EXPLAINER

Advanced Battery Technology to Integrate Intermittent Renewables in the Maldives

An advanced battery storage and energy management system will enhance renewable energy penetration in small island countries like the Maldives. Photo credit: ADB.

The Maldives is adopting advanced low-carbon technologies to reduce emissions and diesel imports with the help of the Japan Fund for the Joint Crediting Mechanism.

Introduction

The Maldives is the first and only country in South Asia with 100% access to electricity. However, this achievement has come at a cost.

The Maldives is an archipelago 750 kilometers (km) southwest of Sri Lanka with 26 atolls and a total land area of about 300 km^2. Of its total population of more than 500,000, about a quarter lives in the capital city of Male while the rest reside in more than 190 islands. As of 2018, there are about 240 megawatts (MW) of installed diesel-based generation capacity on the inhabited islands, out of which approximately 135 MW is in the Greater Male region, which comprises Male and neighboring islands.

Given the geographic spread, each island is electrified with its own diesel-powered grid system, resulting in expensive and not very reliable supply. The cost of diesel power is unaffordable at 30 cents to 70 cents per kilowatt-hour (depending on the island) and requires government subsidies in excess of $40 million annually. Electricity-related subsidies are also a focus area for more robust management of government expenditures.

In 2012, the Maldives spent over $470 million on oil imports, a large share of it being fuel for electricity

generation. Such heavy diesel dependence makes the country's carbon emissions per unit of electricity one of the highest in South Asia.

Supported by the Asian Development Bank and with cofinancing from European Investment Bank, Strategic Climate Fund, and the Japan Fund for the Joint Crediting Mechanism (JFJCM), the Preparing Outer Islands for Sustainable Energy Development Project (POISED) is helping the Maldives transform existing energy grids into a hybrid renewable energy system of solar photovoltaics, energy storage[1] and energy efficient diesel generators with energy management systems. This will significantly reduce the need for diesel to generate electricity in 160 outer islands. The hybrid system will regulate intermittency caused by solar power generation and support limited storage.

The project tapped the JFJCM to finance and pilot test an advanced battery energy storage system, including an energy management system, that can help address the additional challenges of renewable energy in small islands like the Maldives.

Why is a battery energy storage system critical to the project?

In small island countries like the Maldives, renewable energy penetration is inherently limited by their grid capacity. Increasing renewable energy installation requires the grid to absorb intermittent surges from the unpredictable supply of renewable sources, such as solar and wind, and it can create significant challenges for regulating voltage and frequency for isolated small island grids. Increasing renewable energy can also limit the diesel generator to run in its optimum configuration to maintain the grid stability, keeping a high spinning reserve.

Usually, such issues could be addressed by introducing an advanced battery energy storage system, also known as BESS, with an energy management system. However, this involves a high initial investment cost.

BESS uses battery technology to store energy for use later. It is supported by computer-aided tools used by operators of electric utility grids, including microgrids, to monitor, control, and optimize the performance of the generation and/or transmission system.

The problem was more serious in the island of S. Addu, one of the five islands where solar photovoltaic-diesel hybrid solutions were being applied under Phase 1 of the project. Located in the south of the Maldives, S. Addu is the second-largest habited island with a population of more than 23,000 inhabitants in the city. The large urban area has the major modern infrastructures such as an airport, large harbor facilities, a school up to university grade, and a tourist industry. It was expected to be the project site with the highest impact.

Phase 1 was successfully completed and connected to the grid. It achieved reductions in the levelized cost of energy, which measures the present value of the total cost of building and operating a power plant over an assumed lifetime.

Table 1: Phase 1 of POISED Project

Island	Levelized Cost of Energy ($/kWh)	
	Previous	Current
S. Addu City	0.36	0.29
Ga. Villingili	0.47	0.3
Lh. Kurendhoo	0.46	0.29
B. Goidhoo	0.41	0.28
Th. Buruni	0.47	0.28

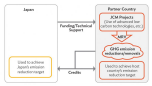
Except for S. Addu City, the designs of the hybrid systems under Phase 1 use conventional (lithium-ion 1C batteries) instead of advanced storage technologies because of their initial high cost and perceived technology risks. The advanced battery storage (lithium-ion 3C batteries) will be installed and pilot tested in S Addu City with JFJCM support.

How does the Japan Fund for the Joint Crediting Mechanism work?

The Japan Fund for the Joint Crediting Mechanism (JFJCM) is a single-donor trust fund established in 2014 and managed by ADB. The fund aims to provide financial incentives for the adoption of advanced low-carbon technologies in ADB-financed and administered sovereign and nonsovereign projects. The fund will provide grants and technical assistance (TA) to ADB projects utilizing the Joint Crediting Mechanism or JCM.

The JCM is a bilateral carbon credit mechanism initiated by the Government of Japan. It facilitates diffusion of leading low carbon technologies, products, systems, services, and infrastructure as well as the implementation of mitigation actions, and contributes to the sustainable development of developing countries. The greenhouse gas (GHG) emission reductions achieved may be used to meet the emission reduction targets of partner countries and Japan.

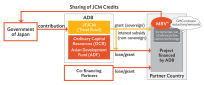
Figure 1: Overview of the Joint Crediting Mechanism Scheme



GHG = greenhouse gas, JCM = Joint Crediting Mechanism, MRV = measurement, reporting, and verification.

A number of ADB's developing members have signed bilateral agreements [2] with the Government of Japan to host Joint Crediting Mechanism projects.

Figure 2: How the Japan Fund for the Joint Crediting Mechanism (JFJCM) Provides Support



*MRV = Measurement, reporting, and verification of the greenhouse gas (GHG) emission reductions.

Sovereign projects	JFJCM provides a grant for incremental cost of advanced low-carbon technologies. **The maximum amount of support is for 10% of the project cost (capped at $10 million)**, or $5 million if the project cost is less than $50 million.
Non-sovereign projects	JFJCM provides an interest subsidy to ADB's loan. **The maximum amount for support is for 10% of the project cost (capped at $10 million).**

What are the technical specifications of the project?

The POISED project is the first approved JFJCM project.

JFJCM provides a $5-million grant to support the installation of a 0.5MWh lithium-ion BESS with high-speed charge/discharge features and advanced energy management system. The project is expected to contribute to increasing solar photovoltaic penetration capacity of the system with maximum demand from 33% to 54% and increase grid stability in Addu City. This investment ensures a significant reduction in the cost of electricity supply and enhanced the security of supply while reducing GHG emissions.

Technical specification of the battery energy storage system

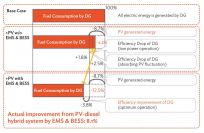
- Cycle of lithium ion battery cells applied in BESS shall be a minimum 13,000 cycle, at depth of discharge (DoD) of 90% or above at rated power. Remaining battery capacity (State of charge or SoC) shall be equivalent to or above 70% at the end of above lifecycle.
- The discharge capacity rate (C rate) of BESS shall be equivalent or above 3C.
- A safety test shall be conducted and no explosions nor fire shall be observed in the test according

to IEC 62619, IEC62660-2, or UL1973.

Specification of the energy management system

- Economic load dispatch (ELD) control and load frequency control (LFD) function.
- Import function for weather forecast data from meteorological organization.
- Generation planning function with demand forecast and theoretical photovoltaic generation forecast, and for creating one-day operation schedule to keep demand and supply balance.
- SoC management function for BESS.
- The system shall be able to command and control charge/discharge of battery.

Figure 3: An Example of How BESS and EMS Improve Diesel Generator Efficiency



BESS = battery energy storage system, EMS = energy management system, DG = diesel generator, PV = photovoltaic.

What are the expected results and what can we learn from this project?

The project is expected to complete the installation of the BESS and energy management system in March 2020, enabling the Maldives to further reduce GHG emissions by an estimated 1,300 tCO_2 annually. The intervention also allows more renewable energy integration in the future, including private sector investment in solar energy on Addu island. Moreover, the BESS and energy management system can contribute to increasing energy supply and grid stability while reducing the cost of energy for consumers and the financial burden of the government.

Small island countries like the Maldives can replicate the introduction of these advanced low-carbon technologies to address the issues associated with increasing renewable energy penetration.

[1]Batteries installed under POISED are maintenance-free lithium-ion types (1C battery).

[2] The JFJCM eligible countries as of November 2019 are Bangladesh, Cambodia, Indonesia, Lao People's Democratic Republic, Maldives, Mongolia, Myanmar, Palau, Philippines, Thailand, and Viet Nam.

Resources

Asian Development Bank (ADB). Maldives: Preparing Outer Islands for Sustainable Energy Development Project.

ADB. Japan Fund for the Joint Crediting Mechanism.

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Jaimes Kolantharaj is working on projects in Bangladesh, India, Maldives, and Sri Lanka. He has a master's degree in Power Engineering from Nanyang Technological University and a bachelor's degree in Electrical & Electronics Engineering from Madras University. He was a project manager in Singapore Power Grid (SPPG), has experience in the renewable energy sector, and worked for a state-owned power utility in India.

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Len George is focal for energy operations in the Maldives. He has worked on renewable energy, regional connectivity, and electricity network investments in South Asia for the last 10 years. He holds a post graduate diploma in Management from the Indian Institute of Management, Ahmedabad and a bachelor's degree in Electrical Engineering from the Delhi College of Engineering. He was a senior manager with PricewaterhouseCoopers before joining ADB in 2009.

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Shintaro Fujii manages the Japan Fund for the Joint Crediting Mechanism (JFJCM), which promotes advanced low-carbon technologies. He also supports the operations on climate change and environmental issues. Prior to joining ADB, he worked for the Ministry of the Environment of Japan for more than 15 years.

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Takahiro Murayama is a lead consultant of the Japan Fund for the Joint Crediting Mechanism (JFJCM) secretariat, specializing in low carbon project development. He has a background in economics and public policy, and holds a master's degree in Environmental Management and Development from the Australian National University.

Asian Development Bank (ADB)

The Asian Development Bank is committed to achieving a prosperous, inclusive, resilient, and sustainable Asia and the Pacific, while sustaining its efforts to eradicate extreme poverty. Established in 1966, it is owned by 68 members—49 from the region. Its main instruments for helping its developing member countries are policy dialogue, loans, equity investments, guarantees, grants, and technical assistance.

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Last updated: November 2019