CLEAN ENERGY MINISTERIAL
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SUPERCHARGING BATTERY STORAGE
AN INITIATIVE OF THE CLEAN ENERGY MINISTERIAL

BATTERY STORAGE UNLOCKED

Lessons Learned from Emerging Economies

Clean Energy Ministerial Supercharging Battery Storage Initiative

November 2024

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Clean Energy Ministerial Supercharging Battery Storage Initiative

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Foreword: International cooperation in action – using the CEM knowledge sharing platform to unlock Battery storage deployment

Recognizing that Battery storage will be vital for integrating renewables, enhancing grid flexibility, resilience, and affordable off-grid energy in support of accelerated clean energy transitions, Leaders agreed at the UN Climate Ambition Summit in New York in September 2023 to coordinate efforts within the Clean Energy Ministerial (CEM) to overcome barriers and accelerate the deployment of utility-scale battery storage by uniting existing initiatives and stakeholders to accelerate this essential technology.

Thus, the CEM Supercharging Battery Storage Initiative was launched at COP28, to boost stationary battery storage development and deployment and reduce technology cost through international cooperation and alignment as appropriate, to build a diversified, sustainable, responsible, secure and transparent supply chain, to promote grid stability and reliability and to support the integration of renewable energy globally.

This new initiative, co-led by Australia and the European Commission with support from Canada and the United States, and recently joined by the Netherlands, intends to bring together nations and partners to co-create effective strategies that enhance policy and regulatory frameworks along with financing solutions. It is a vital contributor to the Agenda for Action on Power Systems Solutions launched during CEM15 in Foz do Iguaçu to support the G20 priority on scaling up investment to bridge the energy infrastructure funding gap.

This report is one of the first outcomes from the Supercharging Battery Storage Initiative collaboration and aims to demonstrate the momentum that is building in this sector through a series of specific cases of BESS deployment. It highlights the remarkable progress achieved globally, specifically in emerging economies, to support the transparent sharing of lessons learned and best practices.

The CEM is proud to provide its collaborative platform to support the Supercharging Battery Storage Initiative community and enable this sharing of knowledge as well as the creation of coalitions bringing together stakeholders - governments, industry leaders, and community advocates – to ensure that successful approaches are replicated and scaled.

As we move from setting targets such as the tripling of renewable power capacity to implementing concrete actions, including accelerating the deployment of stationary battery storage technologies, the CEM and its community remain steadfast in acting together on concrete outcomes to supercharge clean energy deployment and bring communities along to maximize the benefits of an accelerated clean energy transition that leaves no one behind. ■

Jean-François Gagné

Head of the Clean Energy Ministerial Secretariat

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BESS battery energy storage system

BNDES Banco Nacional de Desenvolvimento Econômico e Social

BRPL BSES Rajdhani Power Limited

CEM Clean Energy Ministerial

CIF Climate Investment Funds

GEAPP Global Energy Alliance for People and Planet

GESP Global Energy Storage Program

GHG greenhouse gas

IRENA International Renewable Energy Agency

LDES long-duration energy storage

MSME micro, small, and medium enterprises

NREL National Renewable Energy Laboratory

PV photovoltaic

RELAC Renewables in Latin America and the Caribbean

RMI Rocky Mountain Institute

SDOM Storage Deployment Optimization Model

SIDS small island developing states

SREP Scaling Renewable Energy Program

VRE variable renewable energy

Executive Summary

To further peer-learning under the Clean Energy Ministerial's Supercharging Battery Storage Initiative, this report showcases lessons learned and shares best practices for accelerating battery energy storage systems (BESS) in emerging economies. While the deployment of utility-scale BESS is booming across the developed world, utility-scale storage solutions in emerging economies are still nascent. Emerging economies present unique cases for the deployment of BESS and present significant opportunities for highlighting the role that utility-scale BESS can play in scaling up renewable energy deployment and meeting clean energy goals.

This report focuses on cases across Asia, Sub-Saharan Africa, Latin America and the Caribbean, and the Pacific. Cases are centered on three topics crucial for understanding BESS trends in emerging economies: enabling environment, deployment and financing, and BESS operation and value stack. These topics represent some of the most prominent challenges encountered by emerging economies that align with the Supercharging Battery Storage Initiative's key pillars: policy and regulation, supply chain and manufacturing, and financing. Moreover, sharing the best practices for developing, financing, and operating battery storage projects can not only increase viability of such initiatives, but also empower industry professionals.

The report highlights several case studies from BESS deployment across emerging economies exploring the enabling environments, financing structures, and key market opportunities to help overcome critical barriers to BESS deployment around the world, especially in emerging economies.

Key case studies include:

- **(India) Regulatory Reform and Investment Support** - To meet India's need for clean power, BSES Rajdhani Power Limited (BRPL), New Delhi's utility, has developed the first commercial stand-alone BESS project (20-MW/40-MWh BESS) at the distribution level in India supported by The Global Energy Alliance for People and Planet (GEAPP), in collaboration with IndiGrid and AmpereHour Energy. It will also be the largest of its kind in South Asia at its commercial operation date.

- **(Latin America and the Caribbean) Technical Capacity Building for Energy Storage via RELAC** - The Renewables in Latin America and the Caribbean (RELAC) initiative launched the Accelerated Deployment of Energy Storage in RELAC Countries series which included workshops, in-person trainings, and technical support, to help countries to build their technical awareness for energy storage, estimate their energy storage needs, model storage integration, and assess regulatory gaps and potential improvements.

- **(SIDS) The Role of Battery Storage in Island Power Systems: Insights From the Grid** – IRENA conducts technical grid integration studies to support small island developing states (SIDS) in planning for the technical challenges associated with integrating high shares of VRE. To date, IRENA has completed seven grid assessments for SIDS (Palau, Antigua, Aitutaki, Samoa, Vanuatu, Fiji, and the Dominican Republic). These studies identify the technical constraints associated with integrating levels of VRE needed to meet each country's goals and the possibilities to overcome potential problems with grid stability and reliability through BESS.

- **(Uzbekistan) Promoting Private Sector Engagement in Hybrid Renewables and BESS Projects** – The World Bank Uzbekistan Solar and Renewable Energy Storage Project includes the construction and operation of a 250-MW solar power plant and a 63-MW/126-MWh BESS in the Bukhara region. The project aims to increase private sector-led renewable energy supply in Uzbekistan, contributing to the country's ambitious goal of reaching 25 GW of renewable energy capacity by 2030.

- **(Brazil) Catalyzing Financing for BESS Deployment for Private Sector Enterprises: Bridging Public and Private in Brazil** – Climate Investment Funds, in partnership with the Inter-American Development Bank, and the national implementing agency (Banco Nacional de Desenvolvimento Econômico e Social), provided investment support for the installation of 8.8 MW/26.4 MWh of battery storage capacity for medium voltage behind-the-meter in mini-grid applications targeting micro, small, and medium enterprises and reducing risks associated with high upfront costs in the sector.

- **(Maldives) Transforming Islanded Energy Systems Through a Multimodal Approach** – Climate Investment Fund's Scaling Renewable Energy Program in Low Income Countries (SREP) Investment Plan for the Maldives funded the deployment of 184 MWh of BESS in 116 of the 186 habitable islands in the Maldives. To contribute to cost reduction and stabilization, the SREP Investment Plan also implemented a multi-tier risk mitigation facility that considerably increased the number of private investors and helped reduce the tariff from $0.21/kWh in 2014 to $0.9888/kWh up to date.

- **(Botswana) Supporting Renewables Integration and Grid Flexibility for National Energy Goals Through Grid-Scale 50-MW/200-MWh Stationary BESS** – To increase the penetration of renewables in the national grid of Botswana and to provide grid stability services, the Botswana Power Corporation has planned to set up two 25-MW/100-MWh BESS installations at Phikwe, Central District, and Jwaneng, Southern District of Botswana. The BESS project leveraged Green Climate Fund and World Bank financing under the Sustainable Renewables Risk Mitigation Initiative.

Deploying BESS in emerging economies requires building partnerships among local and international stakeholders. Sharing lessons learned and encouraging battery storage projects worldwide is imperative to ensure the integration of higher shares of renewables and power system decarbonization. While these studies highlight the BESS projects mainly at the initial stages of their development or deployment, it indicates that storage has become a prominent technology in emerging economies and there is strong motivation for its deployment. Fostering partnerships across different sectors, facilitating the development of regulatory environments, and encouraging investment mobilization can accelerate the deployment of BESS in emerging economies.

Figure 1. This map depicts the countries highlighted through this report, including Botswana, Brazil, India, Latin America and the Caribbean, Maldives, Uzbekistan, and Small Island Developing States.

Overview

The Clean Energy Ministerial (CEM) is a global forum that promotes policies and programs that advance clean energy technology. The CEM's mission is to bring together a community of global leaders to scale clean energy, amplifying the impact to all the sectors of the economy and applying a whole-of-society approach to meet collective climate and clean energy goals.

The CEM comprises 29 member countries that represent 90% of installed renewable power generation capacity and 80% of global renewable energy investment. Together, through the CEM, member countries set shared priorities on clean energy topics and create workstreams to further those priorities with other interested states.

Supercharging Battery Storage Initiative

At COP28 in Dubai, United Arab Emirates, the CEM announced the Supercharging Battery Storage Initiative as a vehicle to accelerate battery storage deployment around the world, recognizing its crucial role in accelerating the clean energy transition. The initiative is co-led by Australia and the European Commission, supported by Canada and the United States as key participant countries.

The initiative supports countries around the world in co-creating strategies that enhance policy, regulation, supply chain, manufacturing, and financing solutions for battery energy storage deployment, particularly utility-scale battery energy storage. Additionally, the initiative seeks to reduce the cost of the technology and promote diversified, sustainable, and secure supply chains (CEM n.d.). Through international collaboration, the initiative supports the integration of renewable energy globally, while securing the stability and reliability of the electricity grid.

The Supercharging Battery Storage Initiative is organized around three work pillars, as illustrated in **Figure 2**.

A central focus of the initiative is to address the unique challenges faced by emerging economies in scaling utility-scale battery storage deployment. By fostering collaboration between governments, industry, and the private sector, the initiative promotes knowledge-sharing and capacity-building that can support and accelerate the widespread adoption of battery energy storage.

1 Policy & Regulation	2 Supply Chain & Manufacturing	3 Financing
Goal 1: Integrate stationary battery storage into net zero polict and regulatory frameworks and grid planning in urban, rural and remote settings. **Goal 2:** Leverage policies and regulations to improve technology diversification, ESG responsibility, safety, cost reduction and affodability of stationary battery storage solutions.	**Goal 3:** Build a diversified, sustainable, responsible, secure and transparent supply chain for battery storage, incorporating circularity and recycling, and scale it up to meet grid-scale deployment needs, in line with net-zero goals. **Goal 4:** Support development of supply chains for sustainable cost-competitive alternative battery chemistries to diversify approaches to meeting stationary battery storage needs.	**Goal 5:** De-risk and driver public-private co-investment throughout the supply chain for stationary battery storage solutions.

Figure 2. The pillars of the Supercharging Battery Storage Initiative support collaboration on challenges and opportunities to widespread battery energy storage solutions globally.

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This report, released as part of the Supercharging Battery Storage Initiative, highlights the progress made in deploying storage solutions globally, particularly in emerging economies. The report identifies gaps and shares key lessons learned, offering solutions that can be replicated and scaled across various contexts to further support the deployment of battery storage worldwide.

Structure of the Report

To further peer-learning under the Supercharging Battery Storage Initiative, this report showcases lessons learned and shares best practices for accelerating battery energy storage systems (BESS) in emerging economies. While the deployment of BESS is booming across the developed world, utility-scale storage solutions in emerging economies are still nascent. Emerging economies present unique cases for the deployment of BESS and present significant opportunities for highlighting the role BESS can play in scaling up renewable energy deployment and meeting clean energy goals.

This report focuses on cases across Asia, Sub-Saharan Africa, Latin America and the Caribbean, and the Pacific. Cases are centered on three topics crucial for understanding utility-scale BESS trends in emerging economies: enabling environment, deployment and financing, and BESS operation and value stack. These topics represent some of the most prominent challenges encountered by emerging economies that align with the Supercharging Battery Storage Initiative's key pillars. Moreover, sharing the best practices for developing, financing, and operating battery storage projects can not only increase viability of such initiatives, but also empower industry professionals.

This report features a background section that provides an overview of BESS, including existing chemistries, costs, current deployment trends, and key challenges. The background also features an overview of critical themes for BESS deployment such as enabling environment, deployment and financing, and operation and value stack. It then moves into case studies. These case studies have been contributed by leading BESS partners and highlight different elements critical to battery deployment in a variety of contexts. Key insights from these case studies are featured to provide a concise overview of lessons learned.

Background

1.1 Introduction to BESS

Adopted at the 21st United Nations COP in 2015, the Paris Agreement calls on countries to limit the increase of global average temperatures well below 2°C above pre-industrial levels (UNFCCC n.d.[b]), which requires decarbonization of various sectors of the economy. At COP28, governments pledged to improve the progress on reducing the greenhouse gas (GHG) emissions and accelerate the transition from fossil fuels to renewable energy sources by setting a goal to triple global renewable energy capacity by 2030 (UNFCCC n.d.[a]). Meeting the tripling renewables target, as well as the global temperature goal, will require global renewable energy capacity to grow to at least 11 TW by 2030 (IEA 2024b).

As countries around the world seek to increase the share of renewable energy and meet their national emission targets, operation of the grid with variable renewable energy (VRE) becomes increasingly complex. Advanced solutions, such as battery energy storage systems (BESS) may be used to enhance grid stability and reliability, transforming VRE into reliable, dispatchable baseload power. The role of BESS is becoming even more prominent as the demand on the power sector grows and heating, transportation, and other sectors are moving toward full electrification (Graham et al. 2021). According to the International Energy Agency's Net Zero by 2050 Scenario, 1,500 GW of energy storage, including 1,200 GW of battery storage, may be required by 2030 globally to meet global climate goals (IEA 2024c).

Utility-scale BESS are well-positioned to facilitate the decarbonization of power systems. With capacity ranging from several hundred kWh to GWh, they support the operation of transmission and distribution networks, ensuring the reliable and efficient operation of the grid, and can provide peaking capacity, a variety of ancillary services, black-start capability, and arbitrage opportunities, which will be explored in the following sections (Bowen, Chernyakhovskiy, and Denholm 2019). Additionally, smaller-scale behind-the-meter energy storage, while not in the scope of the Supercharging Battery Storage Initiative, can support a variety of needs on the level of mini-grids and provide time-of-use bill management, backup power, and decreased curtailment of distributed systems (Fitzgerald et al. 2015).

Battery storage has become a critical technology for accelerating the integration of VRE due to its ability to offer multiple services and value stacking opportunities, maximizing potential revenue. The International Energy Agency estimates that, to meet the global goal to triple renewable energy by 2030 and achieve COP28 targets, energy storage must increase to six times current levels. This pace dictates that BESS capacity could grow by an average 25% per year to 2030, which hinges on successful policy implementation and further declines in battery costs (IEA 2024a). Deployment of BESS and other energy storage solutions could be essential for enabling continued changes to power systems around the world.

1.2 Technology Overview

A variety of energy storage technologies are available on the market: electrochemical, thermal, mechanical, and chemical storage. BESS and flow batteries are examples of electrochemical storage, molten salt storage exemplifies thermal storage, pumped hydro serves as a primary example of mechanical storage technology, and hydrogen and power-to-gas storage showcase chemical storage technology (**Figure 3**).

This report focuses solely on battery energy storage. A variety of chemistries are available for BESS, each with their own characteristics, advantages, and limitations. They can be differentiated by energy density, round-trip efficiency, life span, and other factors (Kim et al. 2018).

Lithium-ion batteries are the most popular on the market; they are considered safe and have the highest energy density. Their maintenance is straightforward, and charge times are short; however, this type of battery is sensitive to extreme temperatures, degrading in high temperatures and charging slowly in subzero temperatures (Shuai Ma, 2018). Among lithium-ion batteries, some of the most widely used chemistries include lithium iron phosphate, lithium nickel manganese cobalt oxide, and lithium nickel cobalt aluminum oxide. In 2023, lithium iron phosphate batteries accounted for about 80% of the total BESS market (IEA 2024a), and they are expected to overtake as the dominant chemistry by 2030 (Wood Mackenzie 2020). It is worth noting that these batteries rely on critical raw materials, the mining, processing, and manufacturing of which are largely dominated by a few global suppliers. This concentration raises concerns about the security of critical mineral supply chains (Cohen, Shirley, and Svensson 2023).

There are other battery chemistries available on the market, each with their own challenges and opportunities. These include (Kim et al. 2018):

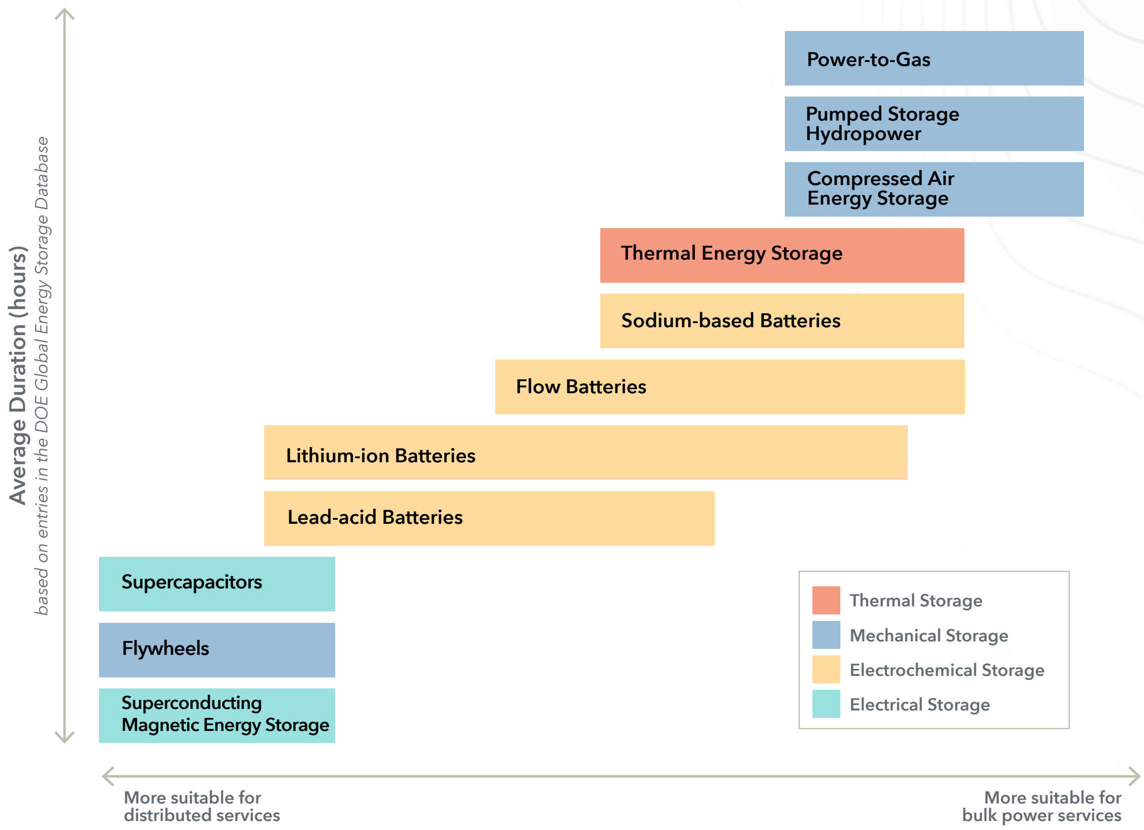


Figure 3. Energy storage types. Source: Chernyakhovskiy et al. (2021)

- **Lead-acid batteries:** While low in cost and efficient in recycling, lead-acid batteries charge slowly and have a limited life cycle.
- **Redox flow batteries:** Using varied chemistry, redox flow batteries have a flexible design and minimal degradation, making them most suitable for long-duration energy storage (LDES).
- **Iron-air batteries:** Not yet technologically mature, iron-air batteries use low-cost materials that are showing promise for storage in emerging economies with limited capital.

1.2.1 LDES

Energy storage is also defined by its duration: short-duration energy storage and LDES. Short-duration energy storage, for instance, 4-hour storage, can serve daily summer peaks, balance renewable sources, and stabilize the frequency of power grids. Short-duration energy storage is widely used at the household level in conjunction with solar panels to smooth production and respond to electricity rate windows. The short-duration energy storage technologies include batteries, flywheels, and some mechanical technologies (DOE n.d.).

Long-duration storage, defined as lasting more than 10 hours, can play a crucial role in supporting demand growth. LDES have the potential to complement the expansion of renewables and enhance the resilience of power grids. Additionally, deploying LDES helps diversify the storage supply chain and avoid supply chain bottlenecks (LDES Council 2023). Among LDES, inter-day, multiday, and seasonal storage is distinguished. The inter-day LDES dispatch duration ranges from 10 to 36 hours and includes mechanical and electrochemical technology, like flow battery, latent heat, and liquid air. Iron-air technology is an example of multiday energy storage (DOE n.d.). The multiday LDES duration of power dispatch is 36 to 100 hours, providing additional resilience and supporting demand growth. LDES can also balance seasonal renewable energy variation, for example, by using hydrogen storage to reduce energy curtailment, replace peak generation capacity, and provide transmission benefits (**Figure 4**) (Guerra and Eichman 2020).

LDES allows energy to be stored for extended periods, providing a solution for the decarbonization of the grid. As VRE sources are deployed to meet rising electricity demand and reduce power sector emissions, LDES provides an opportunity to use energy more efficiently.

For instance, LDES enables a more effective response to changes in consumer demand, climate, and extreme weather events (Stenson 2023). To decarbonize the grid, two types of long-duration storage are expected to be needed: up to 20 hours to manage daily cycles, and 4 weeks and more for seasonal cycle management (Twitchell, DeSomber, and Bhatnagar 2023).

While battery technologies continue to play a vital role in the global clean energy transition, other types of energy storage have the potential to become significant contributors to reducing GHG emissions in power systems. LDES and other storage solutions such as pumped hydrogen, non-lithium long duration storage technologies, and more may intersect with BESS technologies to meet the needs of the power systems of the future.

As the global energy landscape continues to evolve, LDES could play an increasingly important role in accelerating the transition to a decarbonized grid. The ongoing research, development, and deployment of LDES technologies could be essential for managing daily and seasonal energy cycles, enhancing grid reliability, and supporting the broader goal of decarbonization.

While BESS currently dominate the energy storage landscape due to their maturity, cost-effectiveness, and alignment with short-term energy needs, LDES holds significant potential for addressing long-term energy storage requirements. As such, LDES and other technologies are not featured in this report's case studies but are an important part of the context for future power system decarbonization efforts.

1.3 Costs and Deployment Trends

In 2023 alone, the deployment of BESS in the power sector increased 130% compared to 2022, adding a total of 42 GW to global electricity systems (IEA 2024a). The demand for energy storage creates a market opportunity for BESS, and in 2022, more than $5 billion was invested in this technology, representing almost a threefold increase compared to 2021 (McKinsey 2023). Significant investment will need to continue to meet the sixfold increase in energy storage needed to meet the global goal to triple renewable energy by 2030.

In 2023, the National Renewable Energy Laboratory (NREL) indicated that, by 2050, the overall costs for lithium-ion 4-hour utility-scale BESS are projected to reduce by 67%, 51%, and 21% in low-, mid-, and high-cost projection scenarios, respectively, relative to 2022 costs (Cole and Karmakar 2023).

However, as highlighted above, despite decreasing costs, the deployment of BESS is currently led by China, the United States, and the countries of the European Union, while emerging economies have seen limited deployment (IEA 2024a).

1.4 Enabling Environment

The effective deployment and operation of battery energy storage requires a robust enabling environment. Enabling policies and regulation, opportunities for market participation, integrated planning, and resource modeling are among the critical factors for maximizing the potential benefits of BESS. A comprehensive plan for battery storage deployment serves as a foundation for establishing regulatory and technical requirements. This approach can help ensure that the unique nature of BESS charging and dispatching energy is properly considered.

Successful storage policies often include setting energy storage targets and establishing incentive programs to make storage technologies more affordable for both utilities and small consumers (Union of Concerned Scientists 2019). Developing a comprehensive policy framework for BESS requires extensive stakeholder engagement to understand the needs of potential owners and operators, system operators, market operators, and other stakeholders. While valuable, participation of many stakeholders with different goals and interests may add additional complexity and create delays.

While targets and incentives can drive BESS deployment, additional regulations and changes in existing markets are necessary to ensure that the utilization of storage provides the intended benefits. Well-suited regulations for BESS should address the requirements for owning and operating BESS, permitting requirements and timelines, service procurement criteria, and grid code integration requirements, among others. Uncertainty around BESS regulations in emerging economies poses a significant bottleneck for large-scale deployment.

In addition to policy and regulatory frameworks, BESS deployment requires specific market mechanisms in place to make the investment worthwhile. In many emerging economies, however, specific market mechanisms have yet to be introduced, leading to challenges and uncertainties for BESS deployment. Market structures such as day-ahead markets, energy auctions, balancing and capacity markets, among other mechanisms, can enable BESS operators to fairly compete in the energy market when designed considering BESS from the beginning.

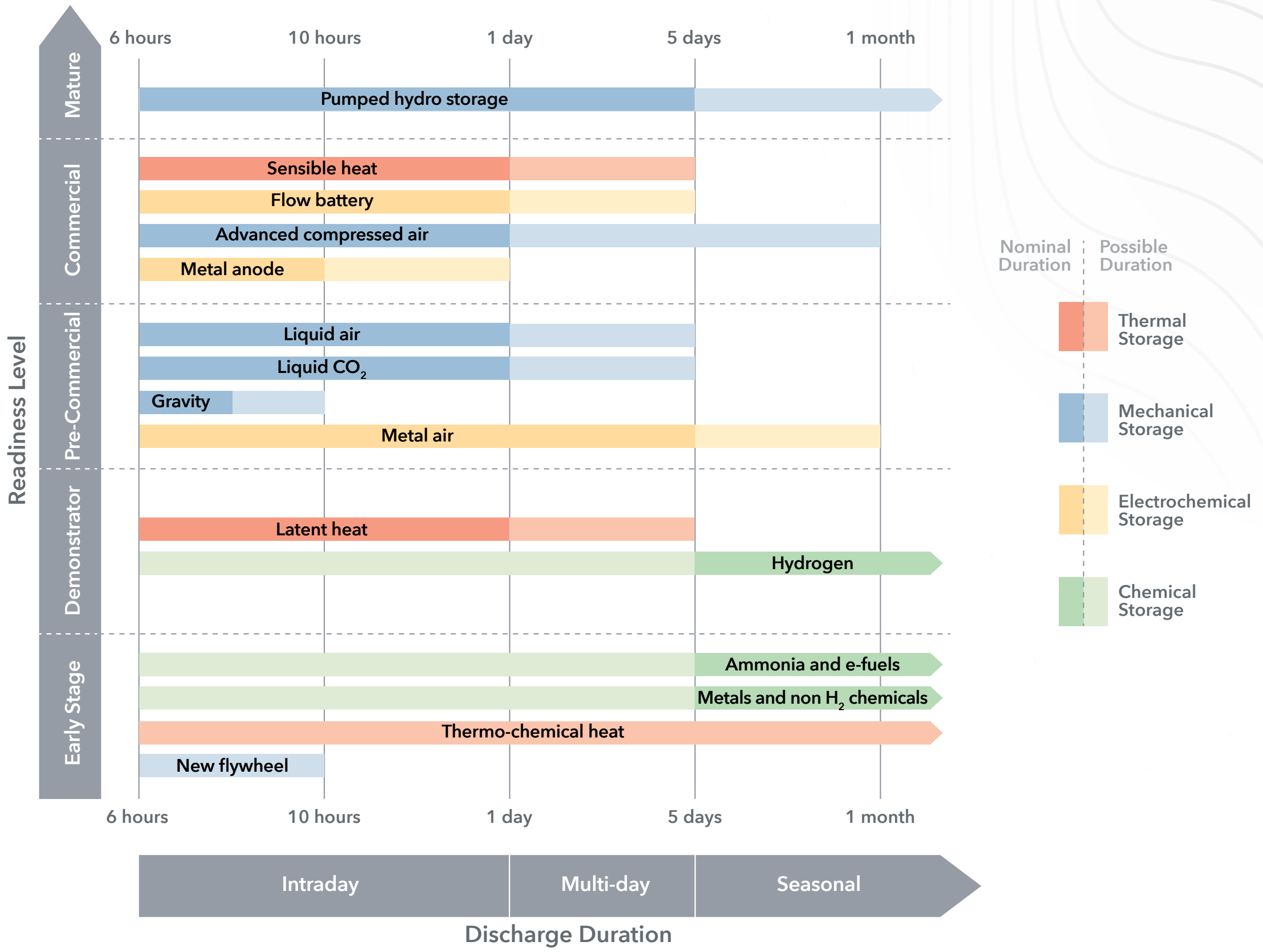


Figure 4. LDES technologies. Source: LDES Council (2023)

Establishing proper compensation for BESS across their variety of services represents an additional challenge. In many countries, BESS are widely considered a generation asset, disregarding the fact that they can be used as a flexible load, substitute grid infrastructure, and provide a variety of ancillary services (IEA n.d.). Value-stacking could also be considered, as it has potential to improve the BESS business case. Globally, research on business models to support BESS deployment continues to evolve; however distinct market mechanisms must be in place to incentivize utility-scale or distributed BESS deployment depending on a country's context and goals (Fihlo, 2023, Greening the Grid, n.d.).

Once policies, regulatory, and market mechanisms are in place, integrated planning and resource modeling is needed to support investment and integration decisions. Tools available for such analysis are diverse; however, these tools rarely consider the wide variety of services that BESS can provide. Energy storage planning should consider modeling of the complex lifetime of BESS to comprehensively understand the impacts and effects that the system might have in a specific context (Haas et al. 2017). Whether the system is being deployed in a hard-to-abate sector, at utility scale, or in a microgrid network, planning efforts that take BESS' wide variety of applications into account can better prepare stakeholders to thoughtfully use, maintain, and decommission a BESS over its lifetime.

Although a relatively small number of countries have created a robust enabling environment for BESS (Sani et al. 2020), lessons can be drawn from the experience of developed economies on incentives, national targets, and policy reform, among other mechanisms:

- **Policy planning:** To align the energy storage deployment with decarbonization targets and strategies, countries will need to incorporate BESS into long-term planning for power systems using tools and methods that consider BESS' various services.

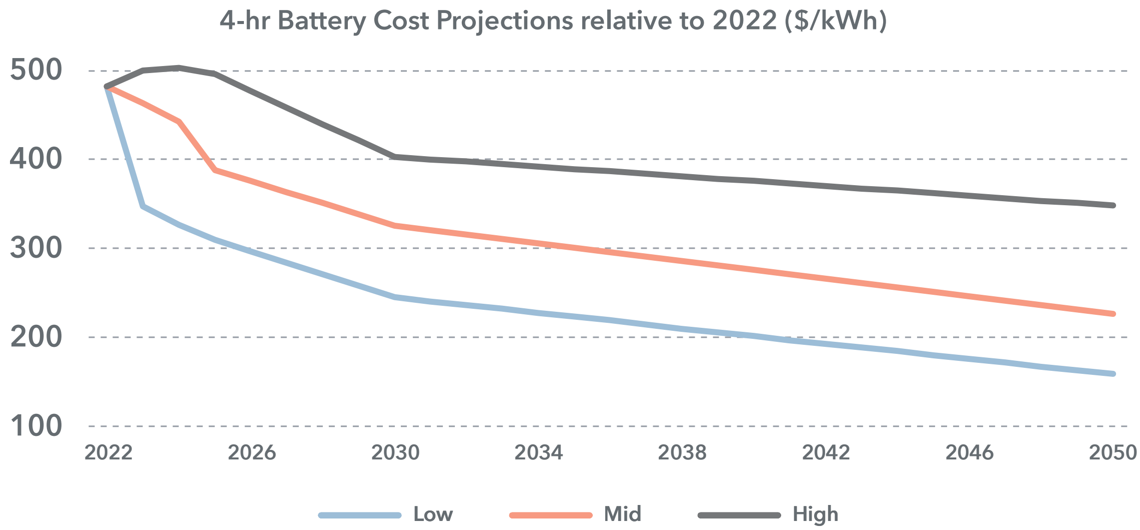


Figure 5. Cost projections for 4-hour battery energy storage. Elaborated using the data from Cole and Karmakar (2023)

- **Regulatory frameworks:** Including the definition of energy storage, establishing clear operation and maintenance rules, defining ownership requirements, and creating a streamlined permitting process can ease the challenges that regulatory frameworks impose on BESS developers.
- **Grid codes:** By emphasizing clear interconnection rules, agreements between grid operators and BESS operators, operational guidelines, channels of communication, and monitoring and reporting protocols, countries may be better suited to ensure that BESS stakeholders are able to navigate the technical considerations needed to support grid integration of energy storage.
- **Market design:** Prioritizing explicit financial incentives and defined payment for various energy markets can ensure that market stability supports cost-effective BESS solutions. Models such as frequency regulation, peak shaving and energy arbitrage, tax credits, loans/grants, and accurate tariff structures may all assist in opening markets for BESS.

Creating an enabling environment for energy storage deployment is instrumental to ensuring that a country can meet its needs for energy storage, including through BESS. Clear regulatory frameworks, policies, grid codes, and market mechanisms can create a strong enabling environment that supports stakeholders in deploying BESS. In service of meeting the goal to triple renewable energy by 2030, BESS enabling environments can be critical for expanding energy storage solutions.

1.5 Deployment and Financing

While battery energy storage is well positioned to tackle a variety of challenges in emerging economies from renewables integration to grid stability and reliability, the deployment of such systems remains limited due to challenges for deployment and financing. For BESS deployment, emerging economies are far behind China, the United States, and the European Union, which collectively deployed nearly 90% of the capacity added in 2023 (IEA 2024a). The lack of data on storage deployment in emerging economies further complicates the analysis of deployment patterns, trends, and opportunities.

There are several different business models for deploying energy storage many of which are similar to the business models for renewable energy projects. They are designed to allocate the responsibility for the development, financing, operation, and ownership of the asset between the utility and a potential third party. Some of the business models can help lift the burden of the initial capital expenditure, making storage projects more accessible for a utility (Lazaroff and Arora 2023):

- **Utility ownership of the asset:** Utility builds, operates, and owns the BESS. The utility or the government bears the initial capital expenditures and receives compensation for BESS services.
- **Power purchase agreements or energy storage services agreements:** These agreements involve an energy company that agrees to provide electricity stored by a BESS to a client. The agreement outlines the specific duration of the provided services and

their price. Power purchase agreements for BESS secure energy stored by the batteries and offer BESS owners income opportunities to support project financing (Act Renewable n.d.).

- **Build-transfer agreements:** Build-transfer agreements combine the features of power purchase agreements and an engineering, procurement, and construction contract. When a BESS achieves commercial operation, the developer would sell the project to the utility. In this arrangement, the utility becomes the long-term owner but does not bear the responsibility for project development and construction (Lazaroff and Arora 2023).
- **Public-private partnership:** Appears as an alternative procurement strategy, helping governments engage with private sector expertise and financial resources (Delplanque and Mensan Gaba 2023). A public-private partnership is especially relevant for developing economies, helping them benefit from private sector technological advancement without burdening their energy budget. It is important to identify the intended use case of the BESS, so the project's objectives and commercial terms are considered in a public-private partnership agreement (Smith 2024).

The business model used determines the risk allocation between parties and outlines the specific responsibilities of the private sector. After the ownership type has been established through the business model, project siting, bid acceptance, and finally installation and commissioning of BESS can be completed.

Attracting private capital for a BESS project in emerging economies is still challenging. Leading investors in BESS mainly reside in China, North America, and Europe, and invest in their local markets or mature BESS markets abroad. BESS projects can also be financed through loans, grants, and guarantees from public sector parties. Multilateral development banks and development finance institutions are best positioned to provide financing for BESS projects, especially in emerging economies where private capital may be limited. A loan or grant from these institutions can de-risk the investment and attract private capital, particularly through risk-mitigation measures (Thakur and Prakash Jena 2024). Additionally, blended financing may be a good strategy to attract private investors by providing a guarantee for the BESS project.

Widespread BESS deployment would require robust mechanisms to ensure that BESS projects are bankable. Combined with regulatory and policy frameworks, financing mechanisms and market measures are instrumental to connecting the public and private sectors to meet a country or region's energy goals.

1.6 Operation and Value Stack

BESS can provide a range of services both at customer and utility levels, solving specific grid issues and enabling the integration of VRE. Additionally, by stacking multiple services, BESS system operators can maximize both VRE integration and financial streams. BESS can provide at least? 13 different services to the electricity system

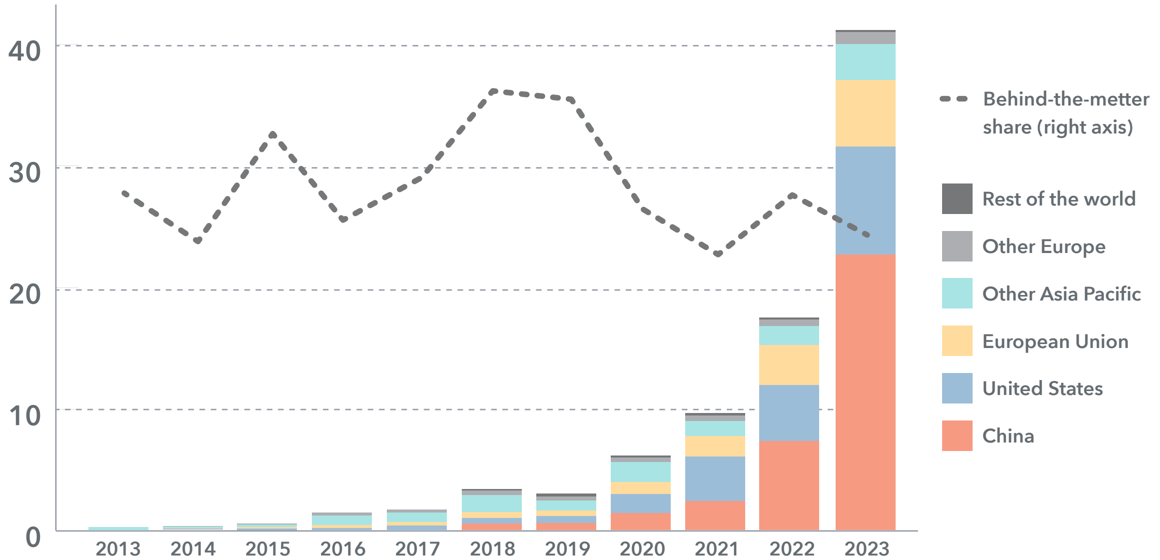


Figure 6. Battery storage capacity additions worldwide have increased disproportionately in China, the European Union, and the United States. Emerging economies remain behind in BESS deployment. Source: IEA 2024a

depending on their location (Fitzgerald et al. 2015). Behind-the-meter batteries mainly benefit customers, while front-of-meter systems can provide benefits for utilities, independent system operators, and regional transmission operators (**Figure 7**).

A range of services that can provide relief at operation, transmission, and distribution levels include (Fitzgerald et al. 2015; Greening the Grid n.d.[b]):

- **Energy arbitrage:** Purchase of energy when the price is low and selling of energy to the wholesale market when price is high due to fluctuations in energy demand.
- **Frequency regulation:** One of the most common services for batteries, frequency regulation helps maintain the frequency of the grid at any predefined frequency in a given jurisdiction to maintain system stability.
- **Spin and non-spin reserves:** Considered to be a set of ancillary services to quickly respond to disruptions in the system, such as sudden change in demand, this service is particularly useful in areas with a high penetration of VRE (EIA 2021).
- **Voltage support:** Service of providing reactive power to the grid to maintain acceptable voltage levels.
- **Black start:** BESS helps to black start without having to rely on emergency generators, which can lead to fuel and maintenance savings.
- **Resource adequacy:** Storage of excess power and release during times of high demand, helping prevent outages.
- **Transmission and distribution upgrades deferral:** Deferral of necessary upgrades by meeting rising peak demand with energy stored during the low-demand periods and released during high-demand periods.
- **Transmission congestion relief:** By storing the excess energy during low-demand periods, BESS reduce the stress on the network infrastructure and improves the asset utilization (**Figure 8**).

The aforementioned services are delivered at different timescales and may have different durations, which means that it is possible to provide multiple services with one BESS project, also known as value-stacking. Value-stacking can improve the utilization of the asset and project economics by ensuring that the operator receives compensation for multiple services (Chernyakhovskiy et al. 2021). Multiple income streams make projects more attractive for private sector participation and incentivize investment. To enable value-stacking, the asset operator should ensure that proper communication and control equipment is in place and that the business model and regulatory climate allows for this type of BESS utilization (Greening the Grid n.d.[b]). Value-stacking is also an economically driven decision; therefore, it is important to prioritize certain services to avoid fast degradation of the asset.

While there are a range of services that battery energy storage can provide, the lack of financial incentives or functioning energy markets may hinder their realization. To assess the viability of battery energy storage in newly established markets, pilot projects can inform potential benefits as well as challenges. This can help ensure that future large-scale battery storage projects are able to effectively provide services to the grid.

It is important to note that battery storage is one option in a wide range of technologies that can support a power system's flexibility and reliability. It is not appropriate for every solution and should be evaluated both from a technological and economic perspective to achieve the most cost-effective solution for the specific system needs (Chernyakhovskiy et al. 2021).

The next section of this report presents case studies that explore the enabling environments, financing structures, and key market opportunities to help overcome critical barriers to BESS deployment around the world, especially in emerging economies. Insights from this report will guide the Supercharging Battery Storage Initiative in advancing its three pillars and can further the development of BESS regulations, policies, and pathways for technology adoption both at the utility and mini-grid scales. Additionally, it illustrates valuable lessons for other emerging economies who are planning to deploy BESS.

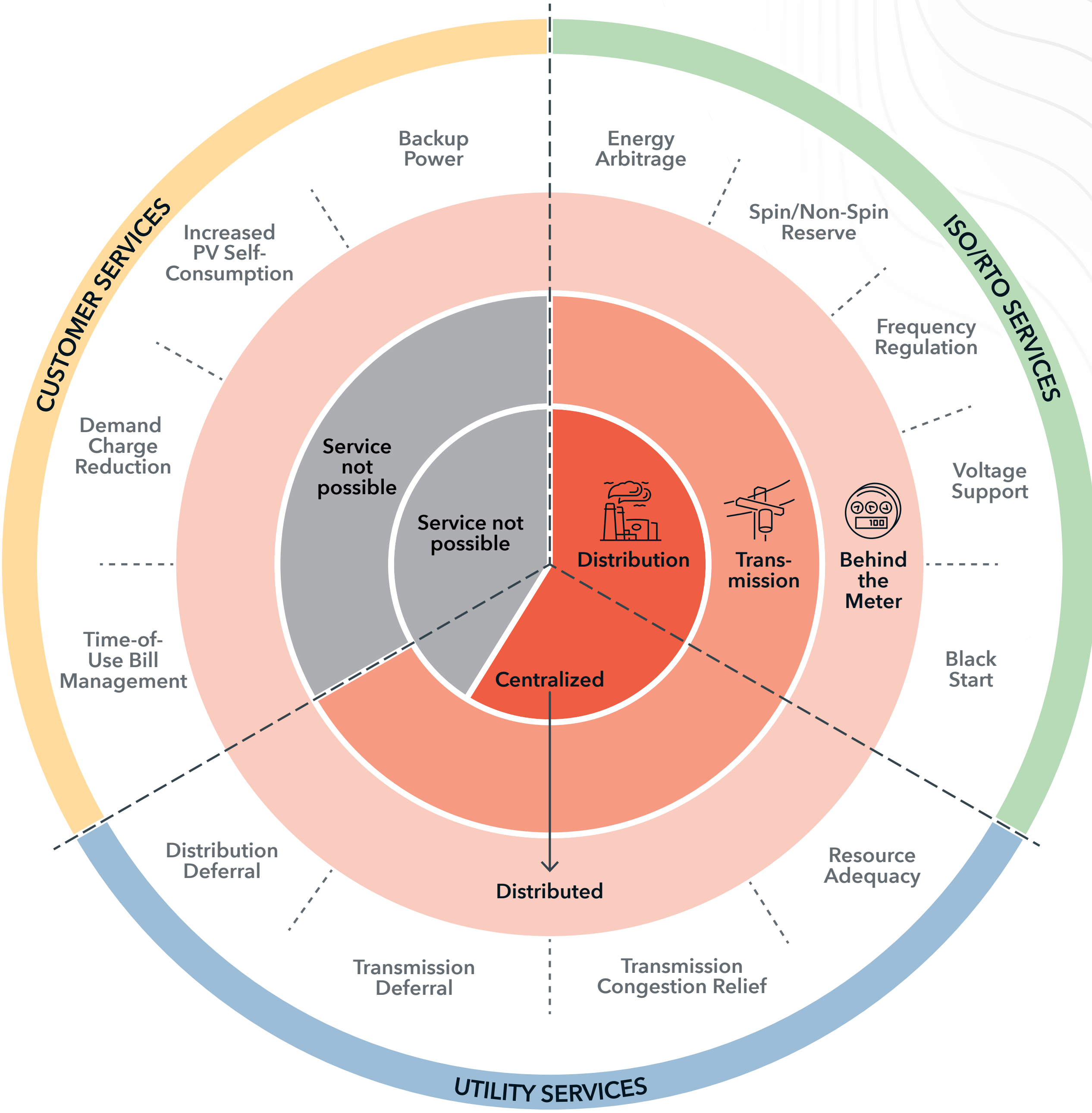


Figure 7. Energy storage services benefit several stakeholders, including system and transmission operators, utilities, and consumers. Source: Fitzgerald et al. (2015)

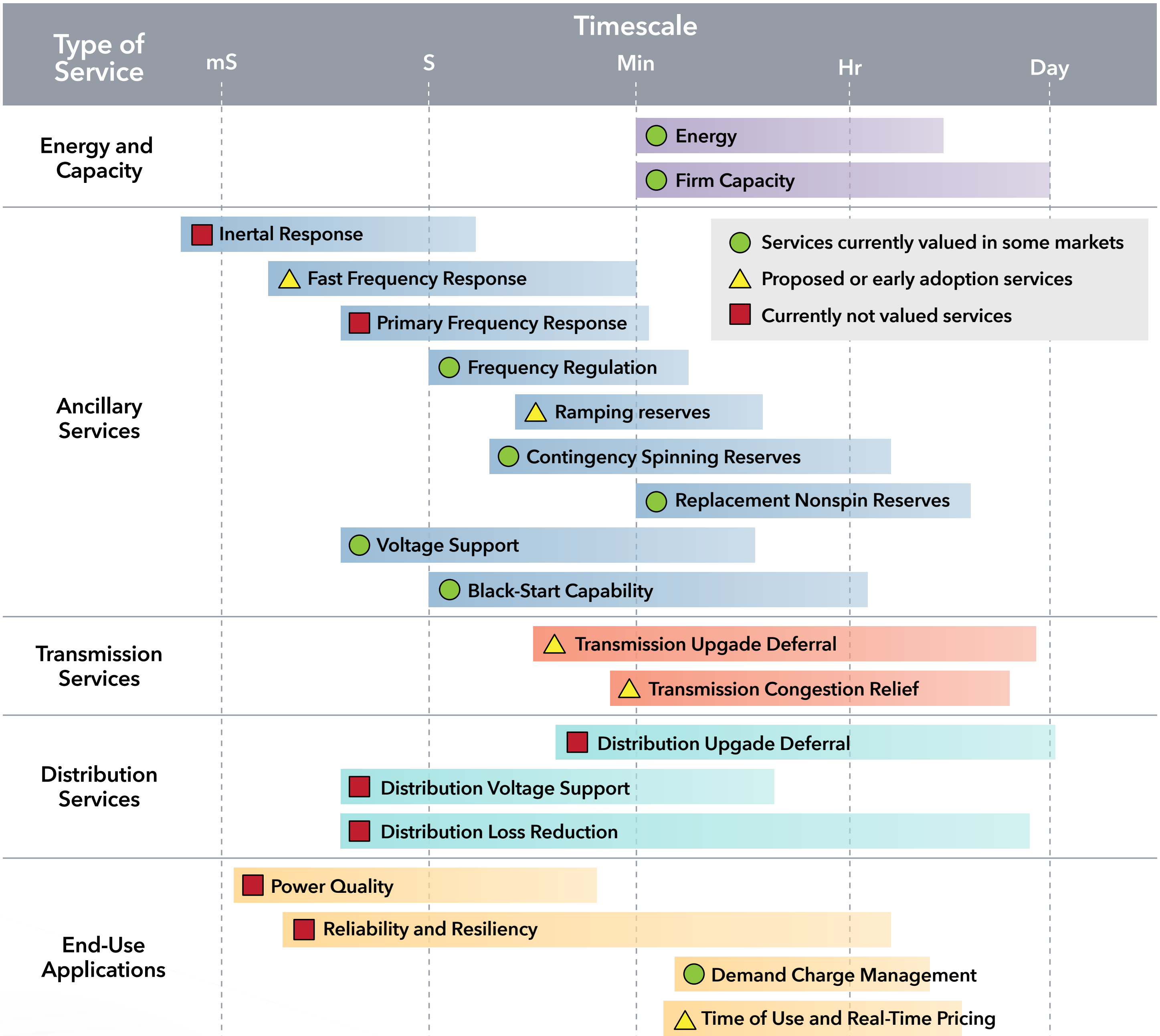


Figure 8. The timescale of different types of services provided by BESS. Source: Greening the Grid (n.d.)

ACCELERATING GLOBAL BESS DEPLOYMENT:

Case Studies From Emerging Economies

India

Regulatory Reform and Investment Support: A First-of-its-Kind Project for India

Contributors: RMI; Global Energy Alliance for People and Planet (GEAPP)

Features

- Enabling Environment
- Policies and market conditions
- Technical assistance
- Dynamic state funding
- Concessional loan programs
- 20-MW/40-MWh BESS.

Summary

To meet India's need for clean power, BSES Rajdhani Power Limited (BRPL), New Delhi's utility, has developed a BESS project (20-MW/40-MWh BESS) supported by GEAPP, in collaboration with IndiGrid (an Indian power sector infrastructure investment trust) and AmpereHour Energy. This system is the first commercial stand-alone BESS project at the distribution level in India to receive regulatory approval for a capacity tariff. It will also be the largest of its kind in South Asia at its commercial operation date.

The project should enable the uptake of low-cost VRE by BRPL by charging during hours when solar/wind are producing the most energy and discharging during peak consumption hours, replacing expensive gas and thermal-based electricity previously used during these times. Located at a high-demand substation (33/11 kVA) in Kilokri, South Delhi, the project should also improve the power quality and reliability for over 100,000 consumers in the substation area and enable 24/7 reliable power.

In parallel to this pilot BESS project, RMI has collaborated with a diverse set of electricity sector stakeholders to establish a set of regulatory and policy recommendations that will help to maximize the system value of BESS assets. RMI is actively engaging with regulatory entities in India on these recommendations to create an enabling environment for BESS, and to ensure distribution company readiness for integration of high volumes of BESS.

Background

India's power sector has undergone significant developments over the past decade. Rapid demand growth driven by advancements in electricity access and economic growth, as well as high volumes of VRE deployment, have put significant stress on India's grid. The demand for electricity is projected to reach nearly 2,474 TWh by 2031–32, an increase of more than 79% from 2021–22, and peak demand is anticipated to grow at a similar pace, exceeding 366 GW in Fiscal Year 2031–32 (Government of India 2022).

To meet its growing demand for energy and contribute to the global clean energy transition, India has set a goal to achieve 50% nontraditional fuel generation capacity installed by 2030. The Central Electricity Authority projects that 42 GW of BESS will be required to facilitate the integration of 100 GW of wind and 292 GW of solar by 2030 and contribute to reaching this goal (CEA 2023).

The Government of India has taken several policy steps laying the groundwork for an enabling environment for the energy storage needed to meet their VRE targets. The 2022 Electricity (Amendment) Rules granted legal status to energy storage projects, making storage a delicensed activity similar to generators (Ministry of Power 2022).[1] The Government of India has also implemented several policy provisions for energy storage, including waiving interstate transmission system charges for BESS commissioned through June 2025.

1. The Electricity Act 2003 delicensed generation (i.e., removed the requirement of obtaining a license for setting up a generation asset), which opened up the generation sector to private investment and competition. Similarly, energy storage has now been delicensed, allowing independent energy storage developers to set up BESS assets.

Under this existing policy framework, there are several economic incentives that enable BESS deployment. Energy arbitrage, tertiary reserve ancillary services,[2] and capital expense deferral are either partially or fully monetizable, which provides market incentives for BESS developers. In addition, wholesale markets currently accessible to BESS in India include similar incentives like tertiary reserve ancillary services and arbitrage in the day-ahead market, high-price day-ahead market, and real-time markets. These market conditions lay a strong foundation for BESS deployment and replicate some of the critical lessons learned from other economies and contexts.

However, other value streams are unclear. For example, the clearing price and participation process for the secondary reserve ancillary services market are not yet fully defined. Uncertainty around quantifying value streams has also hindered project planning and deployment. As a result, multiple solicitations that were released in 2022 (with a total quantum of over 1,200 MWh[3]) have been cancelled due to lack of viability or have seen significant delays between award and signing of agreement due to lack of sufficient regulatory framework.

Supporting policy adoption

As India looks to improve some of the conditions in its enabling environment, ongoing support and resources will be integral to supporting the adoption of policies and market conditions. As part of the BESS project, GEAPP, with RMI, published *Powering Progress: Batteries for Discoms*. In this report, RMI identified the market opportunity for BESS within India's distribution sector, including benefits for capacity expansion deferral, reducing deviation risks, and providing balancing support. RMI also assessed the current wholesale market values of BESS projects participating in energy arbitrage and ancillary service markets. The report reaffirmed the value of BESS in supporting renewable integration and load growth so that utilities, policymakers, and regulators can replicate conditions in the case-studied pilot project and scale adoption (Bertagnini et al. 2023).

Indian stakeholders can draw upon key lessons learned from the report, including the conditions and criteria for successful BESS deployment for distribution companies, the value of monetizable BESS applications under the existing policy and regulatory framework, and estimations of the existing value gap. In close collaboration with a set of regulatory and utility experts, RMI has also developed a policy brief that outlines the regulatory and policy reforms that regulatory entities may undertake to foster reliable revenue streams, facilitate the identification of innovative technological assets, and streamline project development approval processes. RMI has engaged directly with the Central Electricity Authority, Central Electricity Regulatory Commission, and the Forum of Regulators on proposed policy and regulatory enablers. Resources like these will continue to support India in finding and selecting solutions that are replicable and scalable for contexts within the country.

While the enabling environment for BESS remains challenging, the Government of India has made some important commitments to cover existing financing gaps to facilitate large-scale BESS deployment. As part of India's Union Budget for 2023–24, India announced Viability Gap[4] Funding (Government of India 2023). With a budgetary allocation of INR 37.6 billion (USD 450 million), the funding aims to cover 40% of the capital costs for 4 GWh of stand-alone BESS projects. This represents a critical next phase to operationalize the policy and market frameworks in India by building institutional knowledge and capacity and accelerating the adoption and enforcement of regulation for state-level entities, distribution companies, state electricity regulatory commissions, and state load dispatch centers.

Enhancing Project Bankability

BRPL faces severe challenges in managing its peak load and in ramping up supply during non-solar and non-wind hours, causing the utility to rely on expensive gas and high-cost power from the wholesale market to meet its peak demand and universal supply obligations. Previously, BRPL had submitted a BESS project proposal for regulatory approval in 2020 but was rejected due to high costs and a lack of sufficient monetizable value

2. Note: Tertiary Reserve Ancillary Services (or operating reserves, spinning/non-spinning reserves) are the only ancillary service product procured through a market mechanism in India. Operators are required to restore the grid frequency to 50 Hz during large grid disturbance events and must respond within 15 minutes of the dispatch instructions from the system operator and sustain service for 60 minutes (similar to spin/non-spin ancillary services in other international markets) to replenish the secondary reserve resources that were deployed for the first 15 minutes of the event.

3. Note: 1,260 MWh–NTPC (Power Generation Company) 10 MW/40 MWh tender, KSEB (Kerala State Electricity Board Limited) 10 MW/20 MWh tender, GUVNL (Power Company in Gujarat, India) 500 MW/1,000 MWh tender, UPPCL (Uttar Pradesh Power Corporation) 5 x 10 MW/ 40 MWh tender.

4. Viability gap: The difference between the tariff of BESS and the estimated benefits the BESS would provide. For a battery storage project, benefits may include revenue realized from energy arbitrage, participation in ancillary services markets, or deferred investments in transmission or distribution infrastructure. The benefits need to be estimated using a production cost model that considers the demand pattern and the power procurement options of the utility. If the levelized cost of BESS plus the charging cost is higher than the utility's cost of peak power purchase, then a viability gap is present.

streams. To address the issues with demand and value streams, the GEAPP-supported BESS project was designed to benefit from an energy arbitrage opportunity in which the utility can charge BESS during low-cost solar and wind hours and dispatch energy during its morning and evening peak hours.

In 2023, GEAPP provided technical assistance to BRPL for project development activities, including regulatory analysis of BESS use cases, energy and system modeling, techno-commercial business model development, regulatory submissions, auction design, and financial closure. The initiative was designed in collaboration with BRPL, and the project was awarded through a public bid in October 2023.[5] The winning bidder, a consortium of IndiGrid and Amperehour Energy, will install the 20-MW/40-MWh BESS at BRPL's 33/11-kV Kilokri substation in New Delhi. To facilitate the deployment of the system, GEAPP provided a highly concessional loan amounting to 70% of the total project cost (at 1% cost of debt) to the developer, which helped the project achieve a record low tariff.

IndiGrid and Amperehour Energy's winning BESS project is a 2-hour system (0.5 C) capable of operating a maximum of two cycles per day. The project has a lifespan of 12 years, with a maximum annual degradation in dispatchable energy throughput of 2.5%, ensuring a minimum of 70% capacity by the end of its life. The required round-trip efficiency ranges from 85% in the first year to 82% in the twelfth year, and the system must maintain a minimum annual availability of 95%. The responsibility for charging and discharging power to and from the project will lie with BRPL.

In May 2024, the Delhi Electricity Regulatory Commission granted regulatory approval to the project, making it India's first commercial stand-alone BESS project to receive approval. The developer will be paid a fixed-capacity tariff (INR 57.6 lakh/MW/year or USD 69,000/MW/year) by BRPL, subject to availability. This tariff is approximately 55% lower than the previous Indian benchmark discovered in the SECI 500 MW/1,000 MWh tender (INR 130 lakh/MW/year) because of the drop in technology prices and overall changes in market conditions. Furthermore, it is more cost-effective than the equivalent capacity lease price for independent energy storage systems in China, which is set at 300 CNY/kWh (~USD 83,000 per MW per year for a 2-hour storage system). The project is on track to be the fastest BESS project to be commissioned in India, with a record time of 18–20 months from conceptualization to implementation (The Economic Times 2024).

5. In India, once the bidder is awarded, a petition is filed to the regulator for the approval of the tariff.

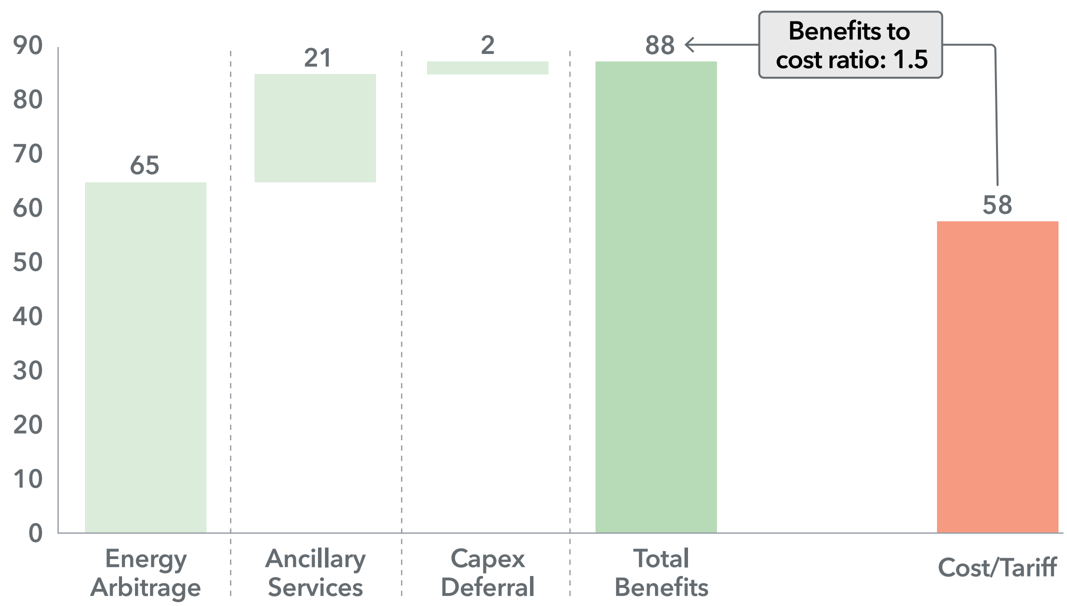


Figure 9. Projected benefit stack vs. tariff (INR Lakh/MW/year) (Bertagnini et al. 2023).

Impact

While the project has a number of significant impacts for Indian stakeholders, one of the clearest is the impact of power reliability and stability for consumers. Located at a high-demand substation, the project is expected to improve the power quality and enable 24/7 reliable power in the area for over 100,000 low-income consumers.

Additionally, the financial implications of the project solve some key issues related to current energy market conditions in India. Due to concessional financing provided by GEAPP, the project was able to realize a projected benefit stack[6] that exceeds the tariff[7], ensuring affordability (see **Figure 4**). As the Regulator enables more revenue streams such as secondary reserve ancillary services and resource adequacy the value provided by the project should increase further.

BRPL and GEAPP have committed to sharing the results of the BESS pilot project with other distribution companies, state regulators, and power sector stakeholders, both domestically and internationally, to facilitate knowledge-sharing, capacity-building, and replicability and scalability of the model. As the first BESS project to receive regulatory approval in India, the project has set a precedent for other state regulators who are evaluating BESS projects. Lessons learned from the project will contribute to the existing technical knowledge base for the BESS Consortium, a multi-stakeholder partnership of countries and resource partners to expand BESS capacity in low- and middle-income countries by the GEAPP Leadership Council.

The success of the BRPL and GEAPP project has encouraged regulators and distribution companies to move forward with their own BESS projects, aiming to accumulate operational experience. Simultaneously, ongoing policy and regulatory reforms, alongside declining BESS prices, are setting the stage for a sustainable BESS market in the future. As BESS conditions in India continue to evolve, GEAPP plans to continue to work with several distribution utilities to develop a 1-GW BESS pipeline by 2026–27 through technical assistance studies and concessional financing (in select cases).

Key Insights

The project provided several key insights that are critical to BESS deployment in India and globally:

- **Value-stacking is crucial for revenue maximization:** Robust benefit analysis through detailed energy modeling and value-stacking is required to maximize the potential revenues of the proposed project.
- **Regulator involvement in the early stage is key:** Engaging regulators throughout the project, both in the development phase and before the tendering process, can lead to better project alignment with regulations and a smoother tariff approval process
- **Dynamic state funding encourages BESS project deployment:** The Viability Gap Funding launched by India covers 40% of the capital costs for 4 GWh of stand-alone BESS projects. Dynamic and aggressive funding mechanisms such as this increase developer confidence and encourage large-scale BESS deployment.

India's goals for VRE deployment are ambitious and will likely need to be coupled with accelerated BESS and energy storage deployment. BRPL and GEAPP's project, as well as RMI's project, highlight a new pathway and mechanism to regulatory approval for BESS in India and has laid the foundation for additional projects using these mechanisms.

Additionally, this model has proven itself effective for scaling, and GEAPP is currently working on similar projects in Vietnam and Malawi. GEAPP's collaboration with the Ministry of Industry and Trade of Vietnam focuses on the integration of renewable energy into the national grid. At a technical workshop co-hosted by the Ministry of Industry and Trade's Electricity and Renewable Energy Authority and GEAPP in June 2024, the Ministry, GEAPP, and the Institute of Energy launched a report titled Enhancing Vietnam's Grid Stability with BESS. The report analyzes the use of BESS to improve frequency stability amid rising renewable energy sources and proposes suitable BESS scales for the system. It supports Vietnam's Power Development Plan VIII, which targets 300 MW of BESS by 2030, recognizing their benefits such as peak shifting

6. The benefits were estimated using the utility's 15-minute demand and supply data for Fiscal Year 2023 and then projected for the next 12 years. Production cost simulations were run with and without the proposed BESS to estimate the system cost savings from the various revenue stream options applicable to the project.

7. The fixed-capacity tariff of Rs 57.6 lakh/MW/yr discovered during competitive bidding and approved by the regulator.

and renewable energy integration. With costs dropping by 40%–50%, BESS are attracting significant investment and are essential for Vietnam's net-zero commitment, sustainable growth, green job creation, and preventing electricity tariff hikes. This initiative underscores GEAPP's commitment to sustainable energy solutions and strengthening Vietnam's energy infrastructure.

In Malawi, GEAPP is supporting the Electricity Supply Corporation of Malawi to design, procure, install, and operate a 20-MW BESS for frequency management to stabilize the national grid. This system is expected to improve electricity access, enable increased uptake of VRE, and replace some peak-demand diesel generators. Furthermore, the system should generate accessible operations guidance and commercial BESS data for developers, utilities, regulators, and other BESS stakeholders to inform the development of further BESS projects. This project is also expected to contribute to the structure of enabling regulatory and tariff tools for grid battery services in Malawi and across the region. ■

Renewables in Latin America and the Caribbean (RELAC)

Together Toward A Clean Energy Future: Energy Storage in Latin America

Contributor: NREL

Features

- Enabling Environment
- Storage modeling and analysis
- Technical assistance
- Regional approach.

Summary

The Renewables in Latin America and the Caribbean (RELAC) initiative was launched during the United Nations Climate Action Summit in 2019. The initiative unites 16 member countries (Guatemala, Honduras, Haiti, Dominican Republic, El Salvador, Nicaragua, Costa Rica, Ecuador, Peru, Colombia, Bolivia, Barbados, Panama, Chile, Paraguay, and Uruguay) around a common goal to achieve a minimum of 70% renewable energy installed capacity and ensure that 80% of the region's total electricity generation comes from renewables by 2030. To support the countries in their goals, RELAC provides technical, matchmaking, and knowledge exchange assistance.

The RELAC initiative launched the Accelerated Deployment of Energy Storage in RELAC Countries series to help countries build capacity for integrating the levels of energy storage needed to support the 80% renewable energy target (Bilich et al. 2024). Through workshops, in-person trainings, and technical support, the RELAC initiative has helped countries to build their technical awareness for energy storage, estimate their energy storage needs, model storage integration, and assess regulatory gaps and potential improvements. This initial project has helped mobilize additional support for improved regulatory frameworks and BESS planning, operation, and deployment across the region.

Background

NREL, in partnership with the Global Climate Action Partnership and the Inter-American Development Bank, initiated the Accelerated Deployment of Battery Storage in RELAC Countries program to assist in the development of country-specific energy storage action plans for RELAC countries. The objectives of the program were to:

- Improve the technical knowledge for planning, operation, and deployment of BESS
- Assist in the acceleration of the development and execution of storage projects across the region
- Strengthen the network of regional stakeholders for knowledge-sharing.

These objectives drove toward an overall goal to promote investment and policy measures that are expected to expedite the deployment of energy storage throughout the region. To accomplish this, partners held an energy storage workshop series to train stakeholders on technical BESS topics, an NREL site visit to deepen expert engagement and provide hands-on learning with cutting-edge technology, and provided technical assistance support for battery storage deployment through country-driven action plans.

NREL's technical assistance included developing energy storage needs modeling and estimates, BESS integration modeling, capacity-building for mini-grid modeling, and regulatory framework support. To assess energy storage needs, NREL utilized its Storage Deployment Optimization Model (SDOM)[1] to evaluate the potential need for integrating short-duration, long-duration, and seasonal storage capacities to support ambitious renewable energy integration targets in three countries: Peru, Uruguay, and El Salvador. This analysis highlighted potential needs of over 15 GW of storage across these three countries to meet renewable energy goals in 2050. Furthermore, NREL used the open-source SIENNA modeling platform[2] to conduct power simulations and identify sites for BESS deployment in Costa Rica, Ecuador, and Honduras. These simulations are working to support specific projects totaling 300+ MW of BESS storage. Additionally, experts supported evaluations for country grid codes related to BESS integration and

1. The NREL SDOM GitHub is available at: https://github.com/NREL/SDOM.

2. NREL's Sienna platform is available at: https://www.nrel.gov/analysis/sienna.html.

helped support specific procurement processes or other regulatory frameworks based on individual country plans. All of this has helped advance country pipelines and enabling environment for energy storage deployment.

The Role of Capacity-Building

The first phase of the RELAC initiative provided capacity-building support for 96 policymakers and stakeholders across RELAC countries on energy storage topics including technical standards and regulatory issues, integrating energy storage into national planning, storage regulations, modeling, value-stacking, and more. The RELAC initiative also helped countries utilize NREL's Readiness Framework for Energy Storage[3] to evaluate potential for energy storage.

Following the initial capacity-building, NREL convened participants across 11 countries for additional peer-learning on energy storage as well as the development of specific energy storage action plans for their individual countries. These action plans highlighted several common focus areas across the countries, including amending grid codes to better support energy storage, techno-economic assessments, modeling energy storage integration into national grids, capacity-building for evaluating energy storage in national energy planning, and support for procurement and request for proposal processes for energy storage.

Technical assistance was then provided by NREL technical experts focused on direct energy storage modeling and analysis support (including capacity-building for modeling platforms) or regulatory enabling conditions for energy storage, based on each country's needs as identified in their action plans.

Using Sienna or SDOM, modeling efforts focused on estimating key storage needs and identifying grid locations for potential investment, as well as convening country stakeholders around common data and models. Modeling support was initially provided to Peru, Uruguay, and El Salvador for SDOM and Costa Rica, Honduras, Ecuador, and the Dominican Republic for Sienna.

Technical assistance for improving regulatory frameworks varied significantly country to country but included accompaniment for the governments of Barbados, Honduras, the Dominican Republic, and Panama in the design, publication, or review of requests for proposals and other procurement and compensation mechanisms for energy storage. Additionally, the project developed in-depth reviews for refining national grid codes for distributed energy resources (including BESS) in El Salvador, Peru, and Ecuador. This work focused on comparing the country's existing regulatory frameworks with best practice standards like Institute of Electrical and Electronics Engineers 2800-2022 and 1547-2018 as well as building capacity for Ministries of Energy in line with the international standards.

Impact

The workshop series, site visit, and technical assistance provided by the RELAC initiative helped catalyze the support for further regulatory support projects for BESS implementation. The action plans became a foundation for technical assistance as well as for crowdfunding support from other partners, including the CEM's Clean Energy Solutions Center, Inter-American Development Bank, and U.S. Agency for International Development. Most notably, RELAC, in collaboration with GEAPP, catalyzed expanded technical assistance for development of energy storage project pipelines in the Dominican Republic, Honduras, Barbados, Brazil, and Uruguay, as well as the development of regional "Centers of Excellence" for knowledge- and innovation-sharing. All of this has significantly strengthened the enabling environment for energy storage in the RELAC countries, providing a strong foundation for accelerated deployment.

Key Insights

- Regional approaches can help accelerate learning and replication and allow for more coordinated technical assistance. RELAC was able to bring together countries at varying stages of energy storage work, which allowed for effective peer-to-peer learning and ongoing collaboration in the region. Further, the regional approach allows for better knowledge management and innovation-sharing as well as an easier pathway for financial partners to engage on energy storage projects in the region.
- Many countries that are in early stages of energy storage need similar support. Countries across the RELAC initiative often needed similar structured support for aspects like country grid codes and broader assessments of the enabling environment. This highlights an important need for guidance or framework resources like the NREL Readiness Framework for Energy Storage used for RELAC to help accelerate countries to a point at which more focused support or investment can be provided.

3. Available at: https://www.nrel.gov/docs/fy21osti/78197.pdf.

- Key need for coordination between entities within a given country. The modeling support provided under the RELAC initiative highlighted that, often different parties within a country (e.g., regulator, ministry, utility, and system operator) are utilizing different modeling platforms or inputs, which can lead to difficulties in coordinating planning for energy storage. Therefore, a key consideration for enabling the environment for energy storage is helping to align stakeholders and models to utilize common frameworks and inputs.

In their pursuit of a common 80% renewable energy by 2030 target, the RELAC countries recognized that other technologies, such as BESS, would be necessary to support the accelerated deployment of VRE. The RELAC initiative's approach to capacity-building for BESS laid a strong foundation for RELAC countries to develop enabling environments for energy storage and pursue avenues for additional support to deploy BESS technologies. As these countries continue to pursue their goal, this enabling environment will likely be essential to ensure that technologies that enhance grid flexibility and stability, such as BESS, are not a limiting factor for clean energy scale-up.

Small Island Developing States (SIDS)

The Role of Battery Storage in Island Power Systems: Insights From the Grid

Contributor: International Renewable Energy Agency (IRENA)

Features

- Enabling Environment
- Grid integration studies
- PV curtailment
- Reduced reliance on imported fuels
- Voltage support and grid stability provisions
- 6-MW/10.2-MWh and 2-MW/3.4-MWh BESS.

Summary

IRENA conducts technical grid integration studies to support small island developing states (SIDS) in planning for the technical challenges associated with integrating high shares of VRE. To date, IRENA has completed seven grid assessments for SIDS (Palau, Antigua, Aitutaki, Samoa, Vanuatu, Fiji, and the Dominican Republic). These studies identify the technical constraints associated with integrating levels of VRE needed to meet each country's goals and the possibilities to overcome potential problems with grid stability and reliability through BESS.

Background

Grid assessment studies evaluate the security of a power system through static and dynamic security analysis for future generation and demand scenarios. The objective of grid assessment studies is to assess whether the power system can accommodate growing amounts of VRE and to identify barriers for the integration of VRE. This case study focuses on the results and insights of the grid assessment studies of four SIDS: Samoa, the Republic of Fiji, the Dominican Republic, and Vanuatu.

Each of these countries face unique issues associated with their energy systems, as highlighted below.

Fiji: Hydropower plays a significant role in the power generation mix for Fiji. In 2017 on Viti Levu, Fiji's largest and most populous island, hydro represented 130 MW of power generation, while diesel accounted for 100 MW and wind for 10 MW. Demand during peak hours on the island amounted to 160 MW. Solar resources have not yet been introduced to the island, so stakeholders were focused on increasing the share of solar photovoltaics (PV) to support the implementation of Fiji's NDC (IRENA 2020c).

Dominican Republic: The Dominican Republic's power system uses mainly natural gas, coal, and petroleum-based fuels (IRENA 2020a). The total generation capacity installed at the end of 2017, when this study began, was around 5,131 MW. Of the installed capacity, 77.72% was thermal generation and 22.28% was in the form of renewable sources. Of net generation, 32.2% was from fuel oil, 23.5% from natural gas, 19.7% from coal, and 5.6% from hydropower. Solar and wind have been growing rapidly, doubling their generation contributions between 2017 and 2018 to reach 4%, and are expected to keep growing rapidly in the coming years. Maximum energy demand was 59.7 GWh, and hourly maximum generation was 2 769 MW. IRENA's analysis indicates the potential for integration of renewable energy to achieve renewable energy targets, if the necessary grid upgrades, including the deployment of BESS, are considered.

Vanuatu: As of 2018, the generation capacity in Luganville, a city on Vanuatu's Espiritu Santo Island, was 1.2 MW of hydropower, 40 kW of solar PV, and 4.5 MW diesel. The annual load of the Luganville power stations in 2018 was estimated to be 10.7 GWh, and the additional load from the Port Olry grid extension is expected to be 0.34 GWh. The 71% of peak demand, or 1.6 MW, is supplied by diesel generators (IRENA 2020b), which significantly drive up the cost of energy and make Vanuatu vulnerable to fluctuating costs in international diesel markets. IRENA's study analyzes the options to increase the use of renewables through expansion of hydro and solar power.

Samoa: As of 2014, when the study began, the peak demand on Upolu Island in Samoa reached approximately 20 MW. At that time, the generation comprised 29.8 MW of diesel/gas, 8.5 MW of hydropower, 2.9 MW of solar PV, and 0.5 MW of wind. To meet the increasing energy demand on the island, IRENA considered the island's significant solar potential, which can help meet 60% of peak load.

While these four SIDS have unique challenges associated with their current power generation matrix, they all hold similarities in the constraints, typically associated with SIDS: smaller size of the island systems, lesser synchronous units and therefore lesser inertia provision, aging infrastructure, the susceptibility to extreme events, the stability issue arising out of increased shares of variable renewables, etc. Solutions must also take into consideration small domestic markets and heavy dependence on a few external and remote markets, little resilience to natural disasters, and fragile natural environments to be able to adequately address these unique challenges in a reliable and cost-effective way. Given these constraints, a BESS was identified as a viable solution to enhance power system stability, reliability, and flexibility; reduce GHG emissions from the power sector; and support VRE integration in these four SIDS, despite the differences in the countries' current generation matrices.

From Research to Regulation

Grid integration studies are an instrumental step for many countries in determining opportunities and next steps for the integration of VRE. Through these studies, IRENA evaluates different scenarios of renewable energy penetration to identify technical constraints in the power system to the addition of VRE. For many countries, solutions for easing the constraints associated with VRE deployment include BESS. Particularly for islanded systems, where there may be a single medium-sized grid or several mini-grids with no interconnection, BESS can provide grid-supporting functionalities needed to enable increased penetration of VRE.

IRENA's grid integration studies for Samoa, Fiji (IRENA 2020c), the Dominican Republic (IRENA 2020a), and Vanuatu (IRENA 2020b) highlight the ways in which BESS can be used to ease the challenges associated with VRE deployment in SIDS:

For the island of Upolu in Samoa, IRENA's study estimated that solar PV generation can cover upward of 60% of the peak load. The grid stability assessment considered a 24-MW wind park, a 10-MW pumped hydro storage system, and 8 MW of biogas, ultimately determining that VRE deployment could feasibly meet Samoa's peak load needs. Still, the study proposed several recommendations for smoother power system operation, specifically, using batteries for continuous and fast frequency control, frequency regulation, provision of reserves, and grid-supporting functionalities from VRE generation. IRENA recommended that batteries above 1-MW capacity have an interface to receive commands to adapt their output power, allowing them to quickly respond to changes in demand. As a result, two battery banks were installed: a 6-MW/10.2-MWh bank at a diesel power station and a 2-MW/3.4-MWh battery at the international airport, which was colocated with a 7-MW solar power plant. By installing these systems, Upolu is providing grid support, maintaining power quality, and reducing the use of diesel generators (Electric Power Corporation 2018). These systems ease the challenges associated with deploying VRE on the island and lay a foundation for further VRE deployment both in Upolu and across Samoa's other islands through scaling and replication.

In Fiji, the IRENA study evaluated the inclusion of VRE on the island of Viti Levu, the largest and most populous island and the site of the nation's capital, Suva. The system-level study showed that, to supplement Viti Levu's current hydropower generation, a realistic scenario of 25 MW of utility-scale PV with up to 40 MW of distributed PV could meet 40% of the island's peak demand. While this is a conservative approach, this value could be further improved with future grid reinforcements to ensure that PV systems do not overload the grid and cause instability. A BESS was recommended as a key solution to reduce PV curtailment in this initial stage, ensuring that energy generated is retained by batteries and discharged at peak times. At both utility-scale and distributed levels, a BESS, along with rooftop solar PV, was considered to provide a robust strategy for integrating VRE while maintaining power system reliability.

For the Dominican Republic, IRENA transmission system studies revealed that VRE integration could lead to frequency stability, congestion, and voltage problems in some instances. Through the study, IRENA recommended that the island use BESS to provide primary frequency support and, over time, add batteries with a larger capacity to avoid reaching the maximum energy capacity for generators and activating the under-frequency load-shedding scheme at the tripping of a generator, thus releasing energy generated. For the Dominican Republic, integration of BESS can assist with capturing excess energy to prevent reaching the stage at which load-shedding is necessary, thus retaining valuable energy generated through VRE and discharging it during peak times. This is especially relevant during low-demand scenarios, when fewer synchronous generation units are in service; given the Dominican Republic's energy generation mix is largely made up of fossil fuels, BESS provide an opportunity to meet peak demand while also reducing reliance on imported fossil fuel generation sources. Since the location of batteries does not impact frequency stability, the battery capacity can also be distributed throughout the system to ensure consistency throughout the power system. Large battery capacities were recommended to perform the role of virtual power lines to resolve congestion issues and ease power system operators in distributing energy according to demand.

The technical assessment of the Luganville grid in Vanuatu included a scenario with 1.9 MW of new hydropower and the integration of 2–8 MW of solar PV. The study evaluated different options for incorporating these VRE sources, including lowest long-term energy cost, highest possible renewable scenario, and a no major enablers scenario. The studies demonstrated that, when the share of wind and solar exceeds 30%, the investment in enabling solutions such as batteries is crucial for Luganville. BESS mitigate increased instability issues, reduce excessive wear and tear on diesel generators, and minimize curtailment. In the highest possible renewable penetration scenario, close to 100% VRE penetration could be achieved only through the deployment of large-scale BESS in addition to VRE sources. Battery deployment at specific locations was recommended to ensure the highest benefit to grid stability. For instance, IRENA recommended Luganville site BESS at the local diesel station to provide voltage support and primary frequency control. In other cases, it is best to site BESS at the renewable generation to provide better communication between charging and discharging systems. To provide additional stability, inverters associated with storage must be fully functioning and certified to new standards, including high-performance grid support. Achieving a zero-diesel operation, particularly with the inclusion of the hydropower plant scenario, would require at least a 1-MW battery (4–8-MWh for solar PV and hydro storage).

Across Samoa, Fiji, the Dominican Republic, and Vanuatu, BESS can help ease the unique challenges associated with integrating VRE. For islands with high levels of VRE penetration already, such as Fiji, BESS can stabilize the grid and ensure that energy can be discharged during peak load times. For others, such as the Dominican Republic and Vanuatu, BESS represent a viable solution to transitioning away from fossil fuel generation sources and ensuring that energy generated is also energy used, not released during load-shedding. But in all cases, BESS bolster the ability of these countries to integrate higher levels of VRE and meet their climate goals.

Impact

The studies have helped these four countries analyze their technical challenges, assess policy needs, and evaluate the feasibility of VRE and BESS while considering the security and reliability of the power system. All these aspects are important to consider when planning power system improvements to achieve renewable energy targets and ultimately each country's climate goals. BESS, both at utility-scale and distributed-scale applications, can offer system-wide benefits, such as frequency support, grid-strengthening, and operation-smoothing, especially with increasing shares of VRE and end-use electrification.

In moving from study to implementation, the proposed effects of BESS are clearest in the case of Samoa, where IRENA's grid integration study informed the deployment of a 6-MW/10.2-MWh battery bank and a 2-MW/3.4-MWh battery bank on the island of Upolu. Stakeholders in Upolu were able to examine the costs associated with the deployment of VRE and BESS and design systems and solutions that not only were cost-effective for energy generation in the country, but that enhanced the reliability of Upolu's power system. Particularly the 2-MW/3.4-MWh system co-sited with 7 MW of solar PV highlights the dual nature of VRE and energy storage—to have more of one, a country must have the other. Samoa's example represents how SIDS can move from grid integration study to implementation and consider the operation of their power system at the current stage to design a future system that meets their energy needs.

Key Insights

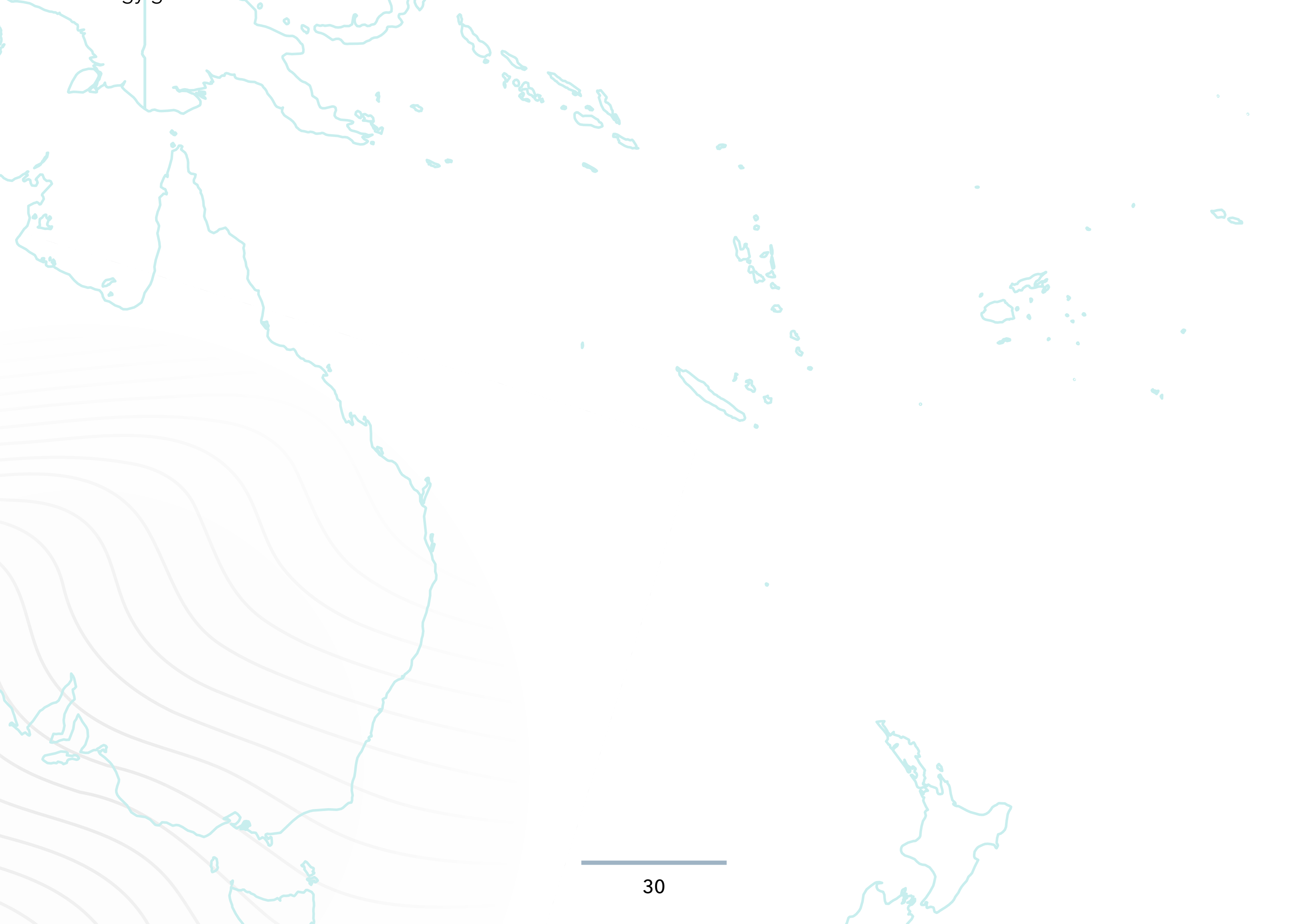
Considering the size and number of powers systems associated with SIDS, the impacts of BESS on the power system are heightened. Particularly in these small island contexts, some key insights include:

- **To have more VRE, a country must have BESS.** The IRENA studies indicate that BESS can smooth the operation of power systems with a high penetration of VRE through fast frequency control, provision of reserves, and grid support. Additionally, BESS is instrumental in reducing PV curtailment in the initial stages of VRE deployment to ensure that energy generation does not overload the grid.
- **New technologies can be cost-effective.** In addition to providing grid support and maintaining power quality, the studies show that BESS can significantly reduce the use of diesel generators to provide spinning reserves. Furthermore, when sited with VRE sources, BESS can reduce the reliance on imported fossil fuels for SIDS, this reducing their risk of fluctuating fuel prices on international markets.
- **PV is variable, but a BESS is not.** Rapid and large-scale VRE integration could lead to frequency stability problems, congestion, and voltage instability.

Especially for SIDS, many of which have abundant opportunity for PV deployment, BESS can provide a solution to these issues by maintaining the current needed for consistent delivery of energy, charging and discharging at peak hours, and mitigating the risk of tripping generators.

- **BESS can improve resilience against extreme events.** Both distributed and utility-scale battery energy storage can improve the resilience of the electrical grid by absorbing excess power and providing backup power during emergencies.

As the clean energy transition advances globally, reducing GHG emissions from the power sector is paramount. However, SIDS have never represented a significant contribution to GHG emissions globally. For these islands, the integration of VRE and BESS represents other opportunities to stabilize the grid, utilize natural resources in place of imported fuels, and contribute to energy access across islanded systems. While reduction in GHG emissions is also a benefit of this transition for SIDS, ultimately BESS represent an opportunity to change the operation of the power system and contribute to local energy generation. ■



Uzbekistan

Promoting Private Sector Engagement in Hybrid Renewables and BESS Projects

Contributor: World Bank Group

Features

- Enabling Environment
- Power sector reforms for private sector investment
- Risk mitigation packages
- Integrated sector planning
- 63-MW/126-MWh BESS.

Summary

The Uzbekistan Solar and Renewable Energy Storage Project is a significant milestone in Uzbekistan's clean energy transition. It involves the construction and operation of a 250-MW solar power plant and a 63-MW/126-MWh BESS in the Bukhara region (World Bank Group 2024a). The project is being implemented by Abu Dhabi Future Energy Company PJSC-Masdar, a global renewable energy developer, and is supported by an International Bank for Reconstruction and Development payment guarantee as part of the World Bank Group's support to the project. The project aims to increase private sector-led renewable energy supply in Uzbekistan, contributing to the country's ambitious goal of reaching 25 GW of renewable energy capacity by 2030.

Background

Uzbekistan's power system is heavily reliant on fossil fuels, particularly natural gas. The country is also vulnerable to climate change, with increasing risks of heatwaves, droughts, and flooding. The Government of Uzbekistan has recognized the need for a clean energy transition and has set ambitious targets for renewable energy development. However, the energy sector faces challenges for enabling the deployment, financing, and operations of renewable energy assets. To facilitate the penetration of high shares of renewables on the grid, the Government of Uzbekistan has pursued a strategy for mobilizing private sector investments by integrating renewables with energy storage as part of a single tendering process (World Bank, 2022). The power purchase agreement signed for the Uzbekistan Solar and Renewable Energy Storage project, for example, had two elements: one for energy generated ($/kWh), and another for storage capacity availability ($/kWac/hour), which represents a two-part contract under the World Bank's framework.

Enabling Utility-Scale Deployment

Several key factors contributed to the enabling environment that facilitated the implementation of the Uzbekistan Solar and Renewable Energy Storage project, and of BESS more generally. First, the Government of Uzbekistan has implemented significant energy sector reforms, including the establishment of a separate energy sector regulator, unbundling of the power transmission company, and tariff adjustments toward cost recovery. These reforms create a more favorable environment for private sector participation, especially for BESS.

The Uzbekistan Solar and Renewable Energy Storage project pioneers the introduction of utility-scale BESS in Central Asia, addressing the intermittency issues associated with renewable energy integration, while leveraging private sector capital through a hybrid renewables-plus-storage approach (Jan, Kanaan, and Maurer 2023). This integrated approach addresses the necessary connections between the deployment of VRE and energy storage as well as between public and private sectors.

Finally, the World Bank Group's International Bank for Reconstruction and Development payment guarantee mitigates perceived risks for international investors, attracting private capital and facilitating the mobilization of debt financing from development finance institutions and bilateral financing (through government agencies). By mitigating the risk associated with the deployment of these solutions, the Government of Uzbekistan incentivizes the private sector to also invest in BESS technologies.

Impact

The project is expected to have a significant impact on grid stability and commercial operations in Uzbekistan. It is expected to contribute 250 MW of solar power and 63 MW of BESS capacity to the grid, increasing the share of renewable energy in the power mix. This project is the first renewable energy independent power producers in Uzbekistan to incorporate a battery storage component, and it is expected to demonstrate the viability of hybrid solar-plus-storage projects, which can help address the intermittency issues associated with renewable energy integration. The successful implementation of this project is expected to encourage the adoption of similar hybrid models for future renewable energy projects in Uzbekistan, thereby accelerating the country's clean energy transition.

The BESS component of the project is expected to enhance grid stability and flexibility by smoothing the integration of renewable energy sources. The BESS will be operated by the National Electric Grid of Uzbekistan to provide ancillary services to help stabilize the grid—for example, by providing a fast-response, dispatchable resource ramping up or down to address fluctuations in power supply. In addition, the project is estimated to avoid 68.3 thousand tons of GHG emissions per year, contributing to Uzbekistan's climate change and decarbonization goals.

Finally, the project mobilizes private capital, demonstrating the attractiveness of Uzbekistan's renewable energy market (IFC 2024). The successful implementation of this project is expected to unlock new potential for higher penetrations of renewables in Uzbekistan's energy mix.

Key Insights

The successful bidders for the project have been awarded in 2024 (Masdar n.d.), and a few important early insights have been determined so far in relation to the hybrid renewables-plus-storage projects in the country.

- **Comprehensive power sector reforms are needed to attract private sector investment.** A comprehensive power sector reform program is crucial for attracting private investment and ensuring the financial viability and sustainability of the sector, particularly focused on decreasing risk through regulatory clarity and cost-recovery tariffs.

- **Simplified regulation and commercial structures can help accelerate deployment and participation.** The two-part contractual business model for energy and capacity allows for a relatively simple structure while having both assets monetized independently, which minimizes perceived risks for the private sector, compared to other more complex business models that combine renewables and storage in the same power purchase agreement.

- **Robust risk mitigation packages are necessary to attract private capital, but broader reforms are needed to ensure financial viability.** A financially viable power sector is essential for the success of independent power producers. Risk mitigation measures such as first-loss guarantees can help bridge the commercial viability gap, but they cannot alone guarantee success if the power market is structurally unsustainable.

- **Integrated sector planning can drive clarity and opportunity for renewables and BESS.** Comprehensive generation and transmission development planning is crucial for facilitating the integration of variable energy sources.

For Uzbekistan, as in many emerging economies, project finance may make or break the country's ability to deploy BESS technologies at a rate that supports VRE integration. Innovative financing mechanisms that reduce risk for the private sector, like the World Bank's International Bank for Reconstruction and Development payments, help stabilize Uzbekistan's emerging market and incentivize investment from investors who may not have previously engaged. Ultimately, deploying BESS to support clean energy goals will require market conditions that allow the private sector to engage with new technologies. ■

Brazil

Catalyzing Financing for BESS Deployment for Private Sector Enterprises: Bridging Public and Private in Brazil

Contributor: Climate Investment Funds (CIF)

Features

- Deployment and Financing
- Multilateral fund
- Blended finance strategy
- 1:16 investment-leverage ratio
- $256 million for clean energy efforts

Summary

Despite diversifying its energy sources, Brazil's heavy reliance on hydropower can lead to grid instability after severe droughts. With the impacts of a changing climate, stability and reliability are needed to ensure that the grid can function during times of drought or other unexpected weather events. To enhance grid reliability and meet its 2030 emission reduction goals, Brazil is increasingly turning to cost-effective BESS to support integration of hydropower and other VRE sources. CIF, in partnership with the Inter-American Development Bank, and the national implementing agency (Banco Nacional de Desenvolvimento Econômico e Social, or BNDES), have collectively channeled $256 million into clean energy efforts in Brazil, enhancing the country's renewable energy capacity and storage capabilities. These investments support the installation of 8.8 MW/26.4 MWh of battery storage capacity for medium voltage behind-the-meter in mini-grid applications.

The initiative primarily targets micro, small, and medium enterprises (MSMEs), as MSMEs account for 99.5% of all businesses and 30% of gross domestic product in Brazil; yet these enterprises continue to face substantial barriers to financing (OECD 2022). CIF's financial support aims to enhance MSME's competitiveness and sustainability through reduced energy costs and improved grid reliability. Through its Global Energy Storage Program (GESP), CIF invested in Brazil's BESS sector, achieving a 1:16 investment leverage ratio while reducing risks associated with high upfront costs in the sector.

Background

Brazil's energy sector has traditionally been dominated by hydropower, which in 2021 accounted for 65% of country's energy. Despite its renewable nature, hydropower has shown significant vulnerabilities to climate change-induced droughts, which leads to frequent grid failures. This natural hazard highlighted the need for enhanced grid reliability through increased investment in energy efficiency measures and distributed generation to reduce stress on the power system and increase the share of VRE sources (Schwab et al. 2017). Additionally, Brazil's updated NDC aims to reduce GHG emissions by 50% by 2030 from 2005 levels, emphasizing the importance of integrating renewable energy sources such as wind, solar, and biomass with BESS to reduce emissions from the power sector and supplement current levels of hydropower to enhance grid reliability (UNFCCC 2022). Furthermore, the declining costs of BESS have proven essential for developers in Brazil due to lowered energy costs, reduced consumption during peak-times, and minimized vulnerabilities in the production process.

At the time of the appraisal of CIF's GESP, the Brazilian government had been working on a new regulatory framework aimed at modernizing the energy sector by incorporating advanced technologies like BESS (CIF n.d.). Their goal was to enhance energy security and facilitate a shift from a centralized electricity system to a more dynamic, user-engaged distributed system.

However, several challenges remain for the widespread adoption of BESS in Brazil, including high capital expenditure requirements, significant tax burdens, and limited access to long-term financing, especially for MSMEs. Regulatory barriers, limited BESS experience, and high credit risk further impede the financial viability and scale up of these investments. As a result, BESS has limited market attractiveness, with only about 1,000 companies achieving a return on investments above 10% (Greener 2021).

Backstopping MSMEs Through Financing

CIF's GESP is the world's largest multilateral fund supporting energy storage. Through concessional financing from the GESP, CIF is partnering with the Inter-

American Development Bank to deliver the "Program to Finance the Sustainable and Productive Recovery of MSMEs" (CIF 2023). The program promotes sustainable economic recovery for MSMEs in Brazil, focusing on increasing access to medium-to-long-term financing post-COVID-19 pandemic to support the early development of the BESS market.

This program will finance initial demonstrations at the MSME and mini-grid levels, provide enhancement of BESS regulation, and facilitate improvement for project identification and capacity evaluation, all of which will help lay the foundation for broader replication and large-scale deployment of these solutions. CIF and the Inter-American Development Bank are providing a total of $256 million of investment and envision the following steps for the project:

1. **MSME financing for energy storage:** $16 million of concessional funds from GESP underpin the Inter-American Development Bank's $240 million capital investment and are aimed explicitly at financing BESS. BNDES plans to on-lend these funds to MSMEs through medium- and long-term credit to private sector investors, including industry, manufacturers, dedicated funds, energy service companies, or other aggregators. Financing would offer competitive terms for subproject sponsors to offset the high capital expenditure requirements and long payback periods related to BESS projects. In some cases, investments could be combined with solar PV or other renewable energy systems investments and support different grid services.

2. **Guarantees for local financial institutions:** BNDES's guarantee fund (Fundo Garantidor para Eficiência Energética, or FGEnergia) expects to offer concessionally priced guarantees to their vast network of partner financial institutions. The guarantees can be used as alternative collateral to expand lending to MSMEs for energy efficiency, distributed generation, and BESS. As part of the fund's credit guarantee mechanism, a $5 million investment from CIF's GESP is set as a contingent investment grant to increase the fund's capacity to take risks.

3. **Technical assistance and enabling environment:** $1 million from CIF's GESP is planned to be used to support the early development of the BESS market in Brazil. This assistance may include proper identification and assessment of a portfolio of BESS projects as well as suitable business models for BESS investments; knowledge-sharing and the establishment of alliances among key stakeholders; improvement of the regulatory environment to enable the scale up of BESS investments; and capacity-building for BNDES for monitoring and evaluating BESS projects by developing proper tools to perform the financial and technical evaluation of BESS investments.

Additionally, in 2023, CIF approved a follow-up investment of $70 million to improve Brazil's electricity grid's flexibility, facilitating more renewable energy integration and reducing emissions from the electricity sector (CIF 2023). This program aims to mobilize an additional $1 billion to support the expansion of broader energy storage technologies, including BESS but also pumped storage hydropower and hydrogen, to improve the integration of VRE and support a greater diversification of the country's renewable energy mix. The deployment of innovative storage systems is expected to contribute to integrating renewable energy in a country that has already exhibited success in attracting and democratizing investments in clean energy technologies.

Impact

The Program to Finance the Sustainable and Productive Recovery of MSMEs aims to install 26.4 MWh of battery storage capacity for medium-voltage behind-the-meter applications at the company level and as part of mini-grids through 2027. Fully realized, the program targets a reduction of over 214,000 tons of CO_2e over the lifetime of the financed assets and is expected to support approximately 4,850 MSMEs, enhancing their competitiveness by reducing energy costs, improving grid reliability, and promoting sustainable economic recovery post-COVID-19 pandemic. Gender equality is also a key tenant of the program, and 30% of the resources are reserved for women-owned MSMEs. The initiative plans to play a pivotal role in building a more diversified and resilient power grid with reliable and lower-cost energy supply for MSMEs.

Concessional financing from CIF's GESP is set to mobilize 16 times the initial investment from partnering entities, leveraging a 1:16 ratio of co-financing. CIF's concessional funds help reduce investment risk for both private and public investors by providing lower-cost capital and mitigating the financial risks of innovative projects.

Key Insights

- **Blended finance drives private sector investment.** Combining concessional loans with guarantees and technical cooperation can significantly reduce financial barriers for MSMEs investing in BESS. This financial strategy is particularly relevant in the energy sector, where upfront costs for innovative technologies like battery storage systems can be prohibitively high.

- **Clear and strong regulatory frameworks are critical.** Strengthening the regulatory environment, specifically the connection requirements and legal status, through technical support is crucial for the successful deployment and scaling of BESS technologies. Ongoing technical support and capacity-building efforts are essential for market development and the successful implementation of new technologies.

- **"Learn by doing" through pilots.** Initial demonstration projects at the MSME and mini-grid levels are critical for building a solid basis for subsequent replication and scale-up of BESS solutions.

The support of MSMEs through GESP has proven to be an effective model for unlocking BESS financing and ensuring that project developers have the proper resources they need to deploy BESS at the rate needed to meet Brazil's energy goals. Coupled with the deployment of other forms of energy storage and VRE sources, Brazil's energy sector is well poised to address reliability and flexibility challenges and ensure that clean energy is available to populations across the country. ■

Maldives

Transforming Islanded Energy Systems Through a Multimodal Approach

Contributor: CIF

Features

- Deployment and Financing
- Market de-risking
- Technical assistance and capacity-building
- $121.68 million invested and $573 million mobilized
- 46-MW/184-MWh BESS.
- 8.8-MW/26.4-MWh BESS.

Summary

In October 2012, CIF's Scaling Renewable Energy Program in Low Income Countries (SREP) developed its Investment Plan in the Maldives, which aimed to transform the energy sector and increase energy security in the country. Since then, CIF has provided $121.68 million in funding and mobilized a total of $573 million to provide technical assistance to the government and deploy solar PV, BESS, grid modernization, and other innovative clean technologies. Initially, the SREP Investment Plan funded the deployment of 184 MWh of BESS in 116 of the 186 habitable islands in the Maldives. To contribute to cost reduction and stabilization, the SREP Investment Plan also implemented a multi-tier risk mitigation facility that considerably increased the number of private investors and helped reduce the tariff from $0.21/kWh in 2014 to $0.9888/kWh up to date.

Since the inception of the project, three follow-up projects receiving funding from CIF plan to deploy an additional 184 MWh (4-hour) of BESS to support the original 116 MW of installed solar and other clean technologies. Overall, the SREP Investment Plan has been labeled as transformative to the Maldives' energy sector toward a cleaner and more reliable power generation.

Background

The Maldives is an island state, an archipelago with 1,200 coral islands. Home to over half a million people, the Maldives generates its electricity through multiple isolated island-grid systems with no inter-island interconnection. With electricity demand growing by an annual average of 6% in recent years, the Maldives primarily imports diesel, which provides 81% of its energy sources through diesel generators. In 2023, fossil fuel imports had already risen to around $730 million, representing a significant cost to the country (Maldives Customs Service n.d.). The reliance on imported diesel also puts the Maldives at risk to changing prices for fuel and represents risks to the reliability of the Maldives' energy sector due to fluctuating fuel costs. When the SREP Investment Plan was approved in 2012, scaling up renewable energy had been identified as a solution to enhance stability and reliability of the Maldives' islanded energy systems and ease the country's multiple power generation challenges (World Bank 2020a).

The Government of the Maldives identified the funding and deployment of renewable energy as a priority in its Maldives Vision 2020, Strategic Action Plan (2008–2013), National Sustainable Development Strategy (2009), Maldives Energy Policy (2010), and 3rd Environment Action Plan (2008) (CIF 2012). Additionally, according to the Maldives' Government, the government aims to achieve 70% renewable energy penetration by 2030 and declared an interim target of 33% over the next 5 years at COP28 (World Bank 2020b).

For islanded systems with ambitious renewable energy targets like the Maldives, BESS can be critical to enhancing renewable energy deployment. BESS are well suited for deployment in mini-grid island systems where each island needs a stabilizing energy source to supplement VRE generation. In place of diesel generation, BESS systems can provide the consistent energy current needed to ensure stability and reliability of the grid for these islanded systems with high penetration of renewables.

Bundling Financing with Regulation and Capacity-Building

CIF's SREP Investment Plan for the Maldives had three components: Renewable Energy for the Greater Malé Region, Renewable Energies for Outer Islands, and Technical Assistance and Capacity-Building. These three components each provided risk mitigation facilities, investment commitments, and technical assistance for renewable energy deployment. While these components addressed renewable energy project financing and development broadly, the SREP Investment Plan also contributed to enabling environment and financing for energy storage solutions, including BESS. This contribution can be divided into three sections:

- **Policy and regulatory framework:** Through its technical assistance component, the SREP IP provided policy and regulatory assistance, advising on policy directives and other documents, which was instrumental in creating the Maldives Energy Act and the Utility Regulatory Act. These acts established the Utility Regulatory Authority, which has independent authority to maintain stability and technical autonomy of the grid. The assistance included drafting the licensing, installation, and operations manuals for solar PV. Moving forward, the Maldives' Ministry of Climate Change, Environment, and Energy aims to adopt similar standards determined during the project implementation for BESS deployment.
- **Capacity-building:** The SREP Investment Plan's capacity-building component focused on training the project management unit, regulators, and other authorities on the necessary regulations for deploying renewables and storage. Technical assistance and trainings related to value-stacking services, public and private asset ownership models, pricing models, and deployment phasing (e.g., system planning and assessment of business model options) were critical to getting stakeholders across the power system up to speed on market mechanisms for VRE and BESS deployment. Additionally, decision makers and technical experts received training on the opportunities for deploying hybrid projects with solar PV and BESS in different modalities.[1] Furthermore, SREP IP trainings contributed to discussions with regulators to reassign and resize their workforces and create coordination mechanisms among authorities for the deployment of renewables and storage. Finally, the Accelerating Sustainable System Development Using Renewable Energy project, a follow-up project of the SREP Investment Plan, is also including an internship program for female graduates of two universities and a women's leadership program, contributing to the development of a more equitable energy workforce.
- **Financing mobilization:** In total, the SREP IP contributed $25.6 million and co-financed $238.59 million from the World Bank's International Development Association, the Asian Infrastructure Investment Bank, and the private sector. The SREP Investment Plan in the Maldives was uniquely designed to mobilize private financing for renewable energy, providing a risk mitigation facility and incentives to expand the country's share of solar PV and BESS. This risk mitigation facility used power purchase agreements with two subcomponents. The first component was tariff buydown grants,

1. Part of this technical assistance was later published at the World Bank's report, *Unlocking the Energy Transition: Guidelines for Planning Solar-Plus-Storage Projects* (Jain, Kanaan, and Maurer 2023).

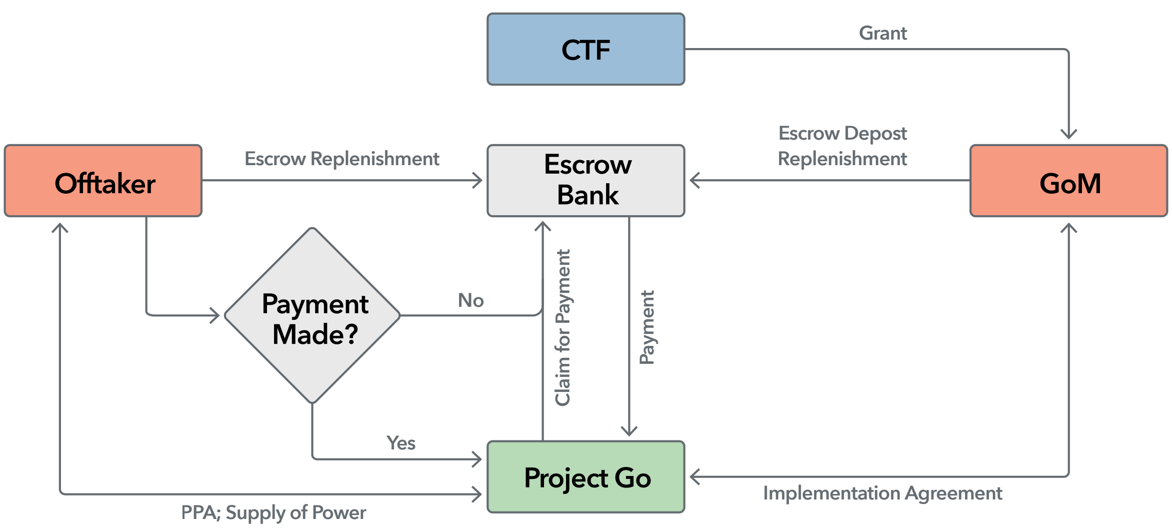


Figure 10. Secured payment mechanism agreement. Source: CIF

which reduced the impact of the financial cost of independent power production on the tariff (mostly floating solar PVs and BESS). The second component was contributions into secured payment mechanisms, mitigating the risk of payment default of the off-taker in connection with power purchase agreements and other associated agreements (World Bank 2020c).

The SREP Investment Plan was only the beginning of efforts to mobilize concessional financing, private investment, and public funding for the deployment of renewable energies and storage in the Maldives. There are now three CIF-financed follow-up projects that emerged as a result of the efforts by the SREP. These three projects are:

- Accelerating Renewable Energy Integration and Sustainable Energy (2021)
- Accelerating Sustainable Clean Energy Investments for Net Zero Transition (2024[2])
- Accelerating Sustainable System Development Using Renewable Energy Project (2024).

In total, with $75 million from CIF's Clean Technology Fund, all three projects are expected to mobilize over $364 million to deploy 184 MWh of BESS and 116 MW of solar, while also piloting new clean energy technologies across the country. Storage and other components of these three follow-on projects are reflected in **Table 1**.

Impact

Through the SREP Investment Plan, solar PV and BESS have been deployed on the Maldives' outer islands. 126 islands were divided into three categories, depending on the potential for renewable energy penetration. The 10 islands that could achieve 10% of renewable energy penetration received investments in solar PV and energy management systems, while 86 islands that were aiming for 20% of RE penetration received investments in solar PV and BESS for grid support. The other 30 islands with more ambitious renewable energy penetration goals (30% or more) received solar PV and BESS investments, but for load-shifting due to the ambitious renewable energy goals and deployment. In total, POISED expects to deploy 22.2 MWh of BESS in 116 of the 186 habitable Maldives islands. The three follow-up projects also receiving funding from CIF are targeting an additional 184 MWh of BESS to support the additional 116 MW of solar and other clean technologies that are planned to be piloted.

The two original projects that received $25.57 million of funding through the SREP Investment Plan mobilized $166 million to deploy solar PV and BESS, modernize the grid, and provide technical assistance to the government. These projects created a strong enabling environment for follow-up financing of over $407 million, of which CIF's Clean Technology Fund provided $40.68 million in grants and $58 million in concessional loans. Overall, CIF has provided over $98 million with an expected co-financing ratio of 1:6.4, the efforts of which are already transforming the Maldives' energy sector toward cleaner and more reliable power generation from VRE sources and away from traditional diesel generation.

Deploying renewable energy and storage through the SREP Investment Plan reduced the Maldives' power sector GHG emissions through renewable energy generation and provided fiscal relief by reducing diesel imports, thus removing the risks associated with fluctuating fuel import costs. ASPIRE estimated 7 million liters of annual diesel savings through its solar deployment (CIF 2012), while POISED estimated 19.76 million diesel savings from solar and BESS deployment. The latter also estimated an annual GHG emissions reduction of 40,000t CO_2 (ADB 2024).

Key Insights

- **Implementation of large-scale PV systems can require BESS for effective integration.** The Maldives has 186 isolated island grids. Due to the nature of these mini-grids, VRE might overload and/or destabilize islands' grids during periods of high energy generation. During the SREP Investment Plan close-out workshop, all participants agreed that projects deploying VRE should include a storage component to mitigate integration challenges. As a result, all three follow-up projects have BESS components totaling 184 MWh.
- **Without economies of scale, it is difficult to determine the appropriate size for solar PV-plus-BESS projects.** The Maldives' unique feature of multiple small-isolated island grids creates larger costs to large-scale BESS investments. For example, early projects allowed for 1-hour storage, but future financing aims to provide up to 3–6 hours of storage. This will likely be a challenge to overcome across other SIDS.
- **De-risk the market to encourage private sector investment in solar PV and storage.** Mechanisms to distribute the risks associated with early market deployments of both technologies between the

2. The project has been approved by CIF's Trust Fund Committee, pending approval from multilateral development banks.

Table 1. SREP IP Projects and Follow-Up Clean Technology Fund-Funded Projects

	POISED (ADB 2021, 2024)	ARISE(World Bank 2020c)	ASCENT (World Bank 2024)	ASSURE (ADB 2023)
Implementing Multilateral Development Bank	Asian Development Bank	World Bank	World Bank	Asian Development Bank
Overall Funding/CIF Funding	$232 million/$12.7 million (all grant)	$107.4 million/$30 million ($7 million grant and $23 million loan)	$216.6 million/$30 million (all loan)	$115.25 million/$15 million ($10 million grant and $5 million loan)
Storage Targets	22.2 MWh in BESS for 126 outer islands	50 MWh of BESS (40 MWh awarded by the time of publication)	90 MWh of BESS	44 MWh in BESS for 20 outer islands
Renewable Energy Targets	28.2 MW of solar PV	36 MW of solar PV pipeline projects (including 10 MW of floating solar)	55 MW of solar	25 MW of solar PV (floating and terrestrial), piloting new technologies (ocean and wind in two outer islands)
Other Components	Grid modernization, capacity-building, and technical assistance	Grid upgrades, financial de-risking mechanisms, and technical assistance	Financial de-risking mechanisms, grid modernization, technical assistance, e-mobility, and new technologies and innovation, other renewable energy technology, including wind, tidal, wave, ocean thermal energy conversion, green hydrogen	Energy management systems, grid upgrades, financial de-risking mechanisms for solar independent power producers, capacity-building, piloting climate-resilient clean energy technologies for farming

public and the private sector offload the budgetary pressure of the utility and incentivize large-scale private investments. Ultimately, these mechanisms contribute to a mature market in which the private sector can eventually grow away from the use of these incentives. The SREP Investment Plan projects in the Maldives include escrow agreements between the Government of the Maldives and commercial banks related to secured payment mechanisms, termination risk mitigation mechanisms, tariff buydown grants, and foreign exchange management tools, which ultimately reduce risk for private sector investors.

- **Technical assistance and capacity-building are essential.** All projects funded by the original SREP Investment Plan (and follow-up Clean Technology Fund-funded projects) had vital technical assistance components. These projects not only created opportunities for project financing, but also aimed to strengthen the institutional capacity and support the design and implementation of policies and regulatory frameworks for deploying future clean energy technologies. For example, the technical assistance to develop the Maldives Energy Act; the Utility Regulatory Act; the licensing, installation, and operations manuals for solar PVs; and the cost-reflective tariff methodology all contributed to creating a lasting enabling environment for VRE and BESS deployment.

- **Tendering preparatory processes for policies and regulatory frameworks could be a starting point to shape up regulations for storage.** In the Maldives, tendering procedures and technical proposals presented for solar PV were sufficient to develop regulations (e.g., solar farm interconnection requirements and adoption of international standards). While BESS is already being deployed and storage regulations in the Maldives are still mostly in discussion phases, regulators could also draw on the existing and upcoming BESS tendering processes for the development of BESS regulation.

The Maldives faces unique challenges for a transition to clean energy, given the country's island nature; however, transitioning to a higher share of VRE and BESS should help to ease the country's reliance on imported fuel and reduce GHG emissions from the power sector. CIF's SREP Investment Plan projects combined multimodal approaches through financing, capacity-building, and technical assistance to assist stakeholders in the Maldives in creating a strong enabling environment for BESS and de-risking investments in renewables for the private sector. The impact of these programs has led to installed capacity for the Maldives, and the model is being scaled through additional CIF projects to help the Maldives meet its ambitious climate goals. ■

Botswana

Supporting Renewables Integration and Grid Flexibility for National Energy Goals Through Grid-Scale 50-MW/200-MWh Stationary BESS

Contributor: World Bank

Features

- Operation and Value Stack
- Integrated planning and investment
- Capacity development
- Blended climate finance strategies.

Summary

To increase the penetration of renewables in the national grid of Botswana and to provide grid stability services, the Botswana Power Corporation has planned to set up two 25-MW/100-MWh BESS installations at Phikwe, Central District, and Jwaneng, Southern District of Botswana. The two projects are planned to be located close to two 50-MWp solar PV plants owned by independent power producers and are expected to primarily help align solar power production to meet evening peak loads while also providing grid services, including for reactive power. The BESS project leveraged Green Climate Fund and World Bank financing under the Sustainable Renewables Risk Mitigation Initiative.

Background

Botswana has excellent solar and wind resources, presenting a promising source of clean and affordable electricity. Diversifying domestic electricity production by using renewable energy sources was set as a target in Botswana's Vision 2036 and the National Energy Policy in 2021 (Government of the Republic of Botswana 2021). The former seeks to increase the share of renewable energy in the generation mix from the current baseline of approximately 2% to 50% by 2036. Given the significant VRE commitments made under the integrated resource plan and Botswana's goal to move from being a net importer of electricity to a net exporter, strengthening the national grid and enabling the integration and management of VRE is a key priority for the country.

The country's first 50 MW of utility-owned BESS projects, with World Bank financing support, are expected to lay the foundation for these goals, helping catalyze a significant pipeline of BESS projects in the country to integrate VRE in the context of the lack of flexibility of the grid.

A Whole-of-System Approach

Several factors were critical for enabling the development, financing, and deployment of the BESS projects, including:

- Botswana has a strong policy framework with clear goals for energy security and an increased focus on renewable energy integration. Large-capacity wind, solar, and concentrating solar power projects have either been awarded or are in different stages of development, and BESS assets have been considered for their seamless integration and operation.
- The ability of BESS to provide additional value like frequency control and reactive power compensation also appealed to the system operators and bolstered their decision to proceed with deployment of BESS systems.
- Close partnership and co-development with the unified power utility of the country, Botswana Power Corporation, helped streamline approval and interconnection processes (e.g., "loop-in-loop-out" approvals) at the inception stage to ensure that the projects can go online and start service immediately after the commencement of commercial operation.
- Supply to World Bank-funded projects has taxation incentives like deemed export benefits that can reduce the tax burden of the project, which may entail a lower upfront capital expenditure for Botswana Power Corporation.

The BESS projects are expected to support a wide range of value for Botswana Power Corporation, including smoothing production and extending the capacity factor/utilization of the collocated solar plants at Phikwe and Jwaneng, displacing expensive thermal generation, as well as provision of primary and secondary reserves. Of these, the renewables integration, firming, and the resulting impact displacing thermal generation are expected to be the largest share of the value stack.

Impact

The BESS projects are expected to yield significant savings and promote broader adoption of storage, enabling higher renewable energy integration while maintaining grid's reliability, flexibility, and stability. Specifically, the project is expected to directly benefit the government, Botswana Power Corporation, and the independent power producers who own the collocated solar plants through cost savings and operational benefits, as detailed below. Further, the project is expected to broadly help enhance business models for grid-connected renewable energy in Botswana (World Bank Group 2024b).

Significant lifetime cost savings are expected, resulting from multiple value stream details.

1. **Reduced fuel costs from thermal generation:** The BESS project reduces the need for thermal generation, leading to lower fuel costs, while providing firm capacity during peak hours. Specifically, significant savings are expected from avoiding peaking diesel costs as well as from Morupule B (a coal-fired power plant).

2. **Reduced import requirement:** Reducing the need to import electricity by discharging electricity from the BESS project leads to savings on import costs and contributes to overall savings from the transition to clean energy.

3. **Reduced primary and secondary reserve shortage:** The BESS project helps reduce primary and secondary reserve shortages, improving grid stability and leading to major economic benefits.

4. **Reduced unserved energy:** By reducing unserved energy, the BESS project ensures a more reliable power supply during peak demand periods.

5. **Reduced curtailed renewable energy:** The BESS project reduces the curtailment of renewable energy sources, maximizing their utilization.

6. **Environmental benefits (emissions reductions):** Botswana Power Corporation maximizes environmental benefits by reducing CO_2 emissions from thermal generation. It is estimated that the BESS investments would result in a reduction of CO_2 emissions by 11.7% of the overall economic savings.

Key Insights

- **Coordinated integrated planning and investment for storage and renewables is critical.** Sequencing investment plans for storage considering the planned solar PV capacities is critical to ensuring adequate integration of assets and maximum reliability of the system. The timing of adding the storage capacity to the grid needs to be in sync with the pipeline of solar PV projects that are tendered or expected to come online.

- **Parallel capacity development for governments and utilities on BESS is a prerequisite for successful planning and project development.** In many developing countries, operating and managing complex assets like BESS requires a deep understanding of the technical functions, operational parameters, and control of BESS assets. A challenge of weak grids, or novelty of the technology when not having a robust supervisory control and data acquisition system in place, requires the utility to develop its capacity for effectively operating BESS assets, and to manage the complexity of the grid as it evolves. Therefore, such BESS investments need to be coupled with comprehensive technical capacity-building for the utility and relevant stakeholders.

- **Holistic institutional frameworks are needed to align renewable energy and BESS development.** The deployment of BESS as a key enabler for renewable energy adoption in a reliable grid requires holistic institutional frameworks, which go beyond simplified stationary BESS applications toward leveraging private sector financing and participation. This requires determining the value streams that can be monetized for BESS while upgrading the grid infrastructure to optimally leverage them.

- **Blended climate finance can help scale up the BESS adoption.** The project in Botswana was made possible through a climate-finance blended approach, in which World Bank lending was coupled with climate finance at concessional rates from the Global Concessional Financing Facility. As the first utility-scale BESS project in Botswana, the climate finance was necessary to make the project economically viable.

Botswana's BESS installations in Phikwe and Jwaneng highlight the opportunities that BESS value-stacking can bring to deployment in emerging economies. By incentivizing BESS deployment through World Bank financing and value-stacking, stakeholders in Botswana are expected to also receive the benefits to the grid such as system stability, reduced reliance on fossil fuels, and load-shifting. As Botswana continues to pursue ambitious clean energy goals, BESS projects like these can help ensure that the deployment of VRE does not introduce instability to the power system, assure that systems of VRE and BESS are profitable for early investors, and reduce GHG emissions from the power sector. ■

Synthesis of Key Learnings

The cases of BESS deployment across emerging economies represent an important source of learning for future storage projects.

First, it is important to note the differences in motivation for deployment of BESS across the case studies, especially in comparison to established markets for storage. While many of the case studies were paired with deployment of renewable energy, particularly solar, others were focused more on grid resiliency and stability benefits.

Further, these studies highlighted the role of effective policy and regulatory environments for enabling BESS deployment. In the Maldives, technical assistance facilitated the development of the Maldives Energy Act, the Utility Regulation Act, and licensing. At the same time, the comprehensive power sector reforms enacted by the Government of Uzbekistan proved to be essential for BESS deployment. Similarly, strong regulatory frameworks for BESS, involvement of the regulator in the initial stages of the project, and the role of tendering preparations are instrumental in creating effective enabling environments in the featured contexts. In the case of India, the engagement with the regulator and local stakeholders at the initial stages of the project and technical assistance provided support for the code updates that facilitated BESS project approval. These case studies highlighted not only the need for a strong policy and regulatory environment, but also the necessity of engaging with local stakeholders for its development.

The questions of financing have also emerged several times, being one of the cornerstones of storage project implementation due to high initial capital expenditures and limited resources for technology deployment in emerging economies. Specifically, it was found that both state funding and blended financing, as well as de-risking mechanisms, can attract private capital and encourage BESS deployment. For instance, in the Maldives, a multi-tier risk mitigation facility helped reduce tariffs per kWh through tariff buydown and mitigation of payment default risks, which helped attract larger numbers of investors. The case of Brazil illustrated that the mix of concessional loans, investment guarantees, and technical cooperation can reduce perceived risks of investment in BESS. Similarly, the blended finance strategy of World Bank lending and Green Climate Fund concessional rates made Botswana's BESS project economically viable. Lastly, in India as well as in Botswana, stacking of ancillary services, arbitrage opportunities, and capital expenditure deferral has supported the viability of BESS financing. While attracting private capital for BESS projects remains challenging for many emerging economies, government incentives, blended financing, and de-risking mechanisms have proven to be viable solutions to ease financing difficulties.

Additionally, these case studies showcase important lessons for BESS deployment considerations. Economies-of-scale facilitate BESS deployment by making it cheaper, while pilot projects and requests for proposals increase developer and local stakeholder confidence. In Brazil, the demonstration project is expected to motivate BESS regulation improvements and lay the foundation for replication of large-scale solutions. BESS deployment in India highlighted that comprehensive requests for proposals could increase developer confidence in the project, raising the number of competitive bids. The island states, such as Samoa and Vanuatu, might encounter additional challenges for BESS deployment, considering the specifics of their power systems, which are largely composed of small systems. The cases of Botswana and Uzbekistan highlight the importance of integrated planning of renewables and BESS to ensure the stability of power systems. These deployment considerations may serve as important lessons for the future deployment of advanced energy storage systems.

While there are few projects that have been operating to date, there are still important lessons to be gleaned about BESS operations and their benefit. For SIDS, BESS can smooth the operation of systems with high shares of renewables, reduce reliance on imported diesel fuels, and maintain consistent delivery of power to the island residents. For instance, in case of the Maldives, it was agreed that BESS can stabilize the grid and mitigate VRE integration challenges. Frequency control, provision of reserves, and decreased VRE curtailment prove BESS to be an invaluable addition for SIDS's power grids. Value-stacking of these services can help maximize revenue streams, as illustrated in India. In summary, BESS services can facilitate the integration of VRE, provide support to the grid, ensure fuel savings, and provide additional revenue streams if the appropriate market mechanisms are in place.

Finally, there is a prominent message across all the case studies: the importance of technical assistance. Technical assistance has been instrumental to the success of BESS projects currently in operation as well as for future storage initiatives. As such, in India, technical assistance led to the enhancement of existing codes and regulatory approval of a proposed BESS project. In Latin America, technical assistance helped stakeholders understand the similar needs of countries in the region for the initial stages of BESS deployment, while the analysis of the regulatory environment identified the existing gaps and established a need for coordination between different entities, further catalyzing the support for BESS deployment in the region. In the Maldives, the training provided to the project management unit, regulators, and other authorities on the necessary regulations to deploy renewables and storage familiarized stakeholders with market mechanisms for BESS, facilitating the adoption of necessary regulations and standards. Technical assistance proves to be an imperative element of BESS deployment, particularly in emerging economies.

Deploying BESS in emerging economies requires building partnerships among local and international stakeholders. Sharing lessons learned and encouraging battery storage projects worldwide supports the integration of higher shares of renewables and power system decarbonization. While these studies highlight the BESS projects mainly at the initial stages of their development or deployment, it indicates that storage has become a prominent technology in emerging economies and there is strong motivation for its deployment. Fostering partnerships across different sectors, facilitating the development of regulatory environments, and encouraging investment mobilization can help accelerate the deployment of BESS in emerging economies. As we look to increase storage capacity globally, shifting the focus to emerging economies and ensuring that BESS deployment is prioritized in these contexts will help contribute to the levels of storage needed to meet the goal of tripling renewable energy by 2030. By fostering global collaboration and integrating best practices, countries can overcome the challenges of BESS deployment and unlock its full potential, ultimately driving forward the clean energy transition. ■

Figure 1. This map depicts the countries highlighted through this report, including Botswana, Brazil, India, Latin America and the Caribbean, Maldives, Uzbekistan, and Small Island Developing States.

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CLEAN ENERGY MINISTERIAL
Advancing Clean Energy Together

SUPERCHARGING BATTERY STORAGE
AN INITIATIVE OF THE CLEAN ENERGY MINISTERIAL

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