ECONOMIC ANALYSIS

A. Introduction

1. The economic analysis of the National Solar Park Project was conducted in accordance with Asian Development Bank (ADB) guidelines,[1] and measured the costs and benefits in 2018 constant prices from 2019 to 2042. The economic internal rate of return (EIRR) was calculated by comparing the with- and without-project scenarios. All financial prices were converted into economic prices by applying the corresponding conversion factors. A sensitivity analysis was conducted to ascertain the robustness of the project.

2. The project's objective is to demonstrate the ability of large-scale solar to improve electricity supply and national grid stability, and as a viable alternative for planned fossil-fuel and hydropower generation. The project will enable Electricite du Cambodge (EDC) to procure land and develop a solar park to support a 100-megawatt (MW) solar photovoltaic plant. The 100 MW solar photovoltaic plant will be financed and constructed in two stages by the private sector as an independent power project with EDC as the sole off-taker. A 60 MW solar photovoltaic plant will be constructed in stage one, followed by a 40 MW solar photovoltaic plant in stage two. Commercial operations of the 60 MW photovoltaic solar plant are scheduled for 2021, followed by the 40 MW solar photovoltaic plant 12 months later. The park will be located about 50 kilometers from the capital city of Phnom Penh and will be connected to the grid via a 230-kilovolt transmission line to be constructed as part of the project. The expected annual energy output of the plant is about 225 gigawatt-hours (GWh) in the first full year of operation; the solar plant is expected to remain in operation for 20 years.

B. Country and Sector Analysis

3. Cambodia has experienced rapid economic growth and increased prosperity since 2006; however, the country's energy sector faces several strategic challenges constraining further growth. The high cost of power, dependence on conventional energy sources, limited transmission and distribution networks, and intermittent power supply are hindering economic competitiveness and discouraging private sector investment.

4. The Government of Cambodia has recognized that access to modern, affordable and reliable forms of energy is essential for the country's social and economic advancement. To meet the recent growth in electricity demand, the government has made significant investments in large hydropower and coal-fired generation. Electricity demand is forecasted to increase three-fold from 2015 to 2030 as outlined in the current Power Development Plan, revised in 2015.[2] The plan states that to meet this future growth in demand additional investment in thermal generation (coal-fired in the short term, and either coal or gas in the long term) and large hydropower plants will be required. However, the environmental impacts and the high cost of imported coal are making these conventional sources of electricity less desirable. Reliance on (in the case of coal) inflexible plants is also creating problems relating to excess generation and transmission grid instability, necessitating further investments to accommodate their output.

---

[1] ADB. 2017. *Guidelines for Economic Analysis of Projects*. Manila; ADB. 2013. *Cost-Benefit Analysis for Development: A Practical Guide*. Manila.

[2] Chugoku Electric Power Co., Inc. 2015. *The Project on Revision of Cambodia Power Development Master Plan*. Presentation prepared for the Government of Cambodia. Phnom Penh. September. Unpublished.

5. The government's Industrial Development Policy 2015–2025 prioritizes the need to develop the energy sector in an affordable and sustainable manner, while also considering the need to minimize adverse environmental and social impacts.[3] Cambodia's ratification of the Paris Agreement and commitment to a 16% reduction in greenhouse gas emissions by 2030 from the energy sector has prompted the government to explore its renewable energy options. However, large-scale hydropower to meet this objective is facing increasing opposition from local communities and civil society, which resulted in the government announcing a moratorium on the construction of new hydropower dams until 2020.

C. Rationale for Intervention

6. Meeting the government's commitment to a 16% reduction in greenhouse gas emissions by 2030 and the challenging environment for large-scale hydropower development will require mobilization of both private and public-sector resources. If the cost of carbon is excluded from the least-cost analysis then solar and hydro power are generally more expensive than conventional coal-fired power in Cambodia, and solar, wind and hydro impose an additional cost burden due to their intermittency. Government intervention has created the necessary legal and regulatory framework to internalize the environmental benefits of renewable energy, but in practice project bankability is still marginal for private developers. Under the project, there is a strong justification for using public financing on the grounds that such public financing will be used to provide services where the public sector has an advantage (e.g., land acquisition, obtaining necessary permits, and providing common infrastructure and interconnections). The project's implementation success will have a significant demonstration impact on the future development of grid-scale solar power in Cambodia.

D. Demand Forecast

7. The government's electricity demand forecast underpinning the 2015 Power Development Plan adopts an econometric approach. Forecasts were prepared by sector, with separate regression models for the industry, commercial, residential and agriculture sectors. The energy forecast was separated by region and converted into a peak demand forecast. The base case projects strong growth in electricity demand to 2030, with annual power consumption increasing from 4489 GWh in 2015 to 7,700 GWh in 2020, and 18,000 GWH in 2030. Peak demand is forecast to increase from 1,000 MW in 2016 to 1,276 MW in 2020, and 3,256 MW by 2030.

E. Least-Cost Analysis

8. The economic costs incorporated in the least-cost analysis are capital costs, fuel costs, other operation and maintenance costs, and the cost of carbon dioxide emissions during the economic life of the alternative power generation systems. The least-cost analysis uses second-quarter 2018 constant prices and a discount rate of 9%. The levelized cost of energy for equivalent dispatchable coal power, hydro power and diesel power plants have been computed using estimates based on precedent transactions in South Asia and Southeast Asia. The levelized cost of energy for the base case (solar) is $0.0700/kilowatt-hour (kWh), which is lower than coal ($0.1107/kWh), diesel ($0.1763/kWh) and small hydropower ($0.0723/kWh). Thus, solar power is economically the least-cost option.

---

[3] Government of Cambodia. 2015. *Cambodia Industrial Development Policy, 2015–2025: Market Orientation and Enabling Environment for Industrial Development*. Phnom Penh.

F. Project Economic Costs

9. Project costs follow a systems-approach where the cost of the solar park, solar photovoltaic plant, common infrastructure and transmission to the national grid are included (i.e., the solar park site acquisition, construction of common and evacuation infrastructure, solar park operating costs, and the construction and operating costs of both solar plants). These costs were provided by EDC and their technical advisors. Cost estimates reflect a second-quarter 2018 constant price level. Cost components were broken down into the following broad categories: equipment, civil works and construction, land, preparatory work, external project management, and environmental and social mitigation. The domestic price numeraire was applied. It was assumed that no significant distortions in the wage rates for local skilled labor apply. In the case of unskilled labor, underemployment exists in the economy, and a shadow wage rate of 0.75 was adopted (based on a project shadow wage rate value used recently in Cambodia).[4] Land was valued at its resettlement and compensation cost, which represents its opportunity cost. Based on the advice of EDC's technical advisors, the annual operation and maintenance cost for the solar park, associated transmission and distribution assets, and the solar photovoltaic plant was estimated to be $2.1 million for the first full year of operations.

G. Project Economic Benefits

10. **Quantification of benefits.** In the without-project scenario, it is unlikely future electricity demand would be met due to the expected strong growth trajectory of demand. In the with-project scenario, the project's total output would be required to meet the demand of new customers (incremental benefits). Therefore, total incremental benefits are estimated as the product of incremental sales (total annual P50 output of the 100 MW photovoltaic plant less average electricity sector losses of 11.42%) and the average willingness to pay (estimated at the current retail tariff of KR610/kWh).[5]

H. Economic Internal Rate of Return

11. The calculation of the project's EIRR and economic net present value (ENPV) are shown in Table 3. The estimated EIRR of 20.0% is above the 9% hurdle rate, indicating that the project is economically viable. The ENPV value at a 9% discount rate is KR396,014 million.

Table 3: Economic Internal Rate of Return Calculation
(KR million)

Year	Economic Benefits		Economic Costs				Net Economic Benefits
	Incremental Sales (GWh)	Incremental Benefits	Capital for Solar Park	O&M for Solar Park	Capital for Solar Photovoltaic Plant	O & M for Solar Photovoltaic Plant	
2019	0	0	29,924	0	0	0	(29,924)
2020	0	0	34,639	0	0	0	(34,639)
2021	30	18,415	25,979	249	273,578	1,059	(282,451)
2022	141	85,889	0	996	155,842	4,948	(75,897)
2023	201	122,361	0	996	0	7,126	114,239
2024	200	121,773	0	996	0	7,109	113,668

[4] ADB. 2016. *Report and Recommendation of the President to the Board of Directors: Proposed Loan to the Kingdom of Cambodia for the Second Greater Mekong Subregion Corridor Towns Development Project*. Manila

[5] Electricity Authority of Cambodia. 2017. *Annual Report on Power Sector for Year 2016*. Cambodia. P50 indicates the estimated plant generation yield will exceed this value 50% of the time for the first full year of operations.

Year	Economic Benefits		Economic Costs				Net Economic Benefits
	Incremental Sales (GWh)	Incremental Benefits	Capital for Solar Park	O&M for Solar Park	Capital for Solar Photovoltaic Plant	O & M for Solar Photovoltaic Plant	
2025	199	121,157	0	996	0	7,093	113,068
2026	198	120,545	0	996	0	7,077	112,471
2027	197	119,935	0	996	0	7,062	111,877
2028	196	119,328	0	996	0	7,047	111,285
2029	195	118,725	0	996	0	7,033	110,696
2030	194	118,124	0	996	0	7,020	110,109
2031	193	117,527	0	996	0	7,006	109,524
2032	192	116,932	0	996	0	6,994	108,943
2033	191	116,341	0	996	0	6,981	108,364
2034	190	115,753	0	996	0	6,970	107,787
2035	189	115,167	0	996	0	6,959	107,213
2036	188	114,585	0	996	0	6,947	106,641
2037	187	114,005	0	996	0	6,937	106,072
2038	186	113,428	0	996	0	6,927	105,505
2039	185	112,855	0	996	0	6,917	104,941
2040	184	112,284	0	996	0	6,908	104,380
2041	156	95,035	0	966	0	5,877	88,162
2042	55	33,475	0	747	0	2,117	30,611
						EIRR:	**20.0%**
						ENPV:	**396,014**

( ) = negative, EIRR = financial internal rate of return, ENPV = economic net present value GWh = Gigawatt hours O&M = operation and maintenance.
Source: Asian Development Bank estimates.

I. Sensitivity Analysis

12. Key assumptions underpinning the analysis were examined to evaluate the robustness of the economic returns from the project. Sensitivity analysis was conducted for adverse changes to four key variables. The results are summarized in Table 4. A reduction in generation output is considered the most sensitive economic risk, as a 10% decrease in generation would result in the EIRR falling to 16.2% from 20.0%. Similar analysis was done for other variables including an increase in capital costs for the solar park and solar photovoltaic plant, an increase in operation and maintenance costs, and a delay to solar photovoltaic plant operations. The cumulative effect of all adverse scenarios was also calculated.

Table 4: Sensitivity Analysis

	Sensitivity Parameter	Variation	EIRR (%)	ENPV (KR)	Switching Value (EIRR)
	Base case		20.0%	396,014	
1	Project capital cost increase	+10%	18.0%	351,608	90
2	Generation output decreases (using P50 level)	-10%	16.2%	250,841	(40)
3	Operation and maintenance costs increase	+10%	19.8%	389,387	648
4	Delay in solar photovoltaic plant operations	1 year	16.7%	321,520	7 years
5	Combined (1, 2, 3, 4)		12.3%	138,874	

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

J. Conclusion

13. Economic analysis indicates the proposed project is economically viable. Sensitivity analysis demonstrates that expected economic performance is robust. These results are conservative in the sense that they exclude potential unquantified benefits, such as piloting and learning from the first large-scale solar photovoltaic park and electrification of previously unserved surrounding areas.