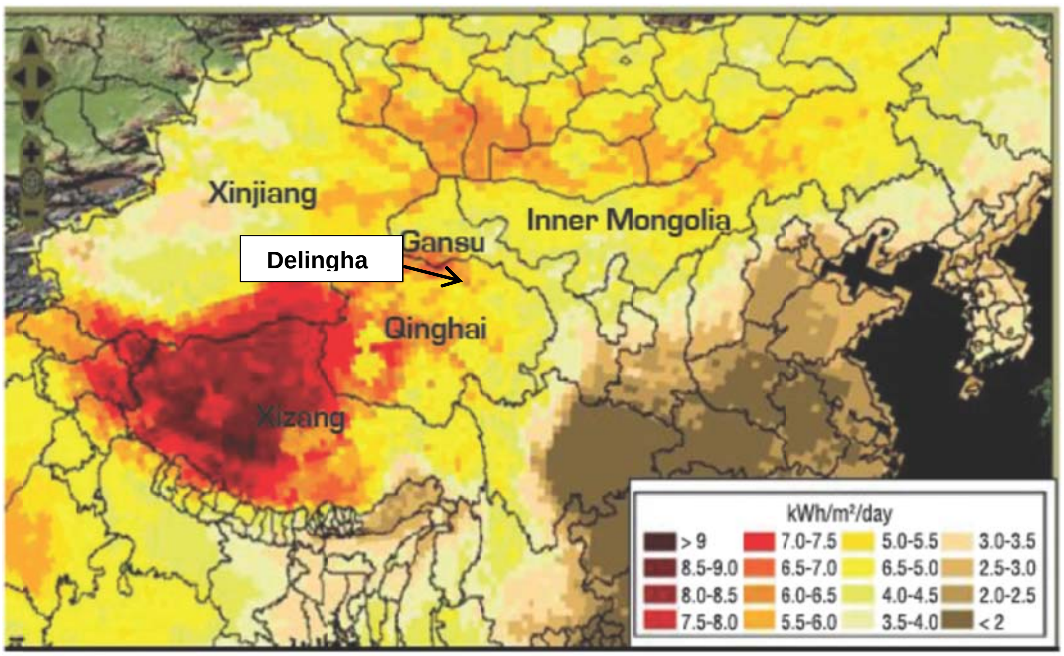
Solar Resource Assessment

A. Location and solar resource

1. **Solar resource in Qinghai province.** Concentrated solar thermal power (CSP) plants are installed in zones where mean yearly value of direct normal solar irradiance (DNI) is at least 1,800 kilo watt hour per square meter (kWh/m^2). In the People's Republic of China (PRC), more than 700,000 square kilometer (km^2) is suitable for CSP installation, which is estimated to potentially generate more than 51,000 terrawatt hour (TWh) of electricity per year compared to PRC's total electricity generation of 4,980 TWh in 2012.[1] Qinghai province which is located in the north-eastern part of the Qinghai-Xizang plateau in the western PRC is one of the provinces in PRC having on an average around 2,100 kWh/m^2/year in average of rich DNI as shown on Figure 1.

Figure 1: Direct Normal Irradiance Resource Map in the PRC



(Source) National Renewable Energy Laboratory, Washington, DC.

B. Project location and solar irradiation data used

2. **Solar resource assessment.** The solar resource assessment (the assessment) has been applied to the project site with geographic coordinates: Latitude 37.3575 S, Longitude 97.2842 E, and 3,001 meters of altitude in Delingha, Haixi prefecture, which is in 550 kilometer (km) west of Xi Ning, Qinghai province. The assessment used hourly values of solar irradiance (global horizontal irradiance, diffuse horizontal irradiance, and direct normal irradiance) and meteorological datasets (ambient temperature at 2 meters, relative humidity, and wind speed) from (i) satellite imaginary database for 11 years from 2000 to 2012 at the site, and (ii) the ground observed data at the site using two pyranometers and one pyrheliometer from 5 June

[1] ADB (2011) Final report on Concentrating Solar Thermal Power Development (TA 7402-PRC).

2011 to 14 November 2012. The period of measurement is 1 minutes and the temporal reference is local time in the PRC (GMT+8, Longitude reference 120°).

C. Assessment methodology and assessment result

3. The assessment was comprised of (i) the ground data quality assessment to filter outlier data derived from measurement error, (ii) statistical comparison and correction of satellite imaginary database using the filtered ground measurement data, and (iii) measurement of DNI for typical meteorological year (TMY) which is used for electricity yield simulation.

4. **Quality assessment of ground measured solar resource.** The ground measured global horizontal irradiance (GHI), diffuse irradiance, and DNI were verified using four layered physical filters (lower and upper physical limit) to detect outlier data which fails to pass filters, in accordance with the recommended quality analysis methodology of the Baseline Surface Radiation Network (BSRM) under the World Metrological Organization, and of Investigaciones y Recursos Solares Avanzados (IrSOLaV) the institute of solar resource analysis and assessment in Spain. Any detected outlier data failed to pass these filters was regarded as calibration error, and was removed from the datasets for the assessment.

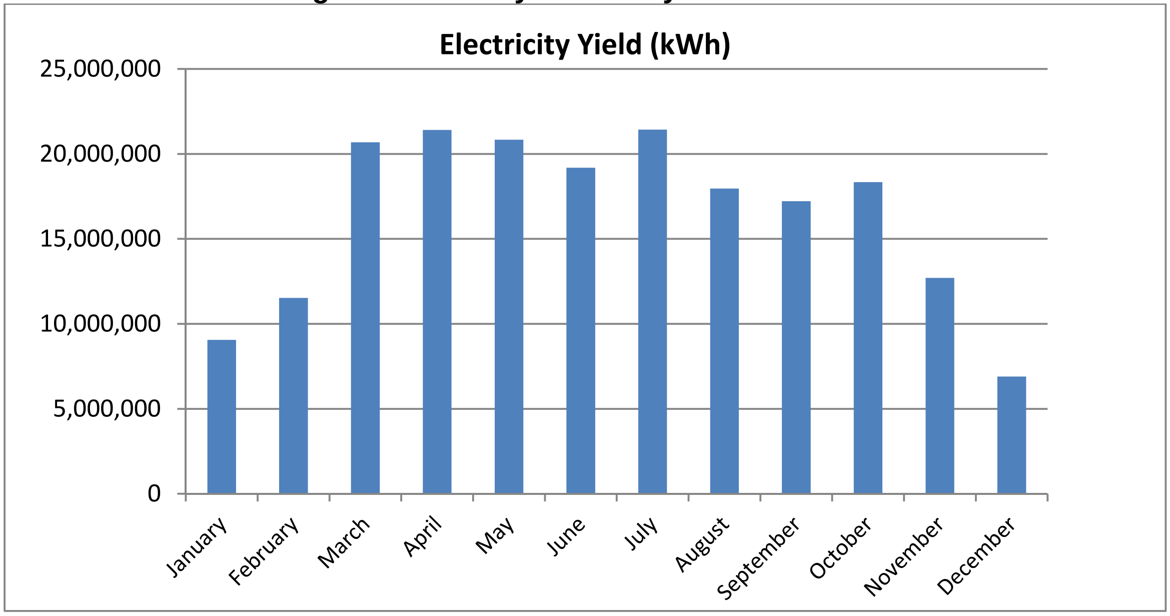
5. **Solar resource estimate from satellite imaginary.** Solar irradiance which derived from the satellite imaginary was computed by a modified version of Heliostat-3 model (the model) using two main inputs: i) attenuating properties of the atmosphere including the daily Linke turbidity which a representative parameter to model the attenuating processes which affects solar radiation on its path through the atmosphere, and ii) geostationary satellite images consisting of one image per hour offering information related with the cloud cover column characteristics in the atmosphere as cloud index.

6. DNI is computed using Dynamic Global-To-Direct Irradiance conversion model (Dirindex). Dirindex is a statistical model to convert hourly GHI derived from satellite imagery and daily atmospheric parameters (aerosols and water vapor) into hourly DNI based on a parameterization of insolation conditions. The satellite imaginary based solar irradiance data sets used for the assessment has been validated in various locations with low uncertainty comparing with hourly ground pyranometric measurements in view of the relative root mean squared error: 12% of hourly value, less than 10% for daily value, and within 5% for annual and monthly means.

7. **Typical Metrological Year (TMY).** The TMY is formed by a set of hourly data including solar irradiance, temperature, humidity, and wind over one year period, which represents solar irradiance and climatic features in the specific location. The TMY for the site was formulated on a basis of satellite imaginary data for 11 years, and ground measurement data for 15 months, thorough comparing the cumulative frequency distribution function (CDF) of each solar irradiance and climatic parameters for a given month (i.e January 2000) with the CDF corresponding to the set of all same months over whole period (i.e January 2000-2011). DNI value in the form of TMY was used for electricity yield projection for the project.

8. **Solar Irradiation at the project site.** On a basis of solar irradiation data (para 2) and assessment methodologies (para 3-7), the assessment concludes that the average value of DNI is 2,082 kWh/m^2 and DNI in TMY is 2,187 kWh/m^2, within 5% statistical uncertainty. Figure 2 shows monthly electricity yield forecast based upon the assessed solar irradiation.

Figure 2: Monthly Electricity Yield Forecast



(Source) The Executing Agency and Asian Development Bank estimate

8. **Recommendation.** The assessment found calibration problems and malfunctioning of pyrheliometer in observing DNI for a few of months in 2011. The continuous proper maintenance of pyranometer and pyrheliometer, and accumulation of good quality of data are essential to improve accuracy of hourly and daily electricity yield forecasting to make the project reliably dispatchable.