ECONOMIC ANALYSIS

A. Introduction

1. The economic analysis of the Ceylon Electricity Board (CEB) Wind Power Generation Project in Mannar Island, Sri Lanka, was conducted in accordance with the guidelines set out by the Asian Development Bank (ADB).[1] The analysis measured the projected costs and benefits at 2017 constant prices for a period of 23 years. The economic internal rate of return (EIRR) was calculated by comparing the "with-project" and "without-project" scenarios, and by considering the incremental annual cash flows over the 23 years. 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 analysis.

2. The project comprises (i) construction of a 100-megawatt (MW) wind farm in Mannar Island, including a fixed-term 7-year operation and maintenance agreement; (ii) installation of 150 megavolt-ampere reactive power compensation equipment, and (iii) project engineering design review and management. The project will be managed by the project management unit of the CEB. Upon project completion, the wind power plant will be transferred to the CEB Generation Licensee and it will be operated on the Sri Lanka national grid. The longer-term average energy available from the wind power plant has been estimated at 345.7 gigawatt-hours (GWh) per year.

B. Economic Rationale

3. **Country and sector analysis.** All fossil fuels required for power generation are imported to Sri Lanka and represent a significant share of national expenditure. In 2016, the annual total expenditure on imported fossil fuel was about 13% of Sri Lanka's import expenditure, and was about 26% of total export income.[2] Therefore, the energy sector has a significant bearing on the country's balance of trade and the exchange rate. In 2015, Sri Lanka's total petroleum product sales were 4.46 million ton, out of which 0.50 million ton (11%) is estimated to have been used for electricity generation.[3]

4. Due to environmental concerns, Sri Lanka delayed the construction of two new coal-fired power plants, that had been previously approved in 2013.[4] These power plants were expected to produce electricity from 2018. Existing diesel and fuel-oil power plants, as well as new diesel power plants, will be required to supply the energy deficit caused by the delay in the implementation of the two coal-fired power plants. Sri Lanka also plans to import liquefied natural gas (LNG) for electricity generation as well as for industrial and transport requirements. No specific projects have been approved to build the LNG importation, regasification, and delivery infrastructure at the end of 2016. Any additional power generation from renewable energy sources will displace power generation from oil and reduce generation from both oil and coal in the immediate future and would reduce LNG imports in the longer term.

5. **Rationale for public involvement.** Meeting the government's non-conventional renewable energy target of 20% by 2020 will require a significant scale-up in both private and public sector investments. 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 the wind power industry in Sri Lanka.

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[1] ADB. 2017. *Guidelines for the Economic Analysis of Projects*. Manila.
[2] Central Bank of Sri Lanka. *Annual Report, 2016*. Colombo.
[3] Government of Sri Lanka, Sri Lanka Sustainable Energy Authority. *Sri Lanka Energy Balance 2015*. Colombo.
[4] Ceylon Electricity Board. 2013. *Long-term Generation Expansion Plan, 2013–2032*. Colombo.

B. Demand Analysis

6. Electricity generation is forecast to grow about 6.9% per year over 2017–2020.[5] Recent annual sales growth rates were 4.07% (2014), 6.30% (2015) and 8.5% (2016estimated. In 2015, total annual electricity sales were about 11,722 GWh, comprising 39% to household customers, 33% to industries, and 28% to commercial enterprises. The overall demand for electricity, however, is constrained by the relatively high prices. Sri Lanka's electricity costs and prices are relatively high by regional norms. One reason is that Sri Lanka does not produce fossil fuels and must, therefore, import them. Another reason is that projects to establish key low-cost coal-fired power plants were not implemented in a timely manner. Consequently, when projects to produce cheaper electricity are delayed, the shortfall continues to be covered by smaller, oil-fired power plants and the government has to import petroleum products to meet the additional fuel requirements.

C. Alternative Analysis

7. Studies to develop a long-term generation expansion plan (LTGEP) are conducted every 2 years by CEB under a statutory requirement. CEB obtains the approval to proceed with generation expansion projects from the Public Utilities Commission of Sri Lanka. The methodology adopted in the study to develop the LTGEP optimally selects power plant additions from a given set of candidate power plants, considering the forecast electricity demand. Targets established in the national energy policy and strategies are included as fixed inputs to the study. The study is conducted under different scenarios, and the least cost option is presented as the base case. The 100 MW Mannar Wind Power Generation Project is included in the latest LTGEP (footnote 5), which ensures that among competing alternatives, the project is included in the pool of projects that form the least cost option to align the plan with national targets for renewable energy development.

D. Cost-Benefit Analysis

8. **Assumptions.** Component 1 is the 100 MW wind power plant. Component 2 provides support for voltage stability of the grid when component 1 is connected. Component 3 provides technical support to implement component 1. Therefore, all the components were included in the economic analysis. The following assumptions were made for the economic cost-benefit analysis of the project.

(i) All costs were estimated in constant 2017 price levels and were converted at an exchange rate of $1 = Sri Lanka Rupee (SLRe/SLRs) 151;
(ii) The economic costs of capital works and operation and maintenance were calculated from the financial cost estimates. Price contingencies, financial charges, and taxes and duties were excluded, but physical contingencies were included;
(iii) All costs were valued using the domestic price numeraire. Tradable inputs were adjusted by the shadow exchange rate factor of 1.1[6] while unskilled labor was adjusted by a factor of 0.40[7] of the market wage rate, to estimate the shadow wage rate;
(iv) The empirical estimate of the social cost of carbon reported by the International Panel on Climate Change was used to estimate the economic benefit of carbon dioxide (CO_2) avoided by the project. The CO_2 value was calculated at US$36.30 per ton based on 2016 prices and increased by 2% annually in real terms;

[5] Ceylon Electricity Board. 2015. *Long-term Generation Expansion Plan, 2015–2034.* Colombo.

[6] Standard Exchange Rate Factor (SERF)

Details	2015	2014	Average
Exports (SLRs million)	1,425,791.00	1,453,176.00	1,439,484.00
Imports (SLRs million)	2,572,467.00	2,535,163.00	2,553,815.00
Customs Duties (SLRs million)	453,948.00	357,484.00	405,716.00
Standard Conversion Factor (SCF)	0.90	0.92	0.91
Standard Exchange Rate Factor (SERF)	**1.11**	**1.09**	**1.10**

[7] Shadow wage factor = official minimum wage/actual wage paid by the project (0.4 = SLRs400/ SLRs1,000).

(v) Electricity generated from the wind power plant would displace electricity generation by existing, committed, and planned thermal power plants;[8]
(vi) The project construction period was assumed to be 3 years and electricity generation would commence from the beginning of year 2021;
(vii) The project economic life was assumed to be 20 years of operation, in line with the practice of CEB in conducting long-term generation planning studies, and the tenure of wind power small power purchase agreements[9] presently operational in Sri Lanka.

9. **Project Benefits.** Sri Lanka has not reported load shedding caused by longer-term capacity shortages for the past 15 years. The installed capacity has been sufficient to cater to the total electricity demand of the country.[10] Also, the government declared that it had achieved its target of 100% household electrification in 2016. Considering these facts, despite the increasing demand growth, only the non-incremental benefit of avoided fuel costs from thermal power plants, both existing and planned, and the global environmental benefits of avoided CO_2 emissions were included in the economic analysis. This approach represents a conservative assessment of the direct benefits of the project.

10. **Alternatives to wind power.** The economic analysis uses generation from thermal power plants as the alternative to electricity generation from this project. In the without-project scenario, the future demand for electricity would be served by existing as well as new power plants (thermal and renewable), which form the least cost generation expansion plan. In the with-project scenario, the same mix of power plants would remain in the generating system, but wind power from the project would partially displace generation from thermal power plants, thus reducing fuel use. Seasonality and intermittency of wind power would cause different types of power plant and fuel combinations to be displaced at different times of the day, and savings vary from month to month. As new power plants are added according to the generation expansion plan and certain power plants are retired, fuel savings change from year to year, as well. The fuel displaced from each power plant in each year was calculated using CEB's Wien Automated System Planning (WASP) model.[11]

11. The composition of displaced energy and displaced fuels in the first year of operation of the project are shown in Table 1. The planned retirement of fuel oil-fired power plants and the planned conversion of diesel-fired combined cycle power plants to LNG makes the displacement of petroleum products to be relatively low. The major savings are in LNG and coal. When planned power plant retirements and commissioning of new power plants take effect, avoided quantities of fuel vary throughout the planning period due to different types of power plants operating in the margin.

12. **Avoided fuel costs.** The fuel displaced was valued at forecast cost, insurance, and freight (CIF) prices. The basis of fuel prices used was the actual CIF prices of fuel in 2014, published in CEB's LTGEP (footnote 5) and the forecast CIF fuel costs for Sri Lanka were estimated following the World Bank commodity prices.[12]

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[8] This includes the displacement of electricity generated by planned diesel power plants to be provided by the private sector on a short-term rental basis to bridge the capacity gap.

[9] The Small Power Purchase Agreement is an agreement to supply electricity to the Sri Lanka grid under feed-in tariffs from renewable energy-based power plants with capacity of less than 10 MW.

[10] There have been short-term (up to 5 days) rolling blackouts about three times over the period 2012–2016, owing to outages of major power plants. These cannot be considered as ongoing longer-term capacity deficits.

[11] WASP conducts a dynamic optimization of the generating system, considering (i) the demand forecast; (ii) existing power plants and their retirement schedule; (iii) new candidate power plants; (iv) fuel prices; (v) system reliability indices (such as reserve margin and loss of load probability); and (vi) economic parameters (such as candidate power plant capital costs, discount rate, and cost escalations). The schedule of new power plant additions developed by WASP presents the least cost (optimal) development path, under the constraints and power plant data presented to the model.

[12] World Bank. World Bank Commodities Price Data. http://pubdocs.worldbank.org/en/790991501702837052/CMO-Pink-Sheet- August-2017.pdf (accessed April 2017)

Table 1: Composition of Displaced Energy and Displaced Fuel in 2021

Fuel	Energy Displaced (GWh)	Portion
Coal	108.7	31.4%
LNG	232.8	67.3%
Petroleum products	4.3	1.3%
Total	**345.8**	**100.0%**
	Fuel displaced (in equivalent MMBTU)	**Portion**
Coal	1,043,932	37.6%
LNG	1,709,410	61.6%
Petroleum products	21,553	0.8%
Total		**100.0%**

GWh = gigawatt-hour, LNG = liquefied natural gas, MMBTU = million British Thermal Units.
Note: Owing to rounding off errors and dispatch model constraints, total energy displaced in a given year may not be exactly equal to the long-term average energy from the wind power plant.
Source: Asian Development Bank estimates.

13. **Environmental Benefit.** Given that the project partially displaces electricity generated in thermal power plants, the project will generate environmental benefits through the reduction of CO_2 emissions. Emissions of fossil fuel-based generation displaced by the wind farm were estimated using the grid emission factor of 768.9 ton per GWh, determined by the Sustainable Energy Authority of Sri Lanka.[13] The annual emission reduction expected from the project for its output of 345.7 GWh per year is 265,731 tons of CO_2.

14. **Project Cost.** The total financial cost of the project is US$256.7 million and its economic cost is US$196.5 million. Land was valued at its resettlement cost only. It was assumed that land had a minimal (or zero) opportunity cost. The surrounding environment is arid, the location remote, and most of the land selected for the project have very low altitude and remains water logged during the rainy season. These factors limit the use of the land for other economic activities. Owing to the availability of a good wind resource, economic benefits from the land in Mannar Island can be gained by constructing wind power plants in this area. An average operating and maintenance cost of 2% of the total capitalized project cost was adopted, reflecting the experience from other wind power plants in Sri Lanka.

15. **Economic Rate of Return.** Results of the economic analysis are presented by means of key economic indicators, such as EIRR and the economic net present value (ENPV) of the project. Results are summarized in Table 2. The project EIRR is 16.6%, and ENPV is SLRs16,487 million (at an economic discount rate of 9% per year) when the global environmental benefit from the reduction of CO_2 emission at the rate of US$36.3 per ton of CO_2 is included in the economic analysis. If the economic benefit of avoided CO_2 emissions is not included in the analysis, the EIRR is 11.3% and ENPV is SLRs4,527 million (at an economic discount rate of 9%).

Table 2: Calculation of Economic Internal Rate of Return of the Project
(SLRs million)

Year	Benefits		Costs		Net Economic Benefits
	Non-Incremental Benefit (Fuel Saving)	**Environmental Benefits** (Reduction of CO_2 emission)	**Capital**	**Incremental O & M**	
2018	–	–	4,681	–	(4,681)
2019	–	–	12,620	–	(12,620)
2020	–	–	8,983	–	(8,983)
2021	4,179	1,608	3,385	494	1,908
2022	4,280	1,640	–	494	5,426
2023	3,716	1,673	–	494	4,894

[13] Source: www.info.energy.gov.lk.

Year	Benefits		Costs		Net Economic Benefits
	Non-Incremental Benefit (Fuel Saving)	**Environmental Benefits** (Reduction of CO_2 emission)	**Capital**	**Incremental O & M**	
2024	4,127	1,707	–	494	5,339
2025	3,965	1,741	–	494	5,212
2026	3,744	1,776	–	494	5,025
2027	5,030	1,811	–	494	6,347
2028	4,914	1,847	–	494	6,267
2029	5,235	1,884	–	494	6,624
2030	4,647	1,922	–	494	6,075
2031	4,344	1,960	–	494	5,810
2032	5,385	2,000	–	494	6,891
2033	5,489	2,040	–	494	7,034
2034	5,097	2,080	–	494	6,683
2035	5,015	2,122	–	494	6,642
2036	4,937	2,164	–	494	6,607
2037	6,307	2,208	–	494	8,020
2038	6,307	2,252	–	494	8,064
2039	6,307	2,297	–	494	8,110
2040	6,307	2,343	–	494	8,155
				EIRR:	**16.6%**

CO_2 = carbon dioxide, EIRR = economic internal rate of return, O&M = operation and maintenance, SLRs = Sri Lanka Rupees.
Note: All costs and benefits are in constant 2017 currency.
Source: Asian Development Bank estimates.

E. Risk and sensitivity analysis

16. **Sensitivity analysis.** To examine the robustness of the calculated EIRR, sensitivity analyses were conducted for adverse changes in five inputs to the economic analysis and the results are summarized in Table 3. The sensitivity of the calculated EIRR to simultaneous adverse variations of the input parameters was also examined. Table 3 also provides the switching value of adverse changes in each input parameter, at which the calculated EIRR would reach the minimum required EIRR of 9.0%.

17. The economic analysis indicates that the project would satisfy the minimum required EIRR of 9.0% and that the result is robust against adverse changes in key input parameters to the analysis.

Table 3: Sensitivity of EIRR to Adverse Changes in Key Input Parameters

	Input Parameter	Variation	EIRR	Switching Value
	Base case		16.6%	
1	Overall capital cost increased	10%	15.1%	73.0%
2	Fuel cost changed (decreased)	(10%)	15.3%	(55.0%)
3	O&M increased	20%	16.3%	515.0%
4	Change in energy yield (reduced)	(10%)	14.8%	(39.0%)
5	Commissioning delayed	1 year	14.3%	
	Combined 1,2,3, and 4		**12.0%**	

( ) = negative, EIRR = economic internal rate of return, O&M = operation and maintenance.
Switching value: The change in the input parameter that would cause the calculated EIRR to reach the benchmark value of 9.0%.
Source: Asian Development Bank estimates.