shtml.
[30] Global and Russian Energy Outlook to 2040, The Energy Research Institute of the Russian Academy of Sciences (ERI RAS) and the Analytical Center for the Government of the Russian Federation (ACRF), Moscow, 2014, p. 130.
[31] Voktor Katona, Realizing Russia's renewable energy potential in 2017, Russia Direct (Feb 1, 2016), http://www.russia-direct.org/opinion/realizing-russias-renewable-energy-potential-2017.
[32] International Energy Agency (IEA), Russia 2014, 222. http://www.iea.org/publications/freepublications/publication/Russia_2014.pdf.
[33] David Ferris, Russia's power grid, held together with spit and grit, Energy Wire (December 18, 2014), http://www.eenews.net/stories/1060010742.
[34] International Energy Agency (IEA), Russia 2014, 191. http://www.iea.org/publications/freepublications/publication/Russia_2014.pdf.
[35] Asia Pacific Energy Portal (APEP) dataset, http://asiapacificenergy.org/#main/graph/3/type/0/sort/0/time/[2007,2014]/indicator/[1896:592]/geo/[MNG]/legend/1.
[36] Mongolia: Renewables Readiness Assessment, IRENA, March 2016, p. XIV.
[37] Mongolia: Renewables Readiness Assessment, IRENA, March 2016, p. 24.
[38] Asia Pacific Energy Portal (APEP) dataset, http://asiapacificenergy.org/#main/graph/8/type/0/sort/0/time/[2007,2013]/indicator/[8515:7772]/geo/[MNG]/legend/1.
[39] In 2014, the Peak Load was 960 MW, Accounting for 93% of the National Total Installed Capacity. The Maximum Available Capacity of Importing Electricity from Russia is about 250 MW, Mongolia: Renewables Readiness Assessment, IRENA, March 2016, p. 11.
[40] Kun Yang, Jiji guojian dongbeiya dianli hutong hulian duiji hezuo jizhe (Actively build a multi-level cooperation mechanism for power interconnection in Northeast Asia), China Power Enterpr. Manage. 11 (2016) 14–19 (In Chinese).
[41] Mongolia energy situation, Energypedia, (Date not indicated), https://energypedia.info/wiki/Mongolia_Energy_Situation#References; "Mongolia", International Energy Agency, (Date not indicated) https://www.iea.org/countries/non-membercountries/mongolia.
[42] Energy Policies of IEA Countries: Japan, International Energy Agency (IEA), 2016, p. 98 http://www.iea.org/publications/freepublications/publication/EnergyPoliciesofIEACountriesJapan2016.pdf.
[43] US Energy Information Administration, Country Analysis Brief: Japan, (February 2017), pp. 13–19 https://www.eia.gov/beta/international/analysis_includes/countries_long/Japan/japan.pdf.
[44] Energy Policies of IEA Countries: Japan, International Energy Agency (IEA), 2016, p. 94 http://www.iea.org/publications/freepublications/publication/EnergyPoliciesofIEACountriesJapan2016.pdf.
[45] See, http://www.renewable-ei.org/en/statistics/resources.php.
[46] Patrick Smith, Japan to develop grid for wind integration, Wind Power Monthly (March 25, 2014), http://www.windpowermonthly.com/article/1286986/japan-develop-grid-wind-integration.
[47] Energy Policies of IEA Countries: Japan, International Energy Agency (IEA), 2016, pp. 112–113 http://www.iea.org/publications/freepublications/publication/EnergyPoliciesofIEACountriesJapan2016.pdf.
[48] Data as of 2014 provided by Korea Energy Economics Institute, available at: http://www.keei.re.kr/web_keei/en_Issues01.nsf/view06/FBBF2DBDEF5BC5024925806F001D9E8E/$file/8%20Energy%20Balance.pdf.
[49] US Energy Information Administration, Country Analysis Brief: South Korea, (January 2017), pp. 14–15.
[50] See, http://www.kemco.or.kr/new_eng/pg02/pg02040705.asp.
[51] Korea Energy Agency (KEA) Annual Report, (2014), p. 14 http://www.energy.or.kr/renew_eng/resources/resources_view.aspx?no=12&page=1.
[52] Korea Energy Agency (KEA) Annual Report, (2014), p. 15 http://www.energy.or.kr/renew_eng/resources/resources_view.aspx?no=12&page=1.
[53] Energy Policies of IEA Countries: Republic of Korea, International Energy Agency (IEA), 2012, p. 10.
[54] https://yearbook.enerdata.net/energy-primary-production.html#electricity-balance-trade-information-by-region.html.
[55] Asia Pacific Energy Portal (APEP) dataset, http://asiapacificenergy.org/#main/graph/8/type/0/sort/0/time/[1999,2014]/indicator/[8525:7772]/geo/[CHN]/legend/1.
[56] Asia-Pacific Energy Portal dataset, http://asiapacificenergy.org/#main/graph/0/type/0/sort/0/time/[1990,2014]/indicator/[2989:3014]/geo/[CHN,ASPA]/legend/1.
[57] For an updated detailed analysis of clean energy development in China, see, John A. Mathews, Xin Huang, Mark Selden, The greening of China's energy system outpaces its further blackening: a 2017 update, Asia Pacific J. Jpn. Focus 16 (9) (2017) 1–18 2.
[58] https://yearbook.enerdata.net/#renewable-in-electricity-production-share-by-region.html.
[59] Renewables generate a quarter of China's Energy; solar, wind lag, China Power (August 26, 2016) Guo-liang.Luo, Fei Zhi, and Xinying Zhang, Inconsistencies between China's wind power development and grid planning: An institutional perspective, Renewable Energy 2012: 48: 52-56 http://en.chinapower.com.cn/2016/08/26/content_4004.html.
[60] Xiaoli Zhao, Sufang Zhang, Rui Yang, Mei Wang, Constraints on the effective utilization of wind power in China: an illustration from the northeast China grid, Renew. Sustain. Energy Rev. 16 (2012) 4508–4514.
[61] China to invest US$31bn in provincial smart grid by 2020, Meter. Smart Energy (November 26, 2015), https://www.metering.com/china-to-invest-us31bn-in-provincial-smart-grid-by-2020/.
[62] China Electricity Council, http://english.cec.org.cn/No.118.index.htm.
[63] GEIDCO, Technology and Prospects for Cross-regional Power Networks (In Chinese), Global Energy Interconnection Development and Cooperation Organization (GEIDCO), Beijing, 2017, p. 31.
[64] GEIDCO, Technology and Prospects for Cross-regional Power Networks (In Chinese), Global Energy Interconnection Development and Cooperation Organization (GEIDCO), Beijing, 2017, p. 32.
[65] Mongolia: Renewables Readiness Assessment, IRENA, March 2016, p. 10.
[66] Electric Power Grid Interconnections in Northeast Asia: a Quantitative Analysis of Economic and Environmental Benefits, Asia Pacific Energy Research Centre, November 2015, pp. 12–22.
[67] Energy Corridors European Union and Neighbouring Countries, Directorate-General for Research 2007 Sustainable Energy Systems, European Commission, 2007, https://www.energy.eu/publications/KINA22581ENC_002.pdf.
[68] For an analysis of the development of renewable energy and grid networking in Europe, see, Katrin Schaber, Florian Steinke, Thomas Hamacher, Transmission grid extensions for the integration of variable renewable Energies in Europe: who benefit where? Energy Pol. 43 (2012) 123–135.
[69] https://sustainabledevelopment.un.org/content/documents/20548china.pdf.
[70] Kun Yang, Jiji guojian dongbeiya dianli hutong hulian duiji hezuo jizhe (Actively build a multi-level cooperation mechanism for power interconnection in Northeast Asia), China Power Enterpr. Manage. 11 (2016) 14–19 (In Chinese).
[71] Asia International Grid Connection Study Group Interim Report, Tokyo, (April 2017) https://www.renewable-ei.org/en/activities/reports/img/20170419/ASGInterimReport_170419_Web_en.pdf.
[72] Qinghua Kong, Dongbeiya dianli hu lianwang ge chengyuan guode tansuo yushijian (Exploration and Practice of Regional Power Networks among Northeast Asian Countries), China Electr. Power Enterpr. Manage. 11 (2016) 28–31 (In Chinese).
[73] Bryan Harris, Jung-a Song, Peter Wells, Plan for north-east Asian electricity 'super grid' boosted, FT (November 2, 2017), https://www.ft.com/content/4b04ed8e-bf8b-11e7-b8a3-38a6e068f464.
[74] Takaki Tominaga, SoftBank's Asia power grid plan advances in the face of challenges, Japan Times (December 1 2016), https://www.japantimes.co.jp/news/2016/12/01/business/corporate-business/softbanks-asia-power-grid-plan-advances-face-challenges/.
[75] Electric Power Grid Interconnections in Northeast Asia: a Quantitative Analysis of Economic and Environmental Benefits, Asia Pacific Energy Research Centre, November 2015, pp. 30–32.
[76] These Two Regional Super Grid Proposals Were Put Forward by Shandong Power Company of National Grid in China. Authors' Interview with Sun Shumin, the Principal Researcher at the Power, Research Institute of Shandong Electric Power Company, April 1, 2017.
[77] Steve Hanley, China, Japan, Russia, & South Korea plan renewable energy super grid, Solar Love (September 16, 2016), http://solarlove.org/china-japan-russia-south-korea-super-grid-renewable/.
[78] Global Trends in Renewable Energy Investment 2016, Frankfurt School of Finance & Management, 2016, p. 23 http://fs-unep-centre.org/sites/default/files/publications/globaltrendsinrenewableenergyinvestment2016lowres_0.pdf.
[79] Ren21, Renewables 2016: Global Status Report, (2016), p. 103 http://www.ren21.net/wp-content/uploads/2016/10/REN21_GSR2016_FullReport_en_11.pdf.
[80] Won-Cheol Yun, Zhong Xiang Zhang, Electric power grid interconnection in Northeast Asia, Energy Pol. 34 (2006) 2301.
[81] Electric Power Grid Interconnections in Northeast Asia: a Quantitative Analysis of Economic and Environmental Benefits, Asia Pacific Energy Research Centre, November 2015, pp. 25–26.
[82] Linas Jegelevicius, Putin strengthening China-Russia Ties for renewable energy development, Renewable Energy World (October 16, 2014), http://www.renewableenergyworld.com/articles/2014/10/putin-strengthens-russias-chinese-renewable-energy-ties.html.
[83] D.G. Streets, Environmental benefits of electricity grid interconnections in Northeast Asia, Energy 28 (2003) 789–807.
[84] GEIDCO, Technology and Prospects for Cross-regional Power Networks, The Report of Global Energy Interconnection Development and Cooperation Organization, (2017), p. 35.
[85] Jaewoo Choo, Energy cooperation problems in Northeast Asia: unfolding the reality, East Asia, Fall 23 (3) (2006) 103.

[86] Kun Yang, Jiji guojian dongbeiya dianli hutong hulian duiji hezuo jizhe (Actively build a multi-level cooperation mechanism for power interconnection in Northeast Asia), China Power Enterpr. Manage. 11 (2016) 14–19 (In Chinese).
[87] In their study, Otsuki, at al. find that in "all grid interconnection scenarios… economic benefits in the form of total cost reductions depend mainly on the fuel cost saved by shifting to cheaper fossil fuel or to renewables", Takashi Otsuki, Aishah Binti Mohd Isa, Ralph D. Samuelson, Electric power grid interconnections in Northeast Asia: a quantitative analysis of opportunities and challenges, Energy Pol. 89 (2016) 324.
[88] Hyun Jin Choi, Fueling crisis or cooperation? The geopolitics of energy security in Northeast Asia, Asian Aff. (2009) 22–23.
[89] A Detailed Simulation Analysis was Carried Out by Asia Pacific Energy Research Centre, Available at: http://aperc.ieej.or.jp/file/2015/11/27/FinalReport-APERC-Electric_Power_Grid_Interconnection_in_NEA.pdf.
[90] Won-Cheol Yuna, Zhong Xiang Zhang, Electric power grid interconnection in Northeast Asia, Energy Pol. 34 (2006) 2306.
[91] By contrast, in other parts of the world, such as in Europe, Southeast Asia, South America, North America, and even in Africa, power sector cooperation has been specifically enforced and has provided good results, Won-Cheol Yuna, Zhong Xiang Zhang, Electric power grid interconnection in Northeast Asia, Energy Pol. 34 (2006) 2298.

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