ADB

# Technical Assistance Consultant's Report

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# Mongolia: Updating the Energy Sector Development Plan

(Financed by the Japan Fund for Poverty Reduction)

Prepared by E. Gen Consultants Ltd. Bangladesh in association with MVV decon GmbH, Germany, and Mon-Energy Consult, Mongolia

For Ministry of Energy, Mongolia



Asian Development Bank

## Updating Energy Sector Development Plan

**Project Number: TA No. 7619-MON**

# *FINAL REPORT*

PART C: Volume - VIII of X

# *SMALL ENERGY REGION EXPANSION*

Prepared for

**The Asian Development Bank**

**and**

**The Mongolian Ministry of Mineral Resources and Energy**

Prepared by

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in association with

MONENERGY CONSULT

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## ABBREVIATIONS

| | | |
|---|---|---|
| ADB | – | Asian Development Bank |
| AuES | – | Altai-Uliastai Energy System |
| CES | – | Central Energy System |
| CHP | – | Combined Heat Power |
| $CO_2$ | – | Carbon Dioxide |
| CPI | – | Consumer Price Index |
| ERES | – | Eastern Energy System |
| EUR | – | European currency unit EURO |
| GHG | – | Greenhouse Gases |
| HOB | – | Heat Only Boilers |
| IDC | – | Interest during construction |
| LCOE | – | Levelized Cost of Energy |
| MoE | – | Ministry of Energy |
| MNT | – | Mongolian Tugrik |
| NOx | – | Nitrogen Oxides |
| O&M | – | Operation and Maintenance |
| PPA | – | Power Purchase Agreement |
| PV | – | Photovoltaic |
| SOx | – | Sulfur Oxides |
| USD | – | United States Dollars |
| VAT | – | Value Added Tax |
| WACC | – | Weighted Average Cost of Capital |
| WRES | – | Western Energy System |

## UNITS OF MEASURE

| | | |
|---|---|---|
| BTU | - | British thermal unit |
| GCal | - | Gigacalorie (one million kilocalories) |
| GJ | - | Gigajoule (one thousand megajoules) |
| kJ | - | Kilojoule |
| kWh | - | Kilowatt-hour |
| MWh | - | Megawatt-hour |
| MWel | - | Megawatt electric |
| MWth | - | Megawatt thermal |
| PJ | - | Petajoule |
| TSC (TPU) | - | Tons of standard coal |
| TJ | - | Terajoule |

## WEIGHTS AND MEASURES

| | | |
|---|---|---|
| GW (giga watt) | – | 1,000,000,000 calories |
| GJ (giga joules) | – | 1,000,000,000 joules |
| GW (giga watt) | – | 1,000,000,000 watts |
| kVA (kilovolt-ampere) | – | 1,000 volt-amperes |
| kW (kilowatt) | – | 1,000 watts |
| kWh (kilowatt-hour) | – | 1,000 watts-hour |
| MW (megawatt) | – | 1,000,000 watts |
| W (watt) | – | unit of active power |

## CONVERSION FACTORS

| | | |
|---|---|---|
| 1 GCal | = | 4.19 GJ |
| 1 BTU | = | 1.05506 kJ |
| 1 Gcal | = | 1.1615 MWh = 4.19 GJ = 1.75 steam tons/hour |
| 1 GJ | = | 0.278 MWh = 0.239 Gcal = 0.42 steam tons/hour |
| 1 MW | = | 0.86 Gcal = 3.6 GJ = 1.52 steam tons/hour |
| 1 TSC | = | 7 Gcal = 29.3 GJ = 8.15 MWh |

## NOTE

In this report, “$” refers to US dollars.

**CONTENTS**

# I. BACKGROUND

## A. Background

1. The development of the small Energy Regions locally and as an Integrated Energy System is a challenging problem due to the vast distances between the population centres in Mongolia.

2. The guiding principles involve consideration of the location of supply sources and load centres. In this regard it is usual practice to plan in terms of power evacuation from generation plant by long double circuit transmission lines delivering power at extra-high voltage to load centres. The load centres are typically served by a ring transmission network, with substations transforming voltage through intermediate voltage levels to supply consumers.

3. Mongolia is endowed with coal basins near to every load centre. Accordingly it is appropriate to build power plants local to individual load centres, and to provide backup from adjacent local grids.

## B. Planning Criterion

4. Reliability in the electricity sector is defined in terms of two components: adequacy and security. Adequacy refers to the ability of the system to supply customer requirements under normal operating conditions. It considers the system statically. Security includes the dynamic response of the system to unexpected interruptions, and relates to its ability to endure them. The objective is to avoid a voltage collapse under contingency conditions.

5. It is not straightforward to calculate adequacy and security measures for a highly meshed transmission grid. However, where load centres are spaced widely apart, with local supply sources, the task can be undertaken for a masterplan by applying typical interconnector failure rates, and power plant availability. This is the approach taken in this masterplan when considering the development of an Integrated Energy System.

6. Further grid studies will be required as part of feasibility studies, however the need for dynamic stability studies is thought to be mainly limited to the north-south transmission corridor linking UB and the South Gobi (Tavan Tolgoi) due to the large load transfers involved. In other cases interconnectors would loosely couple adjacent grids, first contingency loss of load would be small, and load transfers would therefore be small and not expected to create grid security issues.

7. It is with this background in mind that small Energy System expansion plans have been developed, along with a vision for an Integrated Energy System.

# II. SMALL ENERGY REGION EXPANSION OPTIONS

## C. Small Energy System Loads

8. The 2025 load forecasts for Mongolia's Aimag centres, are shown in Figure 3 below. These loads and provincial considerations suggest a grouping of loads into the load centres as shown in Figure 4.

9. As these load centres are separated by large distances and the loads are not particularly high, from the perspective of adequacy and security of supply it is considered that each load centre should be supplied from a local 110kV or 220kV grid. Furthermore each load centre would be linked by 220kV interconnectors capable of bi-directional delivery of power. It is not envisaged that power transfers into the Central Energy System (CES) would be a feature of this arrangement, since the security of the CES should not be compromised in any way by small Energy Systems. A proposed arrangement is shown in Figure 5; power plants are shown sited at local coal basins.

10. The power plants required to supply the load centres would be sized to supply the load centre, in one case with a local 25% reserve margin, in other cases the reserve margin can be provided by transfer from adjacent regions or potentially from Russia. The maximum size of power plant units must be commensurate with the need to maintain adequate voltage stability under load rejection or fault conditions, to perform power plant maintenance, to cope with forced outages, and to provide power on emergency basis to an adjacent Energy System. In practice these conditions could be met with units of minimum 25MW each. Interconnection to the CES and Russia would make the small Energy Systems 'stiffer' or more tolerant of loss of a 25MW unit, however the final arrangements and sizing would require detailed feasibility study. However, in principle this overall supply strategy would guarantee a high level of security on the most economical basis across widely dispersed load centres.

11. The local 220kV grid arrangement would provide for a high level of reliability, with an estimated annual loss of load probability due to grid issues at less than 0.1%. Overall the loss of load probability would be no worse than 0.342%, a typical target for developing countries.

12. A local centralized supply strategy, sharing resources between load centres under emergency conditions is shown in the following table:-

**Table 1: Supply Security**

| Capacity | AuES | WRES | CES | ERES |
|---|---|---|---|---|
| Local | 6 x 25MW | 4 x 25MW | As per CES Expansion Plan | 3 x 10MW CHP<br>2 x 25MW |
| Local Grid Backup (capacity included above) | 1 x 25MW spare | 1 x 25MW spare | CES Scenario 2c | 1 x 25MW spare |
| Remote Backup | 1 x 25MW<br>from WRES | 1 x 25MW<br>from AuES | from South Gobi – Tavan Tolgoi complex | 1 x 25MW<br>from CES<br>(Baganuur / Chandgana) |

13. The arrangement shown in Figure 5 is one of a range of possible options. The actual routing of transmission lines would need to take into account topography during the stage of detailed feasibility study. Nevertheless the general principle would nevertheless apply to integration of Energy Systems.

14. It is required to ensure that the local grid frequency can be controlled (voltage versus reactive power droop considerations). In systems of 50MW to 100MW, the frequency could be controlled by a fast-acting diesel power plant, or alternatively by a hydropower plant. Consistent with the expansion plan for CES, a possible strategy for load following is shown in the following table:-

**Table 2: Load Following Strategy (Frequency Control)**

| Western Region Energy System | Altai – Uliastai / Bayankhongor / Arkhangai / Khuvsgul Energy System | Central Energy System | Eastern Region Energy System |
|---|---|---|---|
| Russian Hydropower via Interconnector | Sheuren Hydropower via Interconnector to CES | Sheuren Hydropower | Russian Hydropower via Interconnector (or Sheuren HPP via Interconnector to CES) |

15. A more detailed consideration at the level of individual Energy Systems is considered in following Sections of this report. The individual Energy System plans are based on the Integrated Energy System (IES) concept expounded in this Section, however the timing of the expansion is given consideration at the local grid level.

**Figure 3: Electricity Demand Forecasts by Aimag Centre - 2025**

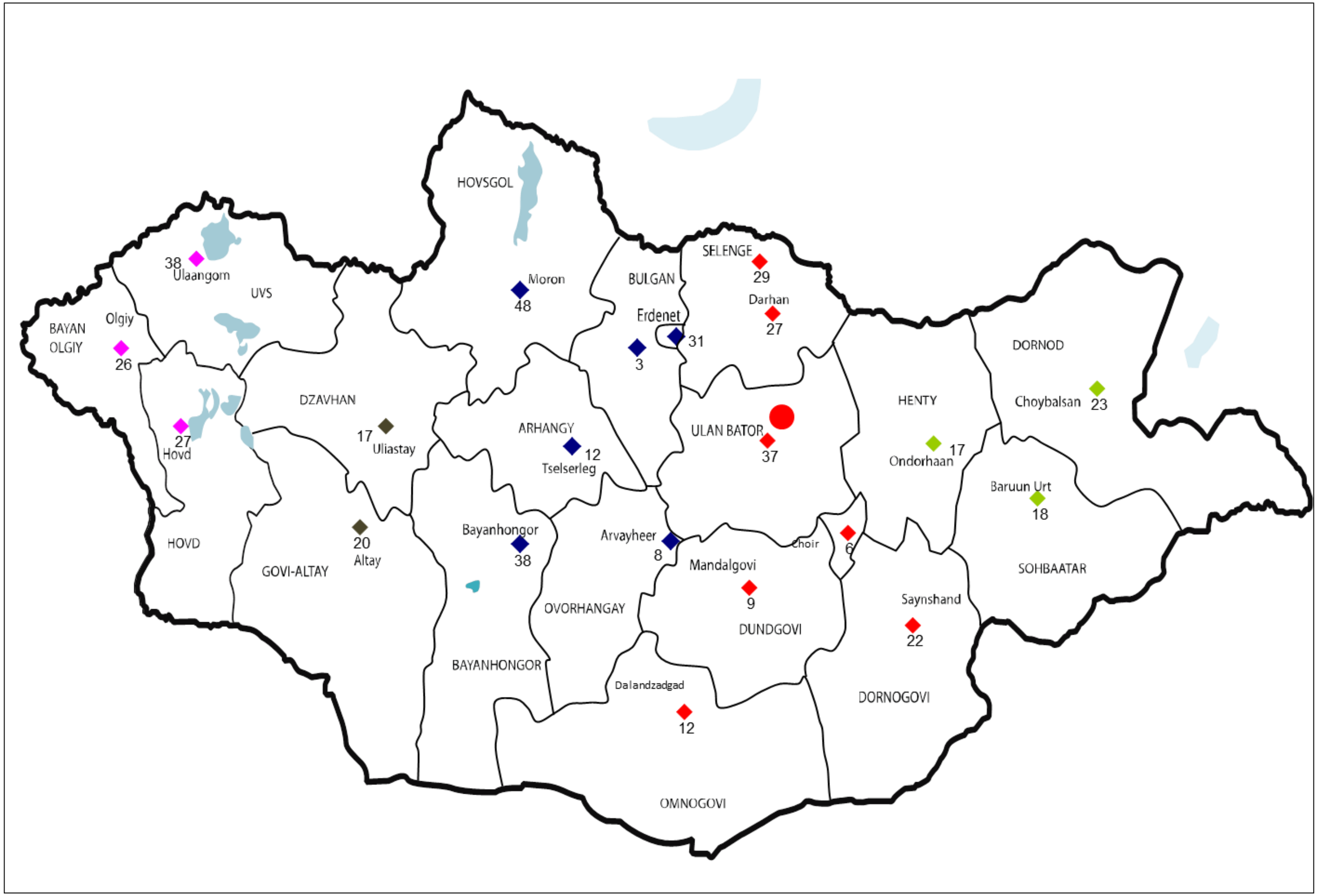


**Figure 4: Load Centres – 2025 (Low Growth)**

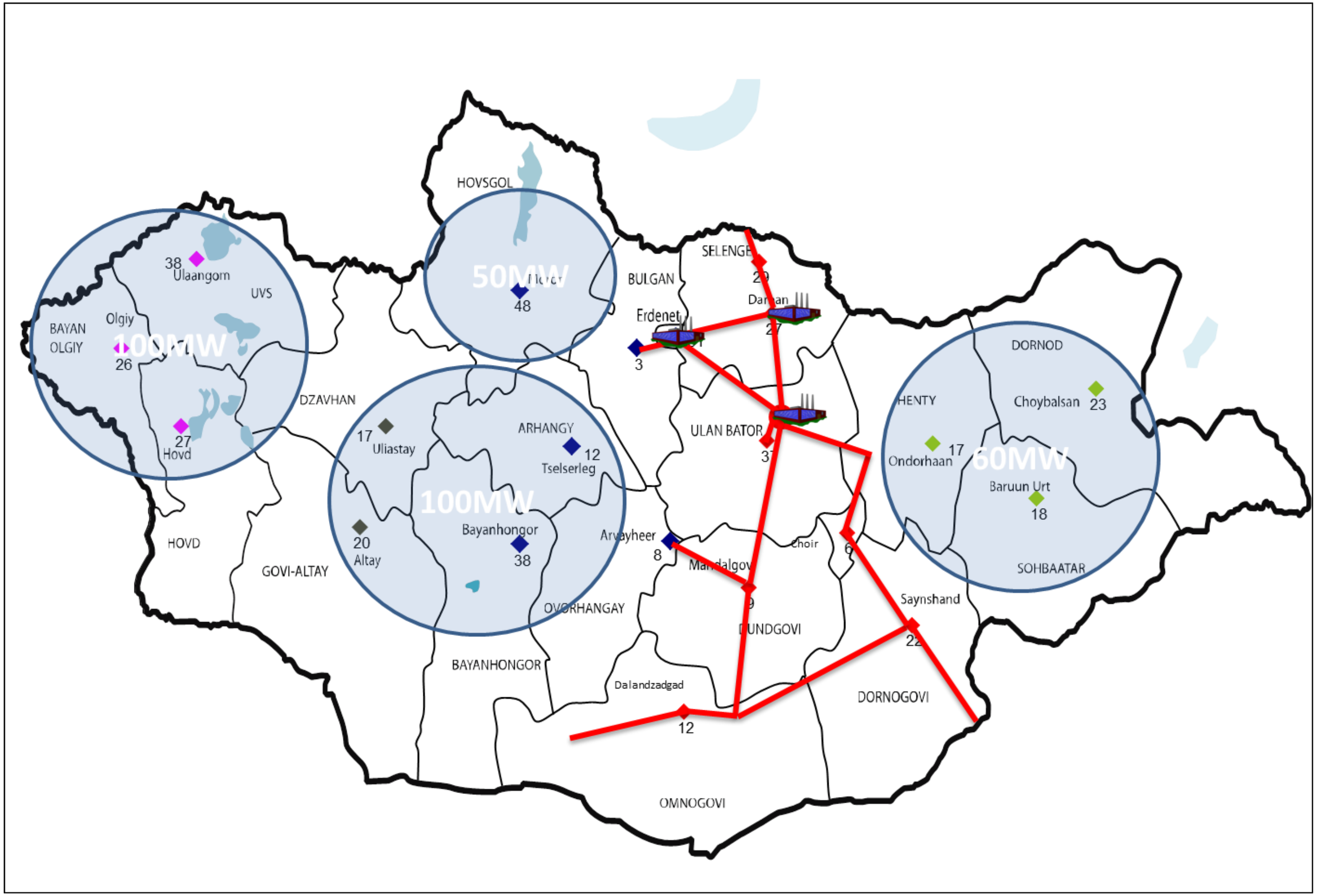
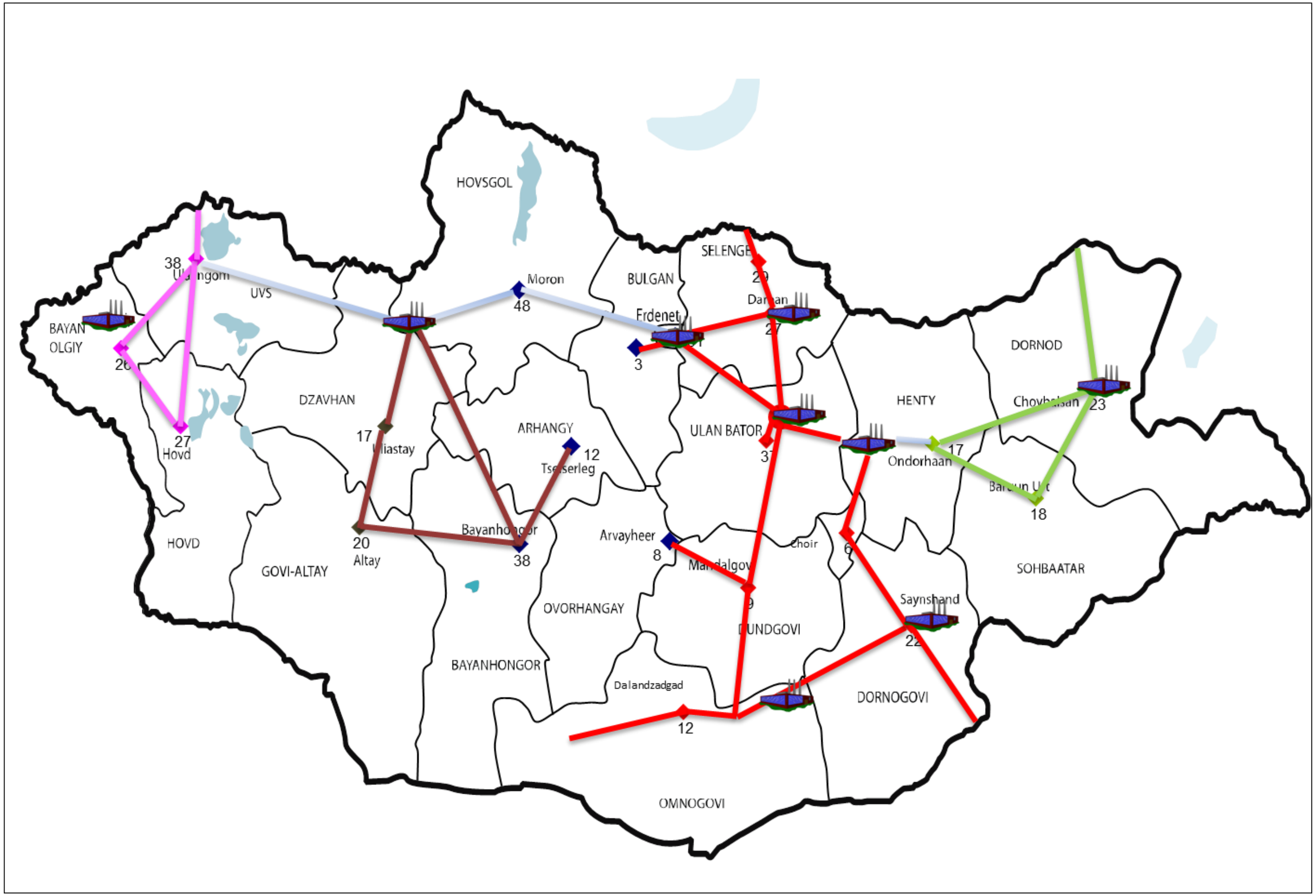


**Figure 5: Vision – Integrated Electricity System – 2025**



# III. ALTAI ULIASTAI ENERGY SYSTEM

## D. Background

16. The Altai Uliastai Energy System serves the Gobi-Altai and Zavkhan Aimags. However in the vision for the Integrated Energy System, this Energy System would embrace large parts of the Bayankhongor, Arkhangai and Khuvsgul Aimags. Table 1 provides the demographics of each Aimag in 2013.

**Table 1: Altai-Uliastai Energy System**

| Aimag | Soums | Population | Urban | Rural | Area |
|---|---|---|---|---|---|
| | | Count | % | % | Sq. km |
| Gobi-Altai | 18 | 58,400 | 32.6 | 67.4 | 141,400 |
| Zavkhan | 24 | 76,900 | 20.4 | 79.6 | 82,500 |
| Arkhangai | 19 | 91,600 | 22 | 78 | 55,300 |
| Bayankhongor | 20 | 85,100 | 33.1 | 66.9 | 116,000 |
| Khuvsgul | 24 | 124,600 | 31.4 | 68.6 | 100,600 |
| Totals | 105 | 436,600 | | | 495,800 |

## E. Electricity Demand Forecast

17. An AuES electricity demand forecast was prepared and presented in the Electricity Load Forecast report. The forecast is repeated here for convenience.

18. Since the load forecast above was prepared, the peak demand in 2012 was reported recently (May 2013) as 14MW. The actual load in 2012 fell between the low and medium forecast of the Consultant. Energy consumption in 2012 was reported to be 37.4GWh, with significant consumption in the towns of Yosunbulag at 9.9GWh and Uliastai at 14.8GWh.

19. It is noted that these loads would only form part of the load of a future Altai Uliastai Energy System.

## F. Electricity Supply Inventory

20. The AuES relies on diesel generation, small hydropower plants and small solar PV. A northern border connection to Russia exists but is not interconnected to the Mongolian grid. There is a major coal field at Mogoin Gol, in the near vicinity just outside the Zavkan Aimag, with significant capacity to support coal-fired power generation.

21. Table 2 summarizes the electricity supply inventory of AuES.

**Table 2: Electricity Supply Inventory**

| Aimag | Hydropower | Diesel Power | Solar PV | Hybrid Solar & Wind | Wind | Electricity Distribution Networks |
|---|---|---|---|---|---|---|
| Gobi-Altai | 2 | 1* | 3 | 1 | 0 | 16 |
| Zavkhan | 4 | 23 | 2 | 1 | 0 | 19 |
| Arkhangai | 0 | 0 | 0 | 0 | 0 | 19 |
| Bayankhongor | 0 | 0 | 2 | 3 | 0 | 17 |
| Khuvsgul | 1 | 0 | 0 | 1 | 0 | 23 |

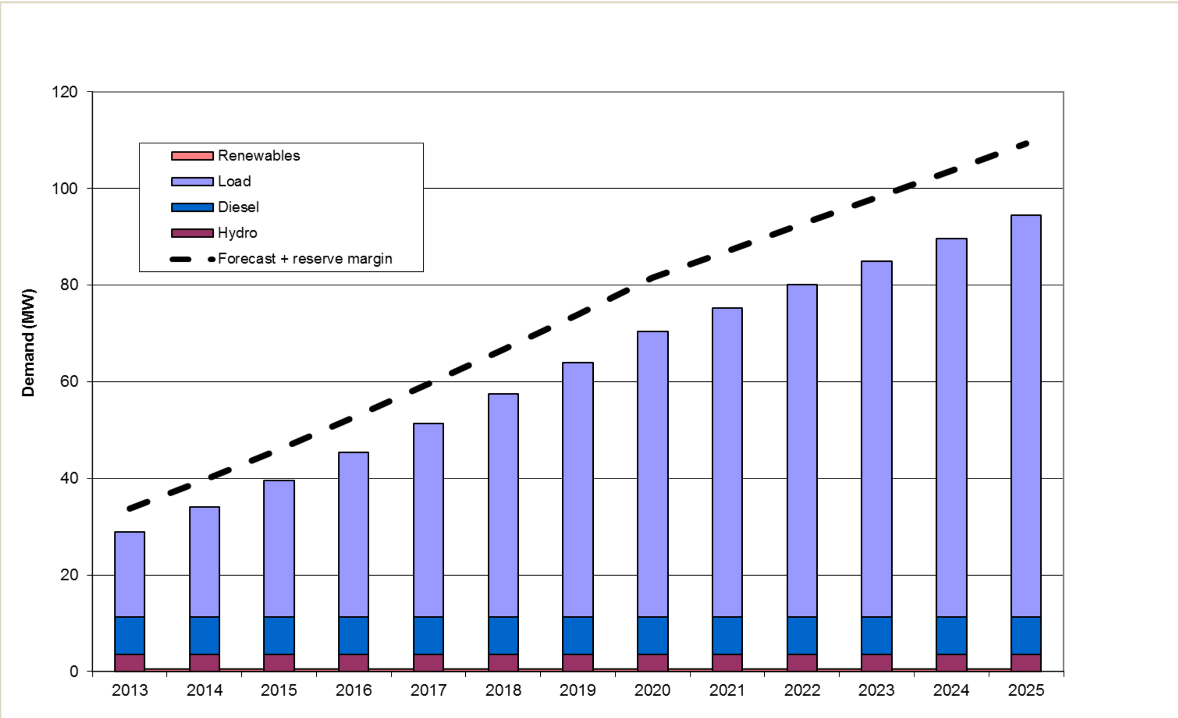
22. The Altai Uliastai Energy System includes hydropower plants Taishir, Bogd gol, Tosontsengel, Guulin, Tsetsen Uul and Zavhan Mandal.

23. The capacity of Taishir hydro power plant is 11MW. At the present time the plant produces between 3.5 and 4.1MW and generates around 12.4GWh per annum. Renewable energy production in total is reported at 1.8GWh. Total supply capacity in 2013 has been reported by the Ministry of Energy to be 11.8MW, i.e. below the 2012 peak demand of 14MW.

## G. Supply – Demand Balance to 2025

24. The following chart is based on the Consultant's demand forecast for AuES as it is currently defined, i.e. for the Gobi-Altai and Zavkhan regions only. The dashed line shows the supply capacity requirement to maintain a reserve margin of 15% for the planning period of 2013 to 2025, under a high growth scenario. The load component is shown filled with existing capacity.

**Figure 3: Supply Expansion**



25. Supply expansion can be met with 4 x 25MW coal-fired power plant. Muren (50MW load) would also be supplied by the Mogoin Gol power plant.

26. The timing of power plant units would be according to actual load growth but an indicative planting schedule with capital disbursement profile is shown in Table 4. The timing of transmission line development is also shown.

**Table 4: AuES Supply Expansion Plan**

| Asset | Capacity | Year | Investment USD$ |
|---|---|---|---|
| Mogoin Gol Coal no. 1 | 25MW | 2018 | $50m |
| Mogoin Gol Coal no. 2 | 25MW | 2018 | $50m |
| Mogoin Gol Coal no. 3 (Muren) | 25MW | 2018 | $50m |
| Mogoin Gol Coal no. 4 | 25MW | 2022 | $50m |
| Mogoin Gol Coal no. 5 | 25MW | 2025 | $50m |
| Mogoin Gol Coal no. 6 (Muren) | 25MW | 2025 | $50m |
| 220kV Interconnector – Mogoin Gol to Ulaangom | 25MW | 2018 | Included in Transmission Expansion Plan report |
| 220kV Interconnector – Mogoin Gol to Erdenet via Muren | 25MW | 2025 | Included in Transmission Expansion Plan report |
| 220kV line – Mogoin Gol to Altai via Uliastai | 50MW | 2023 | Included in Transmission Expansion Plan report |
| 110kV line – Altai to Bayankhongor | 25MW | 2023 | Included in Transmission Expansion Plan report |
| 220kV line – Mogoin Gol to Bayankhongor | 50MW | 2025 | Included in Transmission Expansion Plan report |

# IV. EASTERN REGION ENERGY SYSTEM

## H. Background

27. The Eastern Region Energy System serves the Dornod, Sukhbaatar and Khentii Aimags. Table 1 provides the demographics of each Aimag in 2013.

**Table 1: Eastern Region Energy System**

| Aimag | Soums | Population | Urban | Rural | Area |
|---|---|---|---|---|---|
| | | **Count** | **%** | **%** | **Sq. km** |
| Dornod | 14 | 73,600 | 54.8 | 45.2 | 123,600 |
| Sukhbaatar | 13 | 55,000 | 26.1 | 73.9 | 82,300 |
| Khentii | 17 | 71,800 | 35.1 | 64.9 | 80,300 |
| Totals | 44 | 200,400 | | | 286,200 |

## I. Electricity System Inventory

28. The ERES has limited electricity supply, with the CHP at Choibalsan the only local source. As the Aimag heat expansion planning determined the need for a CHP at Choibalsan, this local source is expected to be able to supply Choibalsan.

29. Outside of the CHP plant at Choibalsan, Table 2 summarizes the electricity supply inventory of the ERES.

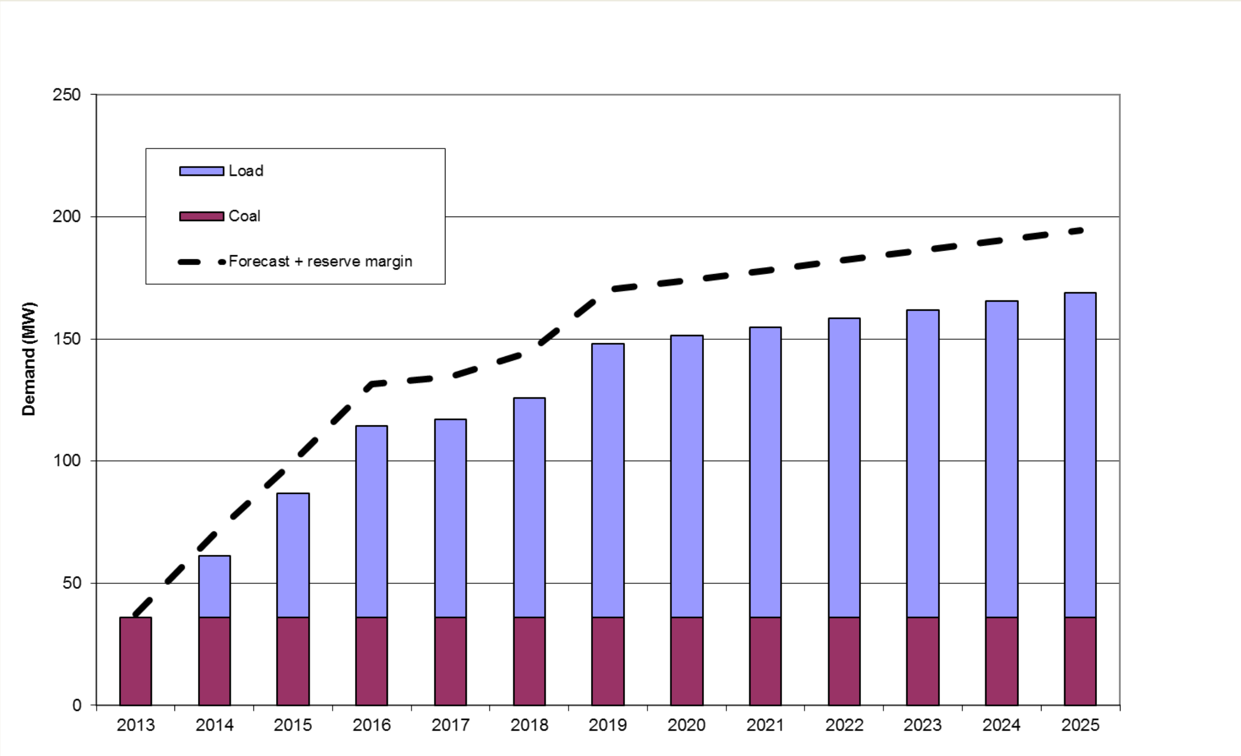
**Table 2: Electricity Supply Inventory**

| Aimag | Hydropower | Diesel Power | Solar PV | Hybrid Solar & Wind | Wind | Electricity Distribution Networks |
|---|---|---|---|---|---|---|
| Dornod | 0 | 0 | 0 | 1 | 0 | 13 |
| Sukhbaatar | 0 | 0 | 0 | 1 | 1 | 13 |
| Khentii | 0 | 0 | 0 | 0 | 0 | 17 |

## J. Supply – Demand Balance to 2025

30. The following chart is based on the Consultant’s demand forecast, and shows the supply expansion required to maintain a reserve margin of 15% for the planning period of 2013 to 2025.

**Figure 3: Supply Expansion – High Growth Scenario**




Sources: Consultants Analyses

31. Supply expansion can be met with a 3 x 10 MW CHP at Choibalsan and a 2 x 25MW coal-fired power plant.

32. The timing of power plant units would be according to actual load growth but an indicative planting schedule with capital disbursement profile is shown in Table 4. The timing of transmission line development is also shown.

**Table 4: ERES Supply Expansion Plan**

| Asset | Capacity | Year | Investment USD$ |
|---|---|---|---|
| Choibalsan CHP | 3 x 10MW | 2018 | Included in Aimag Heat Expansion Plan report |
| Baganuur / Chandgana no 1 | 25MW | 2018 | $50m |
| Baganuur / Chandgana no 2 | 25MW | 2025 | $50m |
| 220kV Interconnector – Banganuur / Chandgana to Ondorhaan | 25MW | 2018 | Included in Transmission Expansion Plan report |
| 110kV line – Ondorhaan to Baruun-Urt | 25MW | 2025 | Included in Transmission Expansion Plan report |
| 110kV line – Baruun-Urt to Choibalsan | 25MW | 2025 | Included in Transmission Expansion Plan report |

# V. WESTERN REGION ENERGY SYSTEM

## K. Background

33. The Western Region Energy System serves the Bayan-Ulgii, Uvs and Khovd Aimags. Table 1 provides the demographics of each Aimag in 2013.

**Table 1: Western Region Energy System**

| Aimag | Soums | Population | Urban | Rural | Area |
|---|---|---|---|---|---|
| | | Count | % | % | Sq. km |
| Bayan-Ulgii | 13 | 100,800 | 34.1 | 65.9 | 45,700 |
| Uvs | 19 | 78,200 | 30.8 | 69.2 | 69,600 |
| Khovd | 17 | 88,400 | 32.8 | 67.2 | 76,100 |
| Total | 49 | 267,400 | | | 191,400 |

## L. Electricity Demand Forecast

34. The peak demand in 2012 was reported as 27.4MW. Energy consumption was 108.9GWh. Energy was imported from Russia and China. The import from Russia was 87.3GWh, and from China 1.7GWh. The Durgun HPP generated 23.6GW.

35. The Consultant's load forecast, based on data supplied by MoE, indicated that the peak load in 2012 was only around 20MW. However, the expansion planning for WRES assumes a high growth forecast which caters for the reported higher demand.

## M. Electricity System Inventory

36. The WRES relies on diesel generation and grid connection. There is a coal field to the west of with capability to supply power to the local grid.

37. Table 2 summarizes the electricity supply inventory of the WRES.

**Table 2: Electricity Supply Inventory**

| Aimag | Hydropower | Diesel Power | Solar PV | Hybrid Solar & Wind | Wind | Electricity Distribution Networks |
|---|---|---|---|---|---|---|
| Bayan-Ulgii | 0 | 12 | 0 | 0 | 0 | 13 |
| Uvs | 0 | 13 | 0 | 0 | 0 | 19 |
| Khovd | 4 | 10 | 1 | 0 | 0 | 16 |

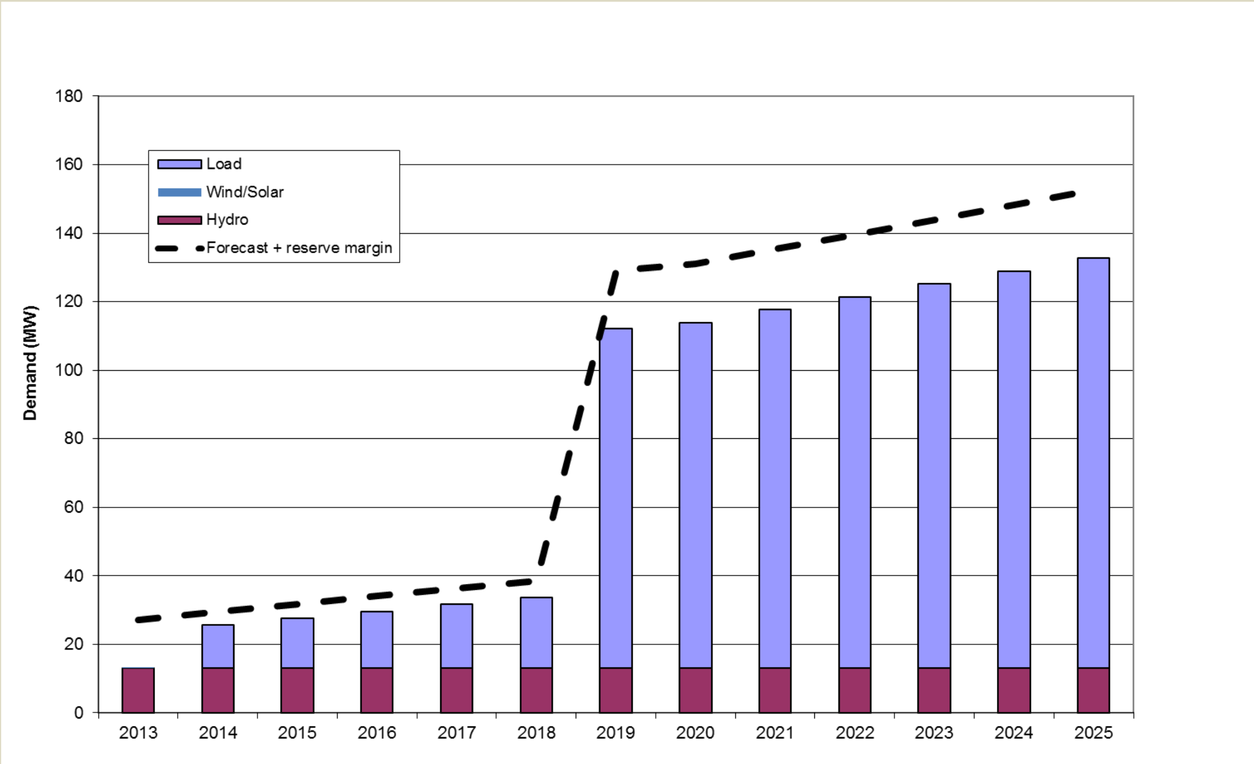
38. The WES is connected at 110 kV to the Russian system at Chadan substation. This small independent network is supplied entirely from Russia and there is currently no local generation (except some standby diesel). The annual Russian import is variously

reported to be between 8 to 10MW.

## N. Supply – Demand Balance to 2025

39. The following chart is based on the Consultant's demand forecast, and shows the supply expansion required to maintain an adequate reserve margin of 15% for the planning period of 2013 to 2025.

**Figure 3: Supply Expansion**




Sources: Consultants Analyses

40. The large step change in demand in 2018 is due to the Asgat silver mine load of 80MW. The mine is in a remote location and it is considered that a small coal-fired mine mouth plant would be more economical than a grid connection. Since this is a commercial venture, the timing of the development of the mine and power plant, and other infrastructure such as rail will be a matter for commercial decision and accordingly the power plant is not included in the expansion plan.

41. Supply expansion could be met with a 4 x 25MW coal-fired power plant. There are a number of possible locations for a power plant(s), at Nuurstkhotgor, Khartarvagatai, Khushuut, Khurengol and / or Telmen.

42. The timing of power plant units would be according to actual load growth but an indicative planting schedule with capital disbursement profile is shown in Table 4. The timing of transmission line development is also shown.

**Table 4: WRES Supply Expansion Plan**

| Asset | Capacity | Year | Investment USD$ |
|---|---|---|---|
| Power plant unit no. 1 | 25MW | 2018 | $50m |
| Power plant unit no. 2 | 25MW | 2018 | $50m |
| Power plant unit no. 3 | 25MW | 2022 | $50m |
| Power plant unit no. 4 | 25MW | 2025 | $50m |
| 110kV line – Ulaangom to Ulgii | 25MW | 2018 | Included in Transmission Expansion Plan report |
| 110kV line – Ulgii to Khovd | 25MW | 2018 | Included in Transmission Expansion Plan report |
| 110kV line – Khovd to Ulaangom | 25MW | 2022 | Included in Transmission Expansion Plan report |

# VI. SOUTH GOBI SYSTEM

## O. Background

43. The South Gobi Energy System serves the Umnugobi Aimag. Table 1 provides the demographics of the Aimag in 2013.

**Table 1: South Gobi Energy System**

| Aimag | Soums | Population | Urban | Rural | Area |
|---|---|---|---|---|---|
| | | Count | % | % | Sq. km |
| Umnugobi | 15 | 51,000 | 34.2 | 65.8 | 165,400 |

## P. Electricity System Inventory

44. The South Gobi Energy System relies mainly on diesel generation and off-grid solar PV. There are major coal fields with capacity to support large coal-fired power generation.

45. Table 2 summarizes the electricity supply inventory of the South Gobi Energy System.

**Table 2: Electricity Supply Inventory**

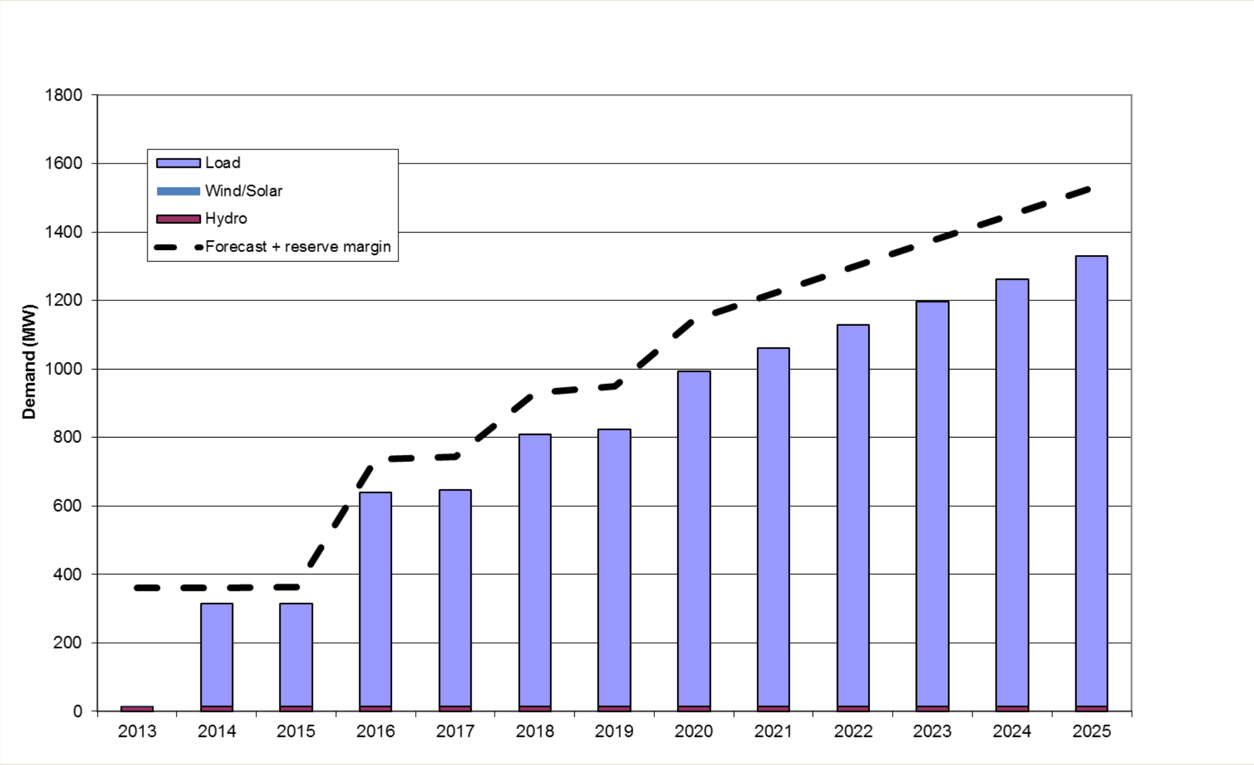
| Aimag | Hydropower | Diesel Power | Solar PV | Hybrid Solar & Wind | Wind | Electricity Distribution Networks |
|---|---|---|---|---|---|---|
| Umnugobi | 0 | 2 | 1 | 1 | 1 | 12 |

46. The South Gobi Energy System also includes the 6MW Dalanzadgad CHP. The Aimag heat supply expansion planning determined that a CHP is not justified for Dalanzadgad, rather a small HOB supply strategy is indicated to be the most economical solution for heat supply. Electricity supply can be provided from the nearby Tavan Tolgoi power plant complex.

## Q. Supply – Demand Balance to 2025

47. The following chart is based on the Consultant's demand forecast, and shows the supply expansion required to maintain an adequate reserve margin of 15% for the planning period of 2013 to 2025.

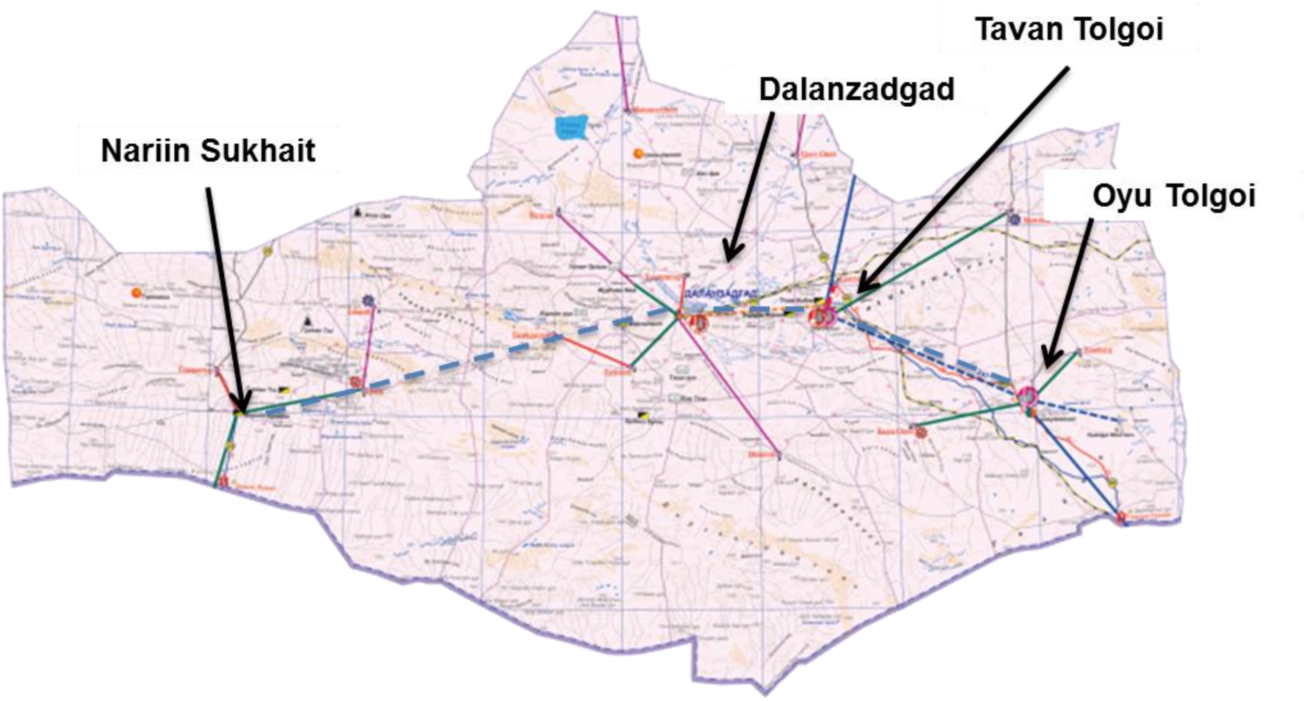
**Figure 3: Supply Expansion**




48. The load forecast includes the Oyu Tolgoi and Tavan Tolgoi mine loads. These loads require a high security of supply, provided by a mine mouth coal-fired power plant at Tavan Tolgoi. This plant will be fuelled by the coal middlings produced by the Tavan Tolgoi coking coal mining operation that would otherwise be literally buried as overburden. As such a plant will potentially develop to around 1,200 MW, there will be ample opportunity to supply the local area, including other smaller mines, on a highly economical basis. It is understood that sufficient water supplies and coal middlings is available at the Tavan Tolgoi site, to easily support generation of 1,200 MW. This expansion is further considered in the Transmission Expansion Plan report, where stability studies were undertaken to determine the viability of integrating a large power plant complex at Tavan Tolgoi with the CES system.

49. The load centres within the Dalanzadgad area are spread to the east and west of the town of Dalanzadgad as shown in the following map:-

**Figure 4: Electricity Load & Location**




50. The timing of power plant units would be according to the development schedule of Oyu Tolgoi and Tavan Tolgoi. In 2011 both mine owners were planning to build power plants but subsequently it has been planned to develop a single power plant complex at Tavan Tolgoi. The mine loads are expected to reach 750MW in total with potential for ultimate expansion to 1,200MW. Mine development and therefore power plant needs are related to the commodity markets affecting the prices and demand for minerals. In this regard it is not possible to be specific regarding the exact timing of power plant development. Nevertheless, an indicative planting schedule with capital disbursement profile is shown in Table 5. The timing of transmission line development is also shown.

**Table 5: South Gobi Supply Expansion Plan**

| Asset | Capacity | Year | Investment USD$ |
|---|---|---|---|
| Tavan Tolgoi units 1 – 3 | 450MW | 2018 | $900m |
| Tavan Tolgoi unit no. 4 | +150MW | 2020 | +$300m |
| Tavan Tolgoi unit no. 5 | +150MW | 2022 | +300m |
| Tavan Tolgoi - Oyu Tolgoi 220kV | 25MW | 2016 | $50m |
| Tavan Tologi – Dalanzadgad – Nariin Suhkait 110kV line | 50-100MW | 2018 | Included in Transmission Expansion Plan report |

# VII. ISOLATED SYSTEMS

51. Outside of the main population centres of the Aimags are many small population centres remote from local or main electricity supply grids. Whilst most of the 330 Soums are connected to the grid, there are reported to be 18 Soums that are too remote to be supplied economically by a grid connection.

52. Power supply in the Soums is by diesel engines. The cost of fuel is expensive, and it is common for power to be generated for only four or five hours per day, to provide lighting at night.

53. These factors support consideration of the use of hybrid diesel / wind and diesel / solar PV systems, wherein the diesel plants provide back-up under emergency conditions.

## R. Isolated Networks

54. Remote area power supplies are popular in sparse populated regions, and in countries where the Government has failed to provide cheap and reliable power to rural populations. Of all of the countries that have introduced off-grid power supply, Western Australia perhaps provides the useful reference site, having used remote area power supplies for the past 30 years.

55. From 2000 to 2006, renewable energy capacity in stand-alone power supply (SPS) systems underwent a dramatic growth in Western Australian (WA) in remote off-grid agricultural and pastoral regions. This growth was encouraged through capital cost subsidies of photovoltaic, wind turbine and enabling technologies. However, in spite of capital subsidies promoting renewables for remote area use, there remains today a group of farmers who continue to rely on diesel engines to meet their needs for power. This has led the Government to consider carefully a policy framework suitable to encourage switching to cleaner forms of power production.

56. The southern Gobi are of Mongolia is a landscape that is particularly similar to the remote areas of Western Australia and it is useful to examine the policy framework of Western Australia for relevance to Mongolia. The key policies considered as necessary for the success of hybrid stand-alone power supply systems are as follows:-

1. Maintain renewable energy capital subsidies. Capital subsidies have performed extremely well over the past several years, as high capital costs are still a major barrier. Removal of subsidies will result in fewer systems being installed;
2. Incorporate a subsidy or rebate to promote the establishment of renewable energy component and system servicing and assist the development of maintenance industries, especially in remote areas;
3. Incorporate information gathering as part of routine maintenance incentives in order to track SPS system strengths and weaknesses for system providers, manufacturers, governments and users;
4. Allocate funds to independent institutions that can develop Australian and international standards, as well as provide capacity building to achieve accreditation for such standards. These standards would also be useful for initiating mandatory minimum performance benchmarks for on and off-grid energy services and components;
5. Allocate funds to support accredited laboratory testing procedures that incorporate technology and system reliability in hot, humid and dusty conditions; and
6. Foster capacity building initiatives to users that incorporate minor system servicing, demand management, fuel substitution and load switching for SPS systems. This could entail components that include case studies and displays indicating system performance

and energy usage patterns to the user.

57. It is reasonable to say that these policies are readily transferable to Mongolia.

## S. SPS Subsidies in Mongolia

58. A simple analysis of a hybrid diesel / wind and hybrid diesel / solar systems provides an indication of the level of subsidy required for such schemes to be introduced in remote areas of Mongolia.

59. The scenarios adopted for the analyses are as follows:-

i. A Soum of 1,000 households is partly supplied by diesel power. Of the 1,000 households, it is assumed that only 25% currently take advantage of 4 to 5 hours of electricity provided by a 3 x 100kW diesel engines. The power is used mainly for lighting purpose in the evenings, and accordingly total energy consumption is only 40MWh per annum in total.

ii. It is proposed to install a hybrid diesel / renewable scheme, with the renewable component having capacity of 75kW. A backup diesel engine system would be maintained for emergency purpose, capacity of 2 x 100kW engines. This would see the annual energy consumption rise to around 220MWh per annum, with the majority of the households being able to enjoy power, on 24 hour basis and on as-needs basis.

iii. It is assumed that the Soum residents currently pay MNT 250/kWh. This price is chosen arbitrarily as a reference cost against which subsidies are determined. In practice the Soum residents may be willing to pay more, but such an assumption is not made in the absence of willingness to pay or affordability studies. Accordingly it is also assumed that the diversified maximum demand will remain relatively low at around 0.8 kW per HH.

iv. In the case of the wind option, the capital cost is estimated at USD$250,000 (around $3,300 per kW). This cost includes battery storage. Operating costs are restricted to annual servicing at a cost of around $1,500 per annum.

v. In the case of the small solar PV option, the capital cost is estimated at twice the cost of the small wind option. A modest allowance is made for annual O&M.

vi. In both cases the diesel plant is assumed to be required to serve 5% of the annual energy consumption.

60. The base tariff rate applicable to a stand-alone diesel engine supply is determined as a reference point.

**Table 1: Diesel Engine Supply**

| Energy Demand | | |
|---|---|---|
| Electricity demand | 0.022 | MW |
| Capacity factor | 21% | |
| Electricity demand | 40 | MWh |

| Unit costs | MNT | | USD | |
|---|---|---|---|---|
| Unit cost of electricity | 0 | MNT/MWh | 0 | $/MWh |
| Unit cost of Diesel capacity | 0 | MNT/(kW) | 0 | $/kW |
| Fuel cost of Mazut | 1,097,700 | MNT/ton | 844 | $/ton |

| **Unit costs** | MNT | | USD | |
|---|---|---|---|---|
| Cost of Mazut including transport | 1,153,900 | MNT/ton | 888 | $/ton |
| Fuel cost of Mazut | 102,296 | MNT/MWh | 79 | $/MWhf |
| **Diesel** | | | | |
| Installed capacity | 0.3 | MW | | |
| Installed cost | 0 | MNT | 0 | $ |
| Cost of Mazut at site | 9,695,658 | MNT/a | 7,458 | $/a |
| Cost of O&M | 423,531 | MNT/a | 326 | $/a |
| Total installed cost | 0 | MNT | 0 | $ |
| Annual cost (WACC 6%, 20 a) | 0 | MNT/a | 0 | $/a |
| Annual O&M cost | 10,119,189 | MNT/a | 7,784 | $/a |
| **Total annual cost** | **10,119,189** | **MNT/a** | **7,784** | **$/a** |

61. A cost of $7,784 per annum equates to a tariff rate of MNT 250/kWh, close to the rate currently paid in the Soum centres. To achieve this rate required a diesel engine capital subsidy of 100%, i.e. the capital cost of the diesel plant is not included in the above calculation of installed cost (the unit cost of diesel plant is set to zero). The analysis explains why isolated Mongolian communities cannot afford electricity.

62. In both of the hybrid supply scenarios that follow, it is assumed that the local distribution grid would need to be extended at a capital cost of USD$150,000.

63. In the following scenario for a hybrid diesel / wind scheme it is found that it would be necessary to subsidize the full cost of the back-up diesel engines but in this case the wind facilities could potentially be paid for by the community due to the larger consumer base.

**Table 2: Hybrid Diesel / Wind Supply**

| **Energy demand** | | |
|---|---|---|
| Electricity demand | 0.075 | MW |
| Capacity factor | 35% | |
| Electricity demand | 218 | MWh |

| **Unit costs** | MNT | | USD | |
|---|---|---|---|---|
| Unit cost of Diesel capacity | 1,170,000 | MNT/(kW) | 900 | $/kW |
| Fuel cost of Mazut | 1,097,700 | MNT/ton | 844 | $/ton |
| Cost of Mazut including transport | 1,153,900 | MNT/ton | 888 | $/ton |
| Fuel cost of Mazut | 102,296 | MNT/MWh | 79 | $/MWhf |
| **Hybrid Wind – Diesel** | | | | |
| Installed capacity Diesel | 0.2 | MW | | |
| Installed cost Diesel / Wind | 368,838,092 | MNT | 283,722 | $ |
| Cost of Mazut at site | 3,724,473 | MNT/a | 2,865 | $/a |
| Cost of O&M | 2,064,305 | MNT/a | 1,588 | $/a |
| Total installed cost | 368,838,092 | MNT | 283,722 | $ |
| Annual cost (WACC 6%, 10 a) | 37,976,589 | MNT/a | 29,213 | $/a |

| Unit costs | MNT | | USD | |
|---|---|---|---|---|
| Annual O&M cost | 5,788,778 | MNT/a | 4,453 | $/a |
| **Total annual cost** | **43,765,368** | **MNT/a** | **33,666** | **$/a** |
| **Cost of local grid** | | | | |
| Installed cost of the line | 130,000,000 | MNT | 100,000 | $ |
| Installed cost of substations | 0 | MNT | 0 | $ |
| O&M cost of electricity grid | 2,600,000 | MNT/a | 2,000 | $/a |
| Total installed cost | 130,000,000 | MNT | 100,000 | $ |
| Annualized (WACC 6%, 50 a) | 8,247,757 | MNT/a | 6,344 | $/a |
| Annual O&M cost | 2,600,000 | MNT/a | 2,000 | $/a |
| **Total annual cost** | **10,847,757** | **MNT/a** | **8,344** | **$/a** |

64. In the following scenario for a diesel / solar PV scheme it is found that it would be necessary to subsidize the full cost of the diesel engines, and the difference between the cost of the solar PV component and wind component. Clearly wind power is a more attractive option in terms of maintaining a low subsidy regime.

**Table 3: Hybrid Diesel / Solar PV Supply**

| Energy demand | | |
|---|---|---|
| Electricity demand | 0.075 | MW |
| Capacity factor | 35% | |
| Electricity demand | 218 | MWh |

| Unit costs | MNT | | USD | |
|---|---|---|---|---|
| Unit cost of electricity | 0 | MNT/MWh | 0 | $/MWh |
| Unit cost of Diesel capacity | 1,170,000 | MNT/(kW) | 900 | $/kW |
| Fuel cost of Mazut | 1,097,700 | MNT/ton | 844 | $/ton |
| Cost of Mazut including transport | 1,153,900 | MNT/ton | 888 | $/ton |
| Fuel cost of Mazut | 102,296 | MNT/MWh | 79 | $/MWhf |
| **Hybrid Solar – Diesel** | | | | |
| Installed capacity Diesel | 0.20 | MW | | |
| Installed cost Diesel / Solar | 307,476,103 | MNT | 236,520 | $ |
| Cost of Mazut at site | 3,724,473 | MNT/a | 2,865 | $/a |
| Cost of O&M | 8,382,305 | MNT/a | 6,448 | $/a |
| Total installed cost | 307,476,103 | MNT | 236,520 | $ |
| Annual cost (WACC 6%, 15 a) | 31,658,589 | MNT/a | 24,353 | $/a |
| Annual O&M cost | 12,106,778 | MNT/a | 9,313 | $/a |
| **Total annual cost** | **43,765,368** | **MNT/a** | **33,666** | **$/a** |
| **Cost of local grid** | | | | |
| Installed cost of the line | 130,000,000 | MNT | 100,000 | $ |
| Installed cost of substations | 0 | MNT | 0 | $ |
| O&M cost of electricity grid | 2,600,000 | MNT/a | 2,000 | $/a |

| **Unit costs** | MNT | | USD | |
|---|---|---|---|---|
| Total installed cost | 130,000,000 | MNT | 100,000 | $ |
| Annualized (WACC 6%, 50 a) | 8,247,757 | MNT/a | 6,344 | $/a |
| Annual O&M cost | 2,600,000 | MNT/a | 2,000 | $/a |
| **Total annual cost** | **10,847,757** | **MNT/a** | **8,344** | **$/a** |

65. The analyses presented here are indicative of conditions in remote areas. The results tend to support experience elsewhere that subsidies are required if SPS schemes are to be successfully deployed in remote areas.

## T. Conclusions

66. The establishment of hybrid stand-alone power supply systems in remote areas of Mongolia will require subsidies (or grant assistance). Whilst the high cost of Mazut results in a more favourable cost comparison of diesel plant against hybrid schemes than is the case in some countries, nevertheless the capital cost of small off-grid hybrid schemes is still high and out of reach of small Mongolian communities to be able to afford such schemes without direct assistance.

67. The policy framework applicable in Western Australia is directly applicable in Mongolia and is recommended as the means to foster the development of power supplies to isolated areas.