ECONOMIC ANALYSIS

A. General

1. The economic analysis of the Qinghai Delingha Concentrated Solar Thermal Power (CSP) Project was conducted in accordance with the *Guidelines for the Economic Analysis of Projects* of the Asian Development Bank (ADB).[1]

B. Assumptions

2. The economic feasibility was evaluated through a comparison of the with- and without-project scenarios as follows:

(i) Under the without-project (baseline) scenario, the energy would be provided by an existing or committed coal-fired power plant.
(ii) Under the with-project scenario, the proposed project would generate alternative energy. Solar energy would replace the energy generated by the equivalent capacity of coal-fired power plant.

C. Demand Analysis: Solar Thermal

3. The energy sector in the People's Republic of China (PRC) has grown rapidly in tandem with economic growth. Installed power capacity has expanded by about 70% since 2008.[2] The energy sector relies heavily on coal-fired power generation, which accounts for over 70% of total installed capacity. Its coal consumption has been a major source of carbon dioxide (CO_2) emissions—50% of total CO_2 emissions in the PRC. Diversifying the energy mix by promoting renewable energy is one of the core development agendas to attain the carbon intensity reduction target. The Twelfth Five-Year Plan, 2011–2015 has set targets to increase the share of renewable energy from 8.9% in 2010 to 11.4% in 2015, and decrease carbon intensity by 17% by 2015 compared with 2010 levels.

4. The PRC's energy consumption is expected to reach 4.5 billion tons of coal equivalent by 2020 and electricity consumption is expected to reach 7,447 terawatt-hours (TWh), compared with 3.2 billion and about 4,000 TWh in 2010.[3] To transit to a clean, reliable, low-carbon energy system, the share of renewable energy (such as wind and solar power) in the electricity generation mix has to be increased. During the Eleventh Five-Year Plan, 2006–2010, the PRC witnessed a rapid growth in wind power and solar photovoltaic development.[4]

5. The rapid development of solar photovoltaic and wind power capacity is posing new challenges to grid stability because of the intermittent nature of power supplied by these plants. For instance, the curtailment of wind power[5] in certain regions of the PRC is as high as 45%,

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[1] ADB. 1997. *Guidelines for the Economic Analysis of Projects*. Manila
[2] National Energy Administration. 2011. *Report on China's Energy Development for 2011.* Beijing: Economic Science Press.
[3] International Energy Agency. 2011. *Technology Roadmap: China Wind Energy Development Roadmap 2050*. Paris.
[4] During this period, the installed capacity of wind power increased from 1.3 GW to 41.8 GW. Solar photovoltaic installed capacity also expanded, but more modestly, from 70 MW to 900 MW during the same period. However, it surged to 7.9 GW in 2012. The PRC has set a target of 35 GW solar photovoltaic capacity by 2015. By 2020, installed capacity of wind energy is expected to reach more than 200 GW and that of solar energy is expected to reach 53 GW.
[5] Non-absorption of electricity generated by wind power plants via the power system dispatch center.

compared with less than 10% in Europe. At higher penetration of solar photovoltaic and wind power generation, increased grid flexibility will be needed to fully utilize the variable and uncertain output from these plants.

6. CSP plants have inherent capacity to store surplus heat energy in thermal storage for sufficiently long periods of time (currently up to 15 hours in operation) and can be equipped with a natural gas backup system to generate electricity when there is not enough solar irradiation. CSP is an alternative to fossil fuel power plants to supply reliable and predictable electricity at any time of day. It also enables grid operators to schedule their dispatch economically, which enhances grid stability. The government has set the installed capacity target for CSP at 1 gigawatt (GW) in 2015 and 3 GW in 2020.

D. Economic Costs

7. Economic analysis was conducted for the project lifespan of 25 years plus the project implementation period of 5 years. The residual value at the end of the project life is assumed to be zero. All prices and costs are expressed in 2013 prices and in the domestic currency using the world price numeraire. As the analysis is carried out using the world price numeraire, the conversion factors are the standard conversion factor of 0.9 for non tradables, 1.0 for tradables and the following specific conversion factors: 1.0 for equipment, 1.0 for skilled labor, and 0.7 for unskilled labor.[6] The financial costs are adjusted to eliminate price contingencies, interest during construction, and taxes, but physical contingencies are included. A discount rate of 12% per annum is assumed.

8. The financial capital costs were converted to the relevant economic values after deducting taxes, subsidies, and price contingencies, then applying the respective conversion factors specified in the assumptions. The capital costs of the project include costs related to civil works, the solar field system, heat transfer fluid, the power block system, thermal energy storage, the auxiliary system, other associated costs, and physical contingency. These costs occur primarily during the construction period, which is within the first 5 years of the project. The operation and maintenance (O&M) costs, assumed to remain constant in real terms, comprise costs for maintenance, raw materials, energy inputs (natural gas), salaries, overheads, and administration expenses as well as major overhauls every 4 years of operation. The O&M costs occur throughout the lifespan of the project, which is 25 years.

E. Economic Benefits

9. The economic benefits of the project include (i) coal saving (non-incremental), incremental electricity sale,[7] and grid reliability; and (ii) direct environment benefits, which are reflected in the reduction of environmental costs from the proposed CSP plant to the reference thermal power plant (baseline scenario).

(i) **Coal saving.** Coal consumption will be reduced since solar energy is replacing coal as a fuel for power generation (footnote 7). The coal saving benefit is derived by multiplying the amount of coal saving by the economic cost of coal.

[6] These conversion factors were consistently used for recently approved energy projects in neighboring provinces in the PRC.

[7] Because of strong demand for clean and reliable electricity from CSP, only 70% (coal contribution to the provincial power generation mix) of electricity generation from the proposed CSP plant was counted for coal saving. The remaining output (30%) is defined as incremental benefit.

(ii) **Incremental electricity sale.** This benefit is calculated by multiplying the amount of incremental electricity generation by willingness to pay (footnote 7).

(iii) **Grid reliability.** CSP plants with thermal energy storage have the capability to (a) shift energy to higher price intervals, (b) supply ancillary service, and (c) reduce the curtailment of intermittent renewable electricity such as solar photovoltaic and wind power. In a power system with low penetration of renewables, this added economic value is generally calculated as $5–$10/MW/hour.[8] The grid reliability benefit of $10/MW/hour was used since the PRC currently experiences the higher wind curtailments rate than Europe and the United States.

10. The project will generate considerable environmental benefits through the reduction of pollutant emissions. It will avoid 122,554 tons of coal equivalent per year, which translates to an annual emission reduction of 154,446 tons of CO_2, 392 tons of sulfur dioxide, 121 tons of nitrogen oxides, and 204 tons of flue dust.[9] The economic evaluation of the environmental impact is based on the benefits transfer method described in ADB's *Workbook on Economic Valuation of Environmental Impact.*[10]

F. Estimation of the Economic Internal Rate of Return

11. Results of the economic analysis have been presented in the key economic indicators, such as the economic internal rate of return (EIRR) and the economic net present value (ENPV) of the project. The projected EIRR is high but regarded conservative, as it takes into account only the main benefits of different components and includes all project-related costs. The ENPV of the project is CNY78 million. The EIRR of the project is 13.3%, which is greater than the 12% economic cost of capital (discount rate). The economic benefits and costs of the project are in Table 1.

Table 1: Economic Costs and Benefits of the Project

(CNY'000)

Year	Economic Capital Costs	Economic Operating Costs	Total Economic Costs	Direct Economic Benefits	Environmental Benefits	Total Economic Benefits	Net Economic Benefits
2013	(368)	0	(368)	0	0	0	(368)
2014	(335,541)	0	(335,541)	0	0	0	(335,541)
2015	(429,501)	0	(429,501)	0	0	0	(429,501)
2016	(140,899)	(14,179)	(155,078)	107,131	29,714	136,845	(18,232)
2017	(266,797)	(18,905)	(285,701)	142,841	39,619	182,460	(103,241)
2018	0	(18,905)	(18,905)	142,841	39,619	182,460	163,555
2019	0	(18,905)	(18,905)	142,841	39,619	182,460	163,555
2020	0	(19,863)	(19,863)	142,841	39,619	182,460	162,597
2021	0	(18,905)	(18,905)	142,841	39,619	182,460	163,555
2022	0	(18,905)	(18,905)	142,841	39,619	182,460	163,555
2023	0	(18,905)	(18,905)	142,841	39,619	182,460	163,555
2024	0	(19,240)	(19,240)	142,841	39,619	182,460	163,220

[8] Concentrating Solar Power Alliance. 2012. *The Economic and Reliability Benefits of CSP with Thermal Energy Storage: Recent Studies and Research Needs*. Washington, DC.

[9] The environmental benefits of a CO_2 emission reduction were estimated using the marginal abatement cost as a proxy for the economic benefits of emission reduction. The marginal abatement cost estimate for CO_2 (CNY233/ton) is based on McKinsey & Company. 2009. *China's green revolution: Prioritizing technologies to achieve energy and environmental sustainability*. Australia. The environment benefits of the other emissions were estimated using the emission charges in the PRC.

[10] ADB. 1996. *Economic Valuation of Environmental Impacts: A Workbook*. Manila

Year	Economic Capital Costs	Economic Operating Costs	Total Economic Costs	Direct Economic Benefits	Environmental Benefits	Total Economic Benefits	Net Economic Benefits
2025	0	(18,905)	(18,905)	142,841	39,619	182,460	163,555
2026	0	(18,905)	(18,905)	142,841	39,619	182,460	163,555
2027	0	(18,905)	(18,905)	142,841	39,619	182,460	163,555
2028	0	(19,863)	(19,863)	142,841	39,619	182,460	162,597
2029	0	(18,905)	(18,905)	142,841	39,619	182,460	163,555
2030	0	(18,905)	(18,905)	142,841	39,619	182,460	163,555
2031	0	(18,905)	(18,905)	142,841	39,619	182,460	163,555
2032	0	(20,055)	(20,055)	142,841	39,619	182,460	162,405
2033	0	(18,905)	(18,905)	142,841	39,619	182,460	163,555
2034	0	(18,905)	(18,905)	142,841	39,619	182,460	163,555
2035	0	(18,905)	(18,905)	142,841	39,619	182,460	163,555
2036	0	(19,863)	(19,863)	142,841	39,619	182,460	162,597
2037	0	(18,905)	(18,905)	142,841	39,619	182,460	163,555
2038	0	(18,905)	(18,905)	142,841	39,619	182,460	163,555
2039	0	(18,905)	(18,905)	142,841	39,619	182,460	163,555
2040	0	(19,240)	(19,240)	142,841	39,619	182,460	163,220
2041	0	(18,905)	(18,905)	142,841	39,619	182,460	163,555
					Base Case	**EIRR** (%)	**13.3**
						ENPV	**77,904**

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

G. Sensitivity Analysis

12. Sensitivity analysis was performed to test the EIRR's sensitivity to certain changes in parameters. This showed that the EIRR could fall to (i) 12.7% if all the economic benefits were reduced by 10%, (ii) 12.0% if the project experienced a cost overrun of 10%, and (iii) 13.2% if the O&M costs rose by 10% (Table 2). Under these sensitivity scenarios, the EIRR will still be slightly greater than or very close to the economic discount rate of 12%. This is mainly because of the still high capital costs of CSP projects. The proposed project entails innovative and first-of-its-kind solar energy technology. As one of the first utility-scale CSP demonstration plants in the PRC, it is expected to bring significant quantitative economic benefits such as technology demonstration[11] to the economy, which is not quantified or included in this analysis. Thus, the project is still considered feasible from the economic point of view.

Table 2: Sensitivity Analysis of the Economic Internal Rate of Return

Case	EIRR (%)
Base Case	13.3
Case 1 (Economic Benefits -10%)	12.7
Case 2 (Project Cost +10%)	12.0
Case 3 (O$M Cost +10%)	13.2

O&M = operation and maintenance.
Source: Asian Development Bank estimates.

[11] It will remove barriers for market acceptance and large-scale CSP deployment in the country, leading to attainment of the government's 1 GW target of installed capacity by 2015 and 3 GW by 2020.