

Strategy for Northeast Asia Power System Interconnection

ADB



OVERVIEW

This brochure summarizes the findings from a technical assistance (TA) project to define a strategy for a Northeast Asia Power System Interconnection (NAPSI) using Mongolia's abundant renewable energy resources. The TA spanned 5 years and involved a highly consultative process among a wide range of stakeholders to develop this strategy and frame the associated technical analysis. The study's approach and main findings are summarized here, and more details can be found in the technical reports available at <https://www.adb.org/projects/48030-001/main#project-documents>.

INTRODUCTION

All of the Northeast Asian countries are dependent on fossil fuels; coal, natural gas, and oil provided 70% of the region's electricity generation in 2018.¹ Countries in the region are diversifying their energy mixes to replace higher-cost, fossil fuel generators with solar, wind, and hydropower, which is contributing also to improved air quality and reduced greenhouse gas emissions. Notably, the People's Republic of China (PRC) has emerged as a world leader in the manufacture and installation of solar and wind power systems. Further expansion of renewable power in the Northeast Asian countries is somewhat constrained by (i) distances between load centers and the areas with best renewable resources, (ii) existing grid and power generators that are not sufficiently robust and flexible for effective resource management, or (iii) land constraints that prevent domestic renewable expansion at levels required to reach climate mitigation goals.

Some countries have overcome similar challenges by expanding power system balancing areas and allowing for substantial cross-border power trade. Currently, the extent of regional power trade in the Northeast Asia region is limited to bilateral electricity trade between the PRC and the Russian Federation, between Mongolia and the Russian Federation, and between Mongolia and the PRC. Previous preliminary studies indicated that the development of an interconnected Northeast Asia power grid would allow for cost-effective increased use of renewable power supply across the region, with much of the renewable generation coming from southern Mongolia and benefitting countries as far as Japan. This TA sought to investigate this possibility through consultations among stakeholder governments and agencies and rigorous technical analysis.

STUDY SCOPE

The study sought to produce an updated analysis of power systems and markets in the Northeast Asia region, and analyze least-cost expansion options considering projected demand growth, Mongolia's renewable resource potential, latest technical and cost data, and local power supply costs within Northeast Asian countries. The Asian Development Bank contracted Electricite de France—in partnership with China Electric Power Research Institute and Hangzhou Dianzi University in the PRC, and Nova Terra LLC in Mongolia—to lead the study. The main activities and findings are summarized, followed by potential next steps.

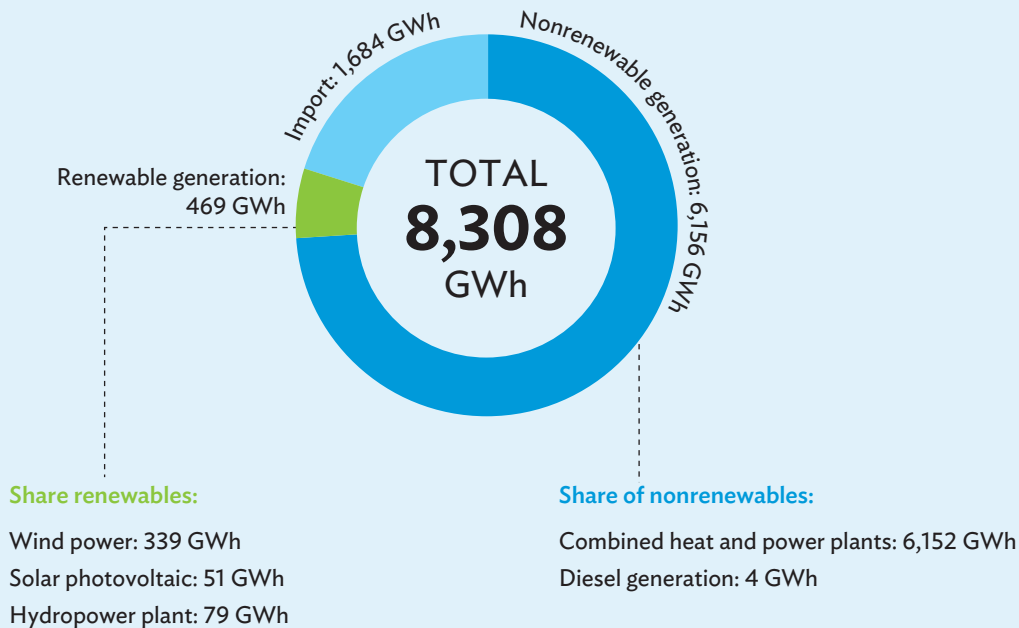
¹ International Energy Agency. *Data and Statistics*. <https://www.iea.org/data-and-statistics/data-tables?country=WORLD> (accessed 11 September 2020).

Mongolia Power System Expansion and Renewable Resource Potential

Current situation. Mongolia's power system is dominated by coal, accounting for 93% of domestic electricity generation in 2018. The country targets renewable electricity-generating capacity to reach 20% of installed capacity by 2023. Mongolia is poised to meet this target with two 50-megawatt (MW) wind farms and two 10 MW solar plants already operating, and more under planning and construction. Mongolia imports 20% of electricity supply (Figure 1). A 220-kilovolt (kV) transmission line, with maximum capacity of 245 MW, from Selendeuna in Buryatia, the Russian Federation supplies electricity

and provides grid services for Mongolia's Central Energy System, which covers the major load centers, including Ulaanbaatar. A 220 kV line from the People's Republic of China supplies power to the Oyu Tolgoi mining operations in southern Mongolia, and this is isolated from the rest of the Mongolian grid. Another 220 kV line, operating at 110kV, from Chadan-Handagaoly in the Russian Federation, feeds the Western Energy System, which has supplied up to 75% of electricity consumed in that region,² though this will decrease once the planned wind and solar plants are commissioned (Figure 2).

Figure 1: Electricity Supply Structure of Mongolia, 2018



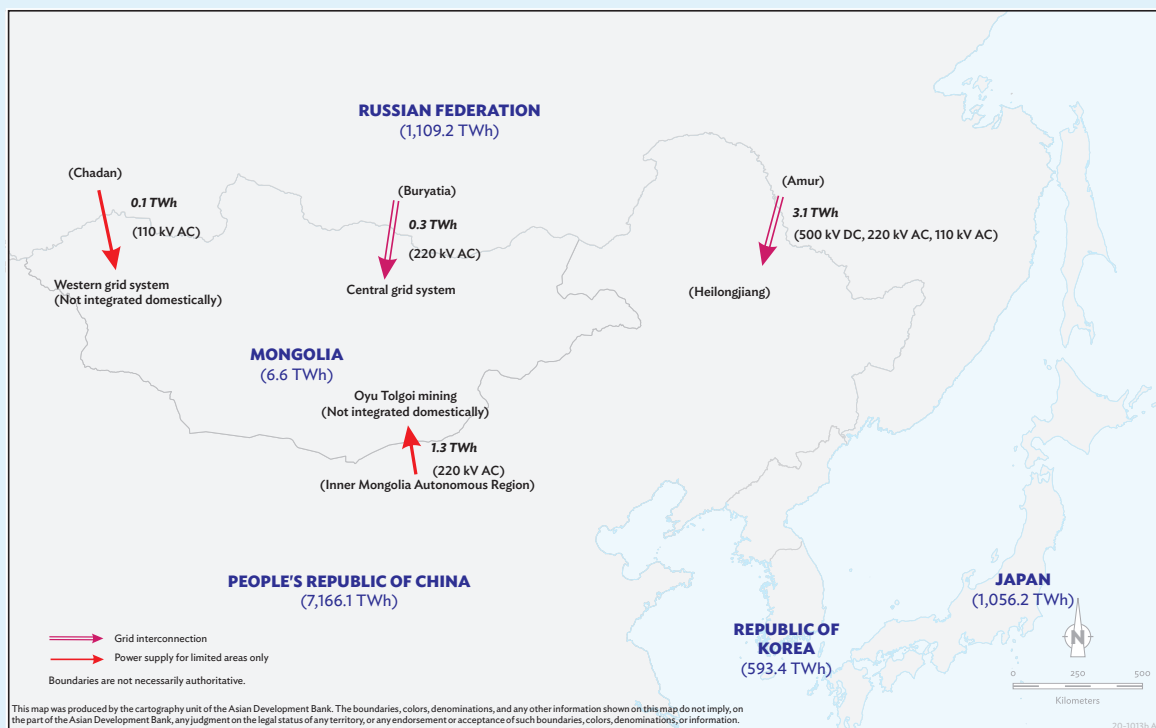
GWh = gigawatt-hour.

Note: Numbers may not total precisely due to rounding.

Source: Energy Regulatory Commission of Mongolia. 2019. *2018 Statistics on Energy Performance*. Ulaanbaatar.

² T. Tumenjargal. 2018. *Current Status and Progress for Mongolia Power Interconnection*. <https://www.unescap.org/sites/default/files/Session%202-1.%20Mongolian%20Energy%20Economics%20Institute.pdf>.

Figure 2: Electrical Interconnections and Domestic Power Generation in Northeast Asia, 2018



kV AC = kilovolt alternating current, kV DC = kilovolt direct current, TWh = terawatt-hour.

Source: Energy Regulatory Commission of Mongolia. 2019. 2018 *Statistics on Energy Performance*. Ulaanbaatar.; BP. 2020. *Statistical Review of World Energy 2020*. London; Inter Raoues. n.d. Trading. <https://www.interra.ru/en/activity/trading> (accessed 15 Oct 2020).

Renewable potential. The study assessed the economic potential for solar and wind development in Mongolia considering a wide range of constraints, such as excluding areas near to natural protection areas, far from roads and transmission infrastructure, and with steep slope or high elevations. The remaining areas with strong resource potential, measured as irradiance and wind speed, and contiguous land area sufficient for either a 10 MW wind farm or 5 MW solar photovoltaic farm, were then ranked based on resource strength and proximity to infrastructure. Even considering these constraints, the study found ample renewable resource for both domestic use and potential export. High-quality resources located within 20–50 kilometers from existing 220 kV substations total 22 gigawatts (GW) of wind and 484 GW of solar photovoltaic. The total economically viable resources were estimated at 192 GW of wind and 1,166 GW of solar photovoltaic. The majority of these resources are located in the south of the country near the Gobi Desert and close to the border with the PRC.

Mongolia power system expansion. Expanding renewable electricity generation in Mongolia beyond what is in planning stages currently is constrained by the limited flexibility of the current power system and the capacity of the transmission network. Though Mongolia has hydropower potential that could provide both electricity and grid services, these resources have not been developed for a variety of reasons, including watershed protection. Under the study, Mongolia’s power system expansion was modeled out to 2036 and considered projected growth rates of 10% in the 2020s and 4% in the 2030s, targeted renewable penetration of 30% by 2030, and a minimum reserve margin of 20% by 2030. The least-cost expansion scenario to meet these targets resulted in a total of 1.1 GW each of wind and solar on the power system in 2036. However, the results also showed that the system flexibility remains an impediment, and substantial renewable electricity would be curtailed without investment in flexible generation assets and transmission system upgrades.

Evaluating the Potential Benefits of Regional Power Trade

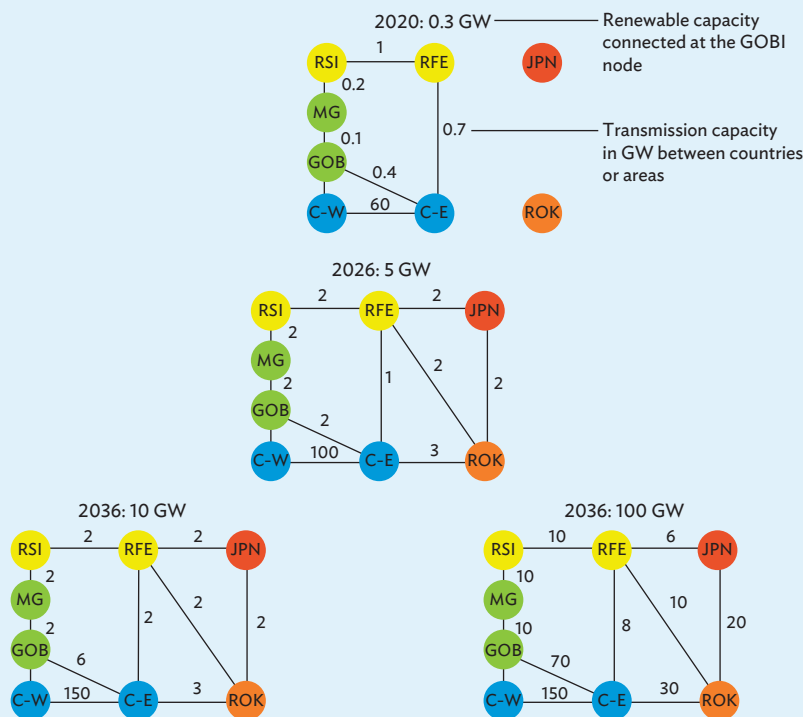
Modeling regional power system expansion. Potential renewable electricity generation in the South Gobi region of Mongolia is well beyond domestic power demand, even many years into the future. To evaluate the potential for regional benefits from developing these resources for export, several scenarios for regional power system expansion were modeled for the period 2020–2036, including:

- **Domestic least-cost expansion.** All countries are modeled individually to identify the least-cost generation expansion to meet growing domestic power demand.
- **Regional interconnections.** The region was modeled in aggregate to find the least-cost generation expansion to meet growing regional demand, including through cross-border power trade.

- **Regional interconnection with development of the South Gobi renewable resources.** This analysis includes build-out of South Gobi’s renewable resources at 10 gigawatts (GW) and 100 GW for export.

The study evaluated the costs of these three options, including capital and operating expenses for electricity generation and cross-border interconnections. The model used an idealized view of the transmission interconnections, where flow was driven by marginal cost differences and does not consider geopolitical factors that might impact actual energy trade. The modelled interconnections across the region under the renewable energy development scenario are presented (Figure 3) showing the number of interconnections and line capacities increasing as the renewable generation in the South Gobi expands.

Figure 3: Modelled Transmission Capacity between Regions in Scenario with South Gobi Renewable Expansion and Regional Power Trade



C-E = China East; C-W = China West; GOB = Mongolia-GOBI; GW = gigawatt; JPN = Japan; MG = Mongolia-Ulanbaar; RFE = Russia-Far East; ROK = Republic of Korea; RSI = Russia-Siberia.

Source: Adapted from: ADB. 2019. *Strategy for Northeast Asia Power System Interconnection*. Consultant Reports. Manila. (TA 9001-MON).

Economic value of the increased power trade. The investment costs and savings from use of lower cost generation were evaluated for the three scenarios, all of which assumed that Mongolia's domestic grid would be harmonized and strengthened outside of the NAPS. Compared with the domestic least-cost expansion scenario, the interconnection scenario resulted in net savings of about \$3 billion annually. Adding the 100 GW renewable energy development in the South Gobi would require substantial investment in renewable energy capacity additions and high-capacity, long-distance transmission lines. But the net savings in this scenario is about \$10 billion annually compared with the isolated grid case. This high-renewables scenario changes the composition of the region's power generation fleet, substantially reducing power supplied from coal and natural gas plants, resulting in an estimated annual avoided carbon dioxide emissions of 210 million tons. These greenhouse gas emission reductions and improved public health from reduced air pollution add to the value of this scenario for the Northeast Asia region.

First step in building an interconnected Northeast Asia power grid. The first investments in a Northeast Asia power grid include (i) 5 GW of solar and wind capacity in Mongolia's South Gobi region, (ii) transmission line between Mongolia's South Gobi region and the northern part of the PRC, and (iii) an undersea connection between the eastern part of the People's Republic of China (PRC) and the Republic of Korea (ROK). The NAPS study results suggest that these should be commissioned by 2026 as the first step in reaching a fully integrated regional grid by 2036 (Figure 4). Given the power shortages in the Seoul region, the link between the eastern part of the PRC and the ROK is the most pressing. A bilateral agreement to develop this link led to negotiations between Korea Electric Power Corporation and State Grid Corporation of China on joint development of the project. To help the ROK in reaching climate mitigation goals, the development of 5 GW renewable capacity in South Gobi and associated power transmission to the ROK would ideally be undertaken at the same time. This investment is also a critical first step to realizing the full benefits of NAPS identified in the study.

Figure 4: Mongolia's Existing Transmission Network, Areas with Economically Viable Wind and Solar Resource, and Proposed First Phase in Developing an Interconnected Northeast Asian Power System



Note: The three components of this first phase are a build-out of renewable generating capacity in the South Gobi, an interconnection to export power to the northern part of the People's Republic of China (PRC), and an undersea transmission line to connect the eastern part of the PRC with the Republic of Korea.

Source: Adapted from: ADB. 2019. *Strategy for Northeast Asia Power System Interconnection*. Consultant Reports. Manila. (TA 9001-MON)

NEXT STEPS

The NAPSI TA has refined estimates of renewable energy resources in Mongolia that could be developed for both domestic and regional use, defined scenarios for staged development of the renewable resources and the associated regional transmission grid development, and aggregated benefits at the regional level. These are valuable additions to the body of work on regional power system integration in Northeast Asia. However, further analysis is needed prior to investment. The current analysis assumed simplified and idealized grid conditions to model scenarios at the regional level. A feasibility study of the first phase would need to be undertaken to analyze these components in more detail, including 5 GW of renewable generation development in the

South Gobi and transmission links between Mongolia and the PRC, and between the PRC and the ROK. In addition, the commercial and regulatory structures should be evaluated and used to develop draft transmission and power purchase agreements for phase 1, including provisions to ensure financial benefit to Mongolia from power exports, and commercial structuring arrangements for transboundary transmission lines. Also, it will be beneficial to develop a more granular analysis of benefits of regional power system integration to articulate benefits for each of the participating countries beyond those aggregated at the regional level. These activities would build on the analysis supported by the study to move the initiative closer to investment readiness.



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Notes:

In this publication, "\$" refers to United States dollars. ADB recognizes "China" as the People's Republic of China, "Korea" as the Republic of Korea and "Russia" as the Russian Federation. Photo credits: ADB.



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