## ECONOMIC ANALYSIS

1. The project will support the government's policy of decarbonizing the energy systems in the remote and less-developed western Mongolia. It will also strengthen institutional capacity to implement the State Policy on Energy, 2015–2030,[1] and Mongolia's Nationally Determined Contribution under the Paris climate accord of 2015,[2] which set the targets of increasing the share of renewable energy in total installed capacity to 20% by 2023 and to 30% by 2030. The project will develop 40.5 megawatts (MW) of a first-of-its-kind distributed renewable energy system and 0.5 MW of a shallow-ground heat pump system in the targeted regions. Once completed, the project will generate 99 gigawatt-hours of clean electricity yearly, thereby enabling the country to reduce its carbon dioxide ($CO_2$) emissions by 87,968 tons of carbon dioxide equivalent ($tCO_2e$) per year. The project will have three outputs: (i) output 1: distributed renewable energy system developed, (ii) output 2: shallow-ground heat pump system developed, and (iii) output 3: institutional framework strengthened and organizational capacity enhanced.

2. The country's power system comprises four grid systems, which have successfully expanded electricity access to 97% of the population. The central energy system covers around 90% of power demand in the country and has already attracted a total of around 400 MW of private sector-led renewable energy projects so far. On the other hand, the grid systems in the western Mongolia, which supply power to 25% of the population in the country and witnessed annual demand growth of more than 10% during 2010–2015,[3] have failed to attract private investment, whether in conventional power capacity addition or in renewable energy development, mainly because of the relatively small size of power demand. Inadequate investment in power generation capacity addition for remote grid systems has led to heavy dependence on high-carbon imported electricity from neighboring countries conveyed through long stretches of transmission lines to meet up to 70% of load demand in geographically scattered load centers, resulting in very high transmission and distribution losses (Table 1).[4] To address such unique challenges in remote grid systems, the government has sought to develop a first-of-its-kind distributed energy system using various renewable energy technologies and resources comprising smaller-scale and modular plants to produce reliable electricity and thermal energy for local use while reducing electricity imports.

**Table 1: Electricity Demand Forecast, and Transmission and Distribution Losses in the Project's Targeted Regions**

| Item | 2010 | 2015 | Forecast 2025 | Forecast 2030 | Annual Growth 2016-2030 (%) |
|---|---|---|---|---|---|
| **Western Region Energy System** | | | | | |
| Sent-out demand (GWh) | 78.4 | 143.1 | 190.6 | 231.8 | 6.5 |
| Transmission and distribution loss (%) | 30.1 | 27.3 | 19.1 | 12.7 | N.A. |

[1] Government of Mongolia. 2015. *State Policy on Energy 2015-2030*. Ulaanbaatar.

[2] http://www4.unfccc.int/submissions/INDC/Published%20Documents/Mongolia/1/150924_INDCs%20of%20Mongolia.pdf

[3] Compounded annual electricity demand growth during 2010–2015 was 17.4% in the western region and 31.1% in Altai–Uliastai.

[4] 95% of electricity is imported from the Siberian grid of the Russian Federation, which depends on coal-fired power plants for over 50% of power generation and has a carbon emission factor of 1.02 $tCO_2e$ per MW-hour.

| Item | 2010 | 2015 | Forecast 2025 | Forecast 2030 | Annual Growth 2016-2030 (%) |
|---|---|---|---|---|---|
| **Altai–Uliastai Region Energy System** | | | | | |
| Sent-out demand (GWh) | 18.6 | 63.3 | 231.9 | 285.1 | 4.6 |
| Transmission and distribution loss (%) | 25.1 | 23.5 | 17.5 | 11.2 | N.A. |

GWh = gigawatt-hour, N.A. = Not Applicable.
Sources: Government of Mongolia, Ministry of Energy. 2017. *Electric Yearbook 2016*. Ulaanbaatar; and Asian Development Bank estimates.

3. The project will install a secondary battery storage in a 5 MW solar photovoltaic power subproject in Uliastai and a 0.55 MW hybrid wind and solar photovoltaic system subproject in Altai *soum* (county) to demonstrate technical feasibility and durability in the cold climate for future uptake. In the targeted regions, it will also install 500 kilowatts-thermal of shallow-ground heat pump capacity in public buildings in five townships.[5] This will supply air pollutant-free space heating for 10,000 square meters of floor area. The subprojects will demonstrate the performance of the heat pump systems and increase experience in design, installation, and operation and maintenance (O&M) for future scale-up.

4. **Economic costs.** The economic analysis of the project was conducted in accordance with the Asian Development Bank (ADB) Guidelines for the Economic Analysis of Projects[6] for a project life span of 25 years for output 1 and 15 years for output 2. Costs for project administration and consulting services for output 3 were allocated to each subproject. The residual value at the end of the project life was assumed to be zero. All prices and costs were expressed in 2018 constant prices using the world price numeraire. The analysis used a standard conversion factor of 0.934 for the shadow pricing of non-tradable goods and services, and a shadow wage factor of 1.0 for skilled labor and 0.8 for unskilled labor.[7]

5. Financial costs, including those for all three outputs, were converted into the relevant economic values, excluding taxes and price contingencies, before the respective conversion factors were applied. The capital costs of the project are costs associated with civil works and installation, equipment and materials, and consulting services. These costs will occur during the construction period, which is within the first 5 years of the project.

6. O&M costs, assumed to remain constant in real terms, will occur throughout the project life span of 25 years for output 1, and 15 years for output 2. A replacement cost for the battery pack, 15 years after full operation, was assumed.

7. **Economic benefits.** The project will supply clean electricity in remote and less-developed regions of the country to replace high-carbon electricity imports from the Siberian grid, thus reducing Mongolia's heavy dependence on imported electricity. Since the renewable energy power subprojects will be sited closer to the load centers, the project will also help reduce transmission loss. The economic benefits quantified for the distributed renewable energy system development component will be as follows: (i) a 98.7 gigawatt-hour reduction in annual electricity imports from the Siberian grid, as non-incremental benefit, valued at the current cost of imported

[5] The subproject will be implemented in three batches starting with a 100-kilowatt installation in the Uvs *aimag* (province) center, followed by a rollout in four *aimag* centers in the western Mongolia.
[6] ADB. 2017. *Guidelines for the Economic Analysis of Projects.* Manila.
[7] These conversion factors were consistently used for ADB projects in Mongolia.

electricity; (ii) a reduction in yearly transmission losses of 1.5% (or 231 MW-hours); and (ii) an 87,968 $tCO_2e$ annual reduction in $CO_2$ emissions from high-carbon electricity imports.[8]

8. Since the Altai *soum* solar photovoltaic and wind hybrid system (independent system) under output 1 will replace diesel power use, the economic benefits of this subproject will be (i) avoidance of 795,080 liters of annual diesel gasoline use for power generation (as a non-incremental benefit, valued at the economic cost of diesel); and (ii) an 826.9 $tCO_2$ annual reduction in $CO_2$ emissions from diesel fuel use.[9]

9. For output 2, the economic analysis assumes that, without the output, small coal-fired heat-only boilers would be used for space heating. The output will have the following economic benefits: (i) avoidance of 1,114 tons of brown coal use yearly for space heating (as a non-incremental benefit, valued at the economic cost of coal); and (ii) a 2,975.5 $tCO_2$ annual reduction in $CO_2$ emissions from coal use. The cost of carbon was set at $36.3 per ton in 2016 prices, with an annual increase of 2%.

10. **Economic internal rate of return and economic net present value calculation.** The economic internal rate of return (EIRR) with environmental benefit for the project is 15.18%, greater than the economic opportunity cost of capital of 9%. The economic net present value is $23,483,530.65. The EIRR without environmental benefit for the project is 7.07%, below the weighted average cost of capital of 9%, and the economic net present value is –$6,851,103.18 (Table 2). For the subprojects, EIRRs range from 11.69% to 17.81%, also greater than the 9% economic opportunity cost of capital.

[8] A carbon emission factor of 0.89 for imported electricity from the Siberian grid was applied. Imported electricity saving is assumed to directly reduce carbon emissions of the Siberian grid since (i) electricity demand in Siberia, as well as in the Russian Federation as a whole, has been constant between 2007 and 2017 and has yet to reach the demand level recorded in 1991; (ii) the capacity factor of coal-fired power plants is declining, reflecting stagnated demand: from 51% in 1998 to 45% in 2017; (iii) oil and natural gas production in the eastern part of the Russian Federation, which is a major electricity demand driver, is forecast to decrease in the long-term projection toward 2040; and (iv) there are no physical grid interconnections to establish new exports to other countries. Thus, avoided imported electricity from the Siberian grid is not assumed to be replaced by domestic demand in the Russian Federation or additional exports to other countries.

[9] A carbon emission factor of 0.72 for diesel fuel combustion was applied.

## Table 2: Economic Analysis for Whole Project

($)

| Year | Capital Expenditure | Operational Outflow | Economic Benefit (i)-(iv) | Avoided Imported Electricity (i) | Transmission Loss Reduction (ii) | Avoided Fuel Use (iii) | Avoided Carbon Emission (iv) | Net Economic Benefit with Environment Benefit | Net Economic Benefit without Environment Benefit |
|---|---|---|---|---|---|---|---|---|---|
| 2018 | 52,701 | - | - | - | - | | | (52,701) | (52,701) |
| 2019 | 28,811,775 | 20,596 | 36,254 | - | - | 11,812 | 23,794 | (28,796,117) | (28,820,559) |
| 2020 | 23,071,790 | 28,260 | 73,459 | - | - | 23,624 | 48,539 | (23,026,591) | (23,076,426) |
| 2021 | 5,200,102 | 502,282 | 8,984,779 | 5,217,606 | 12,931 | 252,031 | 3,500,267 | 3,282,395 | (219,817) |
| 2022 | 93,389 | 599,253 | 9,022,997 | 5,174,440 | 12,905 | 263,410 | 3,569,651 | 8,330,355 | 4,758,112 |
| 2023 | 31,130 | 599,253 | 10,994,828 | 6,346,211 | 15,252 | 274,789 | 4,355,336 | 10,364,445 | 6,005,869 |
| 2024 | - | 599,253 | 10,889,028 | 6,226,576 | 15,221 | 274,358 | 4,369,633 | 10,289,775 | 5,916,902 |
| 2025 | - | 599,253 | 10,725,722 | 6,071,997 | 15,191 | 273,927 | 4,361,367 | 10,126,469 | 5,761,862 |
| 2026 | - | 599,253 | 10,614,527 | 5,950,774 | 15,160 | 273,498 | 4,371,855 | 10,015,274 | 5,640,179 |
| 2027 | - | 599,253 | 10,517,353 | 5,838,925 | 15,130 | 273,069 | 4,386,990 | 9,918,100 | 5,527,870 |
| 2028 | - | 599,253 | 10,433,023 | 5,735,552 | 15,100 | 272,641 | 4,406,491 | 9,833,770 | 5,424,039 |
| 2029 | - | 599,253 | 10,360,474 | 5,639,849 | 15,069 | 272,214 | 4,430,103 | 9,761,221 | 5,327,879 |
| 2030 | - | 599,253 | 10,298,746 | 5,551,089 | 15,039 | 271,787 | 4,457,591 | 9,699,493 | 5,238,662 |
| 2031 | - | 599,253 | 10,246,972 | 5,468,616 | 15,009 | 271,362 | 4,488,744 | 9,647,718 | 5,155,734 |
| 2032 | - | 599,253 | 10,204,367 | 5,391,841 | 14,979 | 270,937 | 4,523,370 | 9,605,114 | 5,078,504 |
| 2033 | - | 599,253 | 10,170,226 | 5,320,231 | 14,949 | 270,514 | 4,561,292 | 9,570,973 | 5,006,441 |
| 2034 | - | 767,253 | 10,143,909 | 5,253,307 | 14,919 | 270,091 | 4,602,352 | 9,376,656 | 4,771,064 |
| 2035 | - | 1,571,253 | 10,079,717 | 5,190,636 | 14,890 | 257,856 | 4,613,744 | 8,508,464 | 3,892,128 |
| 2036 | - | 599,253 | 10,020,948 | 5,131,828 | 14,860 | 245,623 | 4,626,693 | 9,421,695 | 4,793,058 |
| 2037 | - | 599,253 | 9,967,093 | 5,076,532 | 14,830 | 233,390 | 4,641,044 | 9,367,840 | 4,725,499 |
| 2038 | - | 599,253 | 9,917,690 | 5,024,431 | 14,800 | 221,159 | 4,656,652 | 9,318,437 | 4,661,137 |
| 2039 | - | 569,077 | 9,872,317 | 4,975,239 | 14,771 | 208,928 | 4,673,379 | 9,303,240 | 4,629,861 |
| 2040 | - | 569,077 | 9,879,113 | 4,928,698 | 14,741 | 208,510 | 4,727,164 | 9,310,036 | 4,582,872 |
| 2041 | - | 569,077 | 9,890,644 | 4,884,574 | 14,712 | 208,093 | 4,783,265 | 9,321,567 | 4,538,303 |
| 2042 | - | 569,077 | 9,906,633 | 4,842,659 | 14,682 | 207,677 | 4,841,615 | 9,337,556 | 4,495,941 |
| 2043 | - | 569,077 | 9,926,828 | 4,802,761 | 14,653 | 207,262 | 4,902,152 | 9,357,751 | 4,455,599 |
| 2044 | - | 569,077 | 9,951,006 | 4,764,710 | 14,624 | 206,847 | 4,964,825 | 9,381,929 | 4,417,104 |
| | | | **EIRR** | | | | | 15.18% | 7.07% |
| | | | **ENPV** | | | | | $23,483,530.65 | ($6,851,103.18) |

( ) = negative, EIRR = economic internal rate of return, ENPV = economic net present value.
Source: Asian Development Bank estimates.

11. **Sensitivity analysis.** A sensitivity analysis for the project with environmental benefit was conducted to assess the impact of changes in assumptions. The sensitivity analysis indicates that the EIRR for the whole project will decrease to (i) 13.49% if there is a 10% shortfall in economic benefits, (ii) 13.74% if there is a capital cost overrun of 10%, (iii) 15.08% if O&M costs increase by 10%, and (iv) 14.25% if the imported electricity price decreases by 10%. The whole project is economically viable in any adverse condition.

12. With regard to each subproject, the EIRR will decrease by (i) 10.20%–15.67% if there is a 10% shortfall in economic benefits, (ii) 10.52%–16.15% if there is a capital cost overrun of 10%, (iii) 11.51%–17.46% if O&M costs increase by 10%, or (iv) 10.81%–16.27% if the imported electricity price decreases by 10%. Each subproject is also economically viable in any adverse condition.

**Table 3: Sensitivity Analysis**
(%)

| | EOCC | Base Case | 10% CAPEX increase (i) | 10% OPEX Increase (ii) | 10% Economic Benefit Decline (iii) | 10% of Imported Electricity Price Decrease |
|---|---|---|---|---|---|---|
| Whole | 9.00 | 15.18 | 13.74 | 15.08 | 13.49 | 14.25 |
| Umnogovi Wind Power | 9.00 | 17.24 | 15.62 | 17.14 | 15.43 | 16.27 |
| Altai Solar PV | 9.00 | 15.42 | 13.89 | 15.13 | 13.53 | 14.25 |
| Altai Soum Hybrid system with battery[a] | 9.00 | 17.81 | 16.15 | 17.46 | 15.67 | N.A. |
| Uliastai Solar PV and battery | 9.00 | 15.19 | 13.76 | 15.02 | 13.45 | 14.05 |
| Telmen Wind Power | 9.00 | 12.93 | 11.28 | 12.85 | 11.03 | 11.77 |
| Moron Solar PV | 9.00 | 11.69 | 10.52 | 11.51 | 10.20 | 10.81 |
| Shallow-Ground Heat pumps[a] | 9.00 | 16.56 | 14.67 | 16.02 | 14.04 | N.A. |

CAPEX = capital expenditures, EOCC = economic opportunity cost of capital, N.A. = not applicable, OPEX = operational expenditures, PV = photovoltaic.

[a] Since the Altai *soum* (district) hybrid system and the shallow-ground heat pump components do not contribute to imported electricity saving, a change in the imported electricity price does not apply.

Source: Asian Development Bank estimates.