ECONOMIC ANALYSIS

A. Background

1. The Maldives has a small power system of about 100 megawatts (MW) of total installed generation capacity on its 200 inhabited islands, and another 100 MW on the resort islands. These islands are spread over about 1,000 kilometers. Nonetheless, it is the first and only country in South Asia to have achieved 100% electrification of households. The Maldives is also working toward carbon neutrality in its economy, where the energy sector plays a key role. The proposed project is expected to contribute significantly to this endeavor.

2. The project will provide support for renewable energy and supply-side energy efficiency interventions to a major portion of the inhabited islands. It has two outputs: (i) development of renewable-energy-ready hybrid grids on the outer islands and (ii) capacity building for the project management unit (PMU) and FENAKA, the utility in charge of the outer islands, to implement those grids. The State Electricity Company (STELCO)— (responsible for providing electricity services in Greater Malé, the area around the capital city of Malé) —and FENAKA (responsible for providing electricity services in most of the other atolls across the country) form the electricity industry for all inhabited islands, except a few where island councils are still responsible for electricity supply. Output 1 includes the detailed designs and procurement of equipment for solar–diesel hybrid grids for about 160 small and medium-sized outer islands. The project starts before the end of 2014 with phase 1, which involves investments in five sample subprojects on the islands of Addu City, B. Goidhoo, Th. Buruni, Ga. Vilingili and Lh. Khurendhoo. It will then be scaled up to other islands. Output 2 will commence before the end of 2014 with procurement of services to support implementation. The Asian Development Fund and the Strategic Climate Fund (SCF),[1] both administered by the Asian Development Bank (ADB), will provide grants for the project. The European Investment Bank (EIB) and Islamic Development Bank (IDB) will provide cofinancing in parallel to support the project activities.

B. Least-Cost Options for sub-projects

3. Because of the small size of the population (338,442 in 2012) and the geographical spread, the Maldives has only a few options for electricity generation and distribution. At present, almost the whole electricity system depends on diesel-based generation scattered over individual islands. Many of these generators are old and operating at very low efficiencies, while the distribution networks are prone to high technical losses. Also, neither the generation nor the distribution systems are able to absorb intermittent electricity generated from renewable energy sources such as solar photovoltaic and wind power, even if they became available at very low operating cost. However, the Maldives has very high solar power potential across the country, and a certain level of wind power generation is possible on some of the northern islands. In view of these potentials, the project examined the option of replacing some of the traditional power systems with a combination of renewable energy and efficient diesel generation and distribution.

4. For electricity generation, three design categories were found feasible for island grids in the Maldives: (i) type A, where a certain level of electricity generation from renewable energy sources can be deployed without battery storage and additional interventions of diesel generation; (ii) type B, where battery storage and replacement of diesel generators are needed, along with a small amount of renewable energy generation; and (iii) type C, where the interventions are the same as in type B, but with a larger share of renewable energy. The

[1] Under the Scaling Up Renewable Energy Program in Low-Income Countries financed by the Strategic Climate Fund.

analysis considered diesel generation, solar photovoltaic, and wind power as options for power generation. The HOMER software undertook investment optimization based on the total cost for solar, diesel generation and energy storage investments, fuel costs, operational and maintenance cost and replacement cost over a period of 25 years subject to all the technical and generation capacity constraints. The solution proposed for the project is the least-cost option derived from this analysis.

C. Valuation of Costs and Benefits

5. All the cost estimates associated with the project are expressed in US dollars, including the local inputs related to installation, and operation and maintenance costs, which are relatively small compared with the costs for equipment, which is all imported. These costs are in world prices. The official exchange rate in March 2014 was taken ($1.00 = Rf15.00). A 12% economic discount rate has been used. It is assumed that there are no significant distortions in the wage rates for skilled labor. The input relating to unskilled labor is minimal, so its impact was not considered. Considering that almost all the costs are for imports, a factor of 1.0 was taken for converting financial costs to economic costs. All these costs are also considered to be tradable.

6. All costs and benefits are expressed in constant 2014 prices. Capital costs include physical contingencies but exclude taxes, price contingencies, and financial charges during construction. A period of 25 years was used for the economic evaluation, starting in 2014. Benefits are assumed to be realized progressively starting from the year of completion, which in this case is 2016 (January).

7. International diesel price projections take 2014 prices as the base and use International Energy Agency price forecasts, with a 1.39% annual escalation. Industry standard values in dollar terms have been assumed for the operation and maintenance costs of diesel generators, and the solar photovoltaic and battery storage systems.

8. **Non-incremental benefits.** The project is replacing the output of existing diesel-based generation. This is valued at the fuel costs for and the variable costs of these inefficient diesel generators. These resource cost savings are non-incremental benefits of the project

9. **Incremental benefits.** Even at present, some diesel generation capacity is idle on all five sample islands, which are 100% electrified. No induced demand can be attributed to the project, and hence no incremental benefits were considered.

D. With-Project and Without-Project Scenarios

10. Without project, the Maldives will continue to rely heavily on diesel-based generation to meet its increasing demand. Many of the existing generators are mostly part-loaded and highly inefficient. Further, the end-user tariffs are not cost reflective and the subsidy burden on the government is high. At the same time, all diesel used for generators is imported, which compromises the country’s balance of payments and energy security.

11. The project will introduce electricity generation from indigenous renewable energy to the power systems of about 160 islands. It will replace the existing inefficient diesel generators with efficient generators. It will also upgrade the distribution networks on the islands and introduce proper controls to absorb increased levels of intermittent generation based on renewable energy. Although both solar photovoltaic and wind power were considered as options for renewable

energy use, only solar photovoltaic was found to be a part of the best solution on the five sample islands. Table 1 shows the characteristics of these islands.

Table 1: Characteristics of the Sample Islands

	Estimated required generation in 2014 (MWh)	**Total Investment** ($ million)	**Optimal Share of Solar PV in the Generation Mix** %	**Diesel Used in Diesel Generators under the Project** (l/kWh)
S. Addu	26,442	6.12	7.30	0.26
B. Goidhoo	483	1.05	37.50	0.29
Th. Buruni	373	0.55	31.00	0.31
Ga. Vilingili	3,203	2.04	11.00	0.29
Lh. Khurendhoo	1,051	1.43	38.00	0.30

l/kWh = liters per kilowatt-hour, MWh = megawatt-hour, PV = photovoltaic.
Source: ADB staff estimates based on feasibility studies undertaken by the PPTA consultants.

E. Economic Internal Rate of Return

12. **Combined**. The estimated economic internal rate of return (EIRR) for the combined sample island subprojects is in Table 2.

Table 2: Economic Internal Rate of Return of Combined Samples
($ million)

	Costs			**Benefits or Avoided Costs**		**Net Benefit**
Year	**Capital**	**Fuel**	**O&M**	**Fuel**	**O&M**	
2014	0.00	0.00	0.00	0.00	0.00	0.00
2015	11.19	0.00	0.00	0.00	0.00	(11.19)
2016	0.00	9.26	0.99	12.29	1.15	3.19
2017	0.00	10.04	1.05	13.29	1.23	3.44
2018	0.00	10.25	1.06	13.58	1.24	3.51
2019	0.00	10.43	1.06	13.82	1.24	3.57
2020	0.00	10.59	1.06	14.02	1.24	3.61
2021	0.00	10.75	1.06	14.23	1.24	3.66
2022	0.00	10.91	1.06	14.44	1.24	3.70
2023	0.00	11.08	1.07	14.65	1.24	3.75
2024	0.00	11.25	1.07	14.87	1.25	3.80
2025	0.00	11.42	1.07	15.08	1.25	3.84
2026	0.00	11.59	1.07	15.31	1.25	3.89
2027	0.00	11.76	1.07	15.52	1.25	3.94
2028	0.00	11.94	1.07	15.74	1.25	3.98
2029	0.00	12.11	1.07	15.96	1.25	4.02
2030	0.00	12.29	1.07	16.18	1.25	4.07
2031	0.00	12.47	1.07	16.40	1.25	4.11
2032	0.00	12.65	1.07	16.63	1.25	4.15
2033	0.00	12.84	1.07	16.86	1.25	4.20

2034	0.00	13.02	1.08	17.10	1.25	4.24
2035	0.00	13.22	1.08	17.33	1.25	4.29
2036	0.00	13.41	1.08	17.58	1.25	4.34
2037	0.00	13.60	1.08	17.82	1.25	4.39
2038	0.00	13.80	1.08	18.07	1.25	4.43
2039	0.00	14.01	1.08	18.32	1.25	4.48
					EIRR	**31.3%**

( ) = negative, EIRR = economic internal rate of return, O&M = operation and maintenance.
Source: ADB staff estimates based on feasibility studies undertaken by the PPTA consultants.

13. **Individual**. The EIRRs and the benefit–cost ratios for the five sample islands have also been determined separately and are in Table 3. As can be seen, the EIRRs range from 14.00% to 40.17%, while the benefit–cost ratios range from 1.06 to 1.40.

Table 3: Economic Returns and Benefit–Cost Ratios of Sample Island Subprojects

Sample	EIRR %	NPV (Benefits)	NPV (Costs)	Benefit–Cost Ratio
S. Addu	40.17	95.33	84.02	1.13
B. Goidhoo	14.00	2.24	2.12	1.06
Th. Buruni	28.89	2.22	1.59	1.40
Ga. Vilingili	19.19	12.66	11.75	1.08
Lh. Khurendhoo	23.85	5.06	3.98	1.27
Combined sample	31.32	117.51	103.46	1.14

EIRR = economic internal rate of return, NPV = net present value.

14. **Sensitivity analysis.** Table 4 gives the effect of changes in oil prices, capital costs, and solar photovoltaic outputs, which are considered to be critical inputs in the economic benefit calculations.

Table 4: Sensitivity of Economic Returns and Benefit–Cost Ratios

		No oil price rise	Capital cost escalation		Solar PV Output Reduced by		Combined Effect
	BAU		10%	20%	10%	20%	
S. Addu	40.17%	37.88%	36.65%	33.71%	39.04%	37.91%	33.44%
B. Goidhoo	14.00%	12.25%	12.66%	11.50%	14.00%	14.00%	10.93%
Th. Buruni	28.89%	26.56%	26.45%	24.40%	28.89%	28.89%	24.20%
Ga. Vilingili	19.19%	16.65%	17.44%	15.95%	19.19%	19.19%	14.99%
Lh. Khurendhoo	23.85%	21.64%	21.74%	19.95%	23.85%	23.85%	19.59%
Combined sample	31.32%	29.06%	28.59%	26.29%	30.70%	30.08%	25.85%

BAU = business as usual, PV = photovoltaic.
Sources: ADB staff estimates based on feasibility studies undertaken by the PPTA consultants.

F. Unquantified Benefits

15. In addition to the quantified benefits of the project as used in the economic analysis there are unquantified benefits such as (i) environmental benefits in the form of emission reductions; (ii) less pressure on country's balance of payments due to fewer diesel imports; (iii) reduction in subsidies to electricity industry, which can have an indirect beneficial impact on other sectors; and (iv) improved energy security, which will indirectly benefit the economy through less volatility in the cost of electricity supply.

G. Conclusion

16. The EIRRs of both the combined sample subprojects and the individual sample subprojects are above the 12% threshold. The sensitivity analysis also shows that the EIRR of the combined samples is above the 12% threshold, even under adverse circumstances. The benefit–cost ratios follow the same pattern. Further, the EIRRs and benefit–cost ratios are likely to be even better if the unquantified benefits are taken into consideration. It is therefore concluded that the project is economically feasible and extremely attractive to a country like the Maldives, which is heavily dependent on imported fossil fuels for its energy requirements.