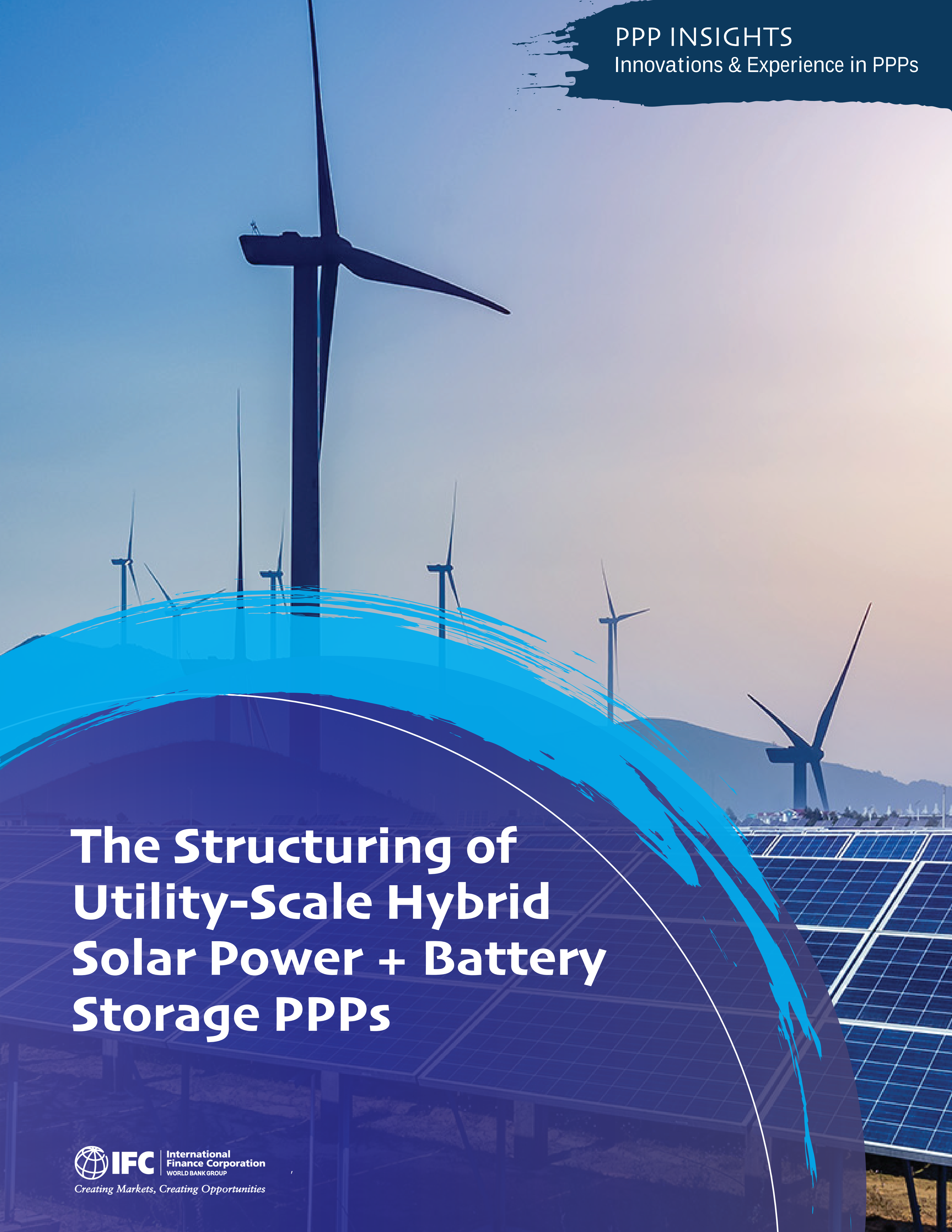


PPP INSIGHTS

Innovations & Experience in PPPs

The Structuring of Utility-Scale Hybrid Solar Power + Battery Storage PPPs

IFC International Finance Corporation
WORLD BANK GROUP
Creating Markets, Creating Opportunities

SOLAR power has transformed the power generation landscape, becoming one of the most affordable sources of energy in the world. But the intermittent nature of solar energy has been an obstacle to widespread adoption.

Battery storage technology has made huge advances and could help solve the problem of intermittency. Many governments in emerging markets are looking to develop public-private partnerships (PPPs) that integrate battery storage in their solar power tenders. But is the technology at the stage where it is an economical option for developing country governments?

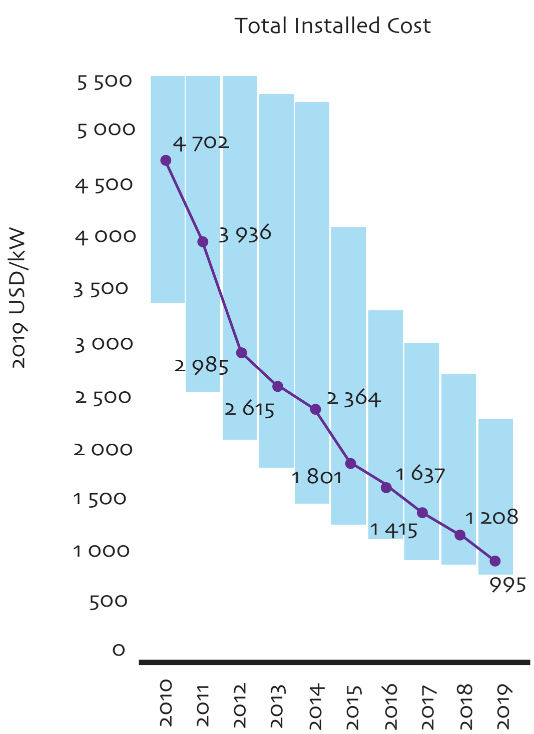
This IFC Sector Note looks at developments in battery storage technology and what needs to be considered when structuring utility-scale hybrid solar power + battery park PPPs in a developing country context to ensure they are viable and sustainable.

This note is part of the PPP Insights series developed by the IFC PPP Transaction Advisory Department for infrastructure specialists, governments, and PPP practitioners. PPP Insights provides sector analysis and case studies looking at infrastructure needs and challenges in developing countries and how PPP structuring techniques are being used to help deliver improved outcomes.

Solar power has become competitive in terms of costs with traditional energy sources, such as fossil fuels. While wind power was typically cheaper than solar, solar panel costs have now declined significantly, resulting in lower generation prices.

The cost of solar power per installed kilowatt (kW) has fallen from over USD $4 per kW prior to 2010 to below USD $1 per kW in 2019, with some recent large-scale solar photovoltaic (PV) parks being developed for as low as USD 0.84 per kW.

Figure 1: Global weighted average total installed costs for solar PV (2010-2019)



Source: Renewable Power Generation Costs in 2019 report, IRENA, June 2020, p. 27

The technical parameters of solar photovoltaic panels are improving steadily as well. The capacity factor of panels has reached over 20% with manufacturers now offering guaranteed performance (or guaranteed "degradation curves") for a 25-year lifecycle.[1]

Solar energy has been the most innovative energy form in the renewable energy industry, driving significant technological improvements in terms of lower cell cost, higher cell capacity factor, and efficiency. It also spurred the development of downstream technological breakthroughs and innovations, including batteries, grid management, and smart grids. But most importantly, solar energy has significantly impacted energy system integrations, market models, and overall energy sector regulation.

New and emerging technologies, such as floating solar[2] or PV traffic noise barriers[3], have recently emerged along with ways to reduce land use and spatial footprint, by integrating solar production to existing infrastructure.

Solar PV combined with batteries also allows for significant improvements in the overall grid management and smart grid solutions. Batteries, adequately placed across a country, allow for new renewable energy developments across regions and improve the economics of renewables for governments.

The levelized cost of electricity ("LCOE") for solar power has already fallen to levels comparable to the LCOE of fossil fuel plants.

Battery Energy Storage, the mitigant to intermittency that is spurring the development of solar generated power

While technological advances in solar panels have led to cheaper prices and strong growth in the industry, the intermittency of solar power has limited its expansion, especially in developing countries where grids may need significant investment to be able to handle large amounts of intermittent power.

> Intermittency, and the uncertainties it creates, has been the main obstacle to more widespread roll-out of solar PV.

Power is being generated during the day, with significant known variations depending on the hour of the day and seasons. However, while certain variations in the electricity output can be estimated, the effects of fast changing climatic conditions, on the other hand, such as passing clouds and the resulting fall in power generation, create challenges in terms of grid management (balancing needs, in addition to frequency and voltage control).

Fortunately, recent technological developments of utility scale batteries, and most specifically, short duration batteries (<4hrs), have started to provide a solution. As a result, the industry is now seeing more projects that pair solar PV parks with short duration batteries, resulting in a growing number of "hybrid PV parks".

The economics of hybrid PV and battery parks

The economics of combining solar PV with battery energy storage systems ("BESS") are increasingly attractive, but remain limited to short-duration wholesale and commercial use in emerging markets, and there remains a challenge for demonstrating a compelling business case for deploying combined PV and BESS for residential and longer-duration wholesale projects like those successfully developed in the US or in Australia, for example.

One of the principal reasons for this is the fact that the underlying technology of the short duration batteries still makes them more economical from a cost perspective and reliability, as opposed to the long duration batteries, which are based on less proven technologies. In addition, while owners and operators of combined solar PV parks and short duration BESS derive value from the economy of scale and shared infrastructure (i.e. inverters, interconnection), they also derive value from the ability to reduce curtailment by managing and optimizing the dispatching into the grid, as well as benefiting from various revenues streams, such as time shifting related revenues and providing different ancillary services. Residential combined PV and BESS on the other hand, are merely benefiting from the avoidance of high retail energy or demand charges.

Current typical use of short duration BESS combined with PV, capacity, and location

Reducing Intermittency: BESS is a mitigant for the intermittency issue generated by solar and wind energy: The issue facing the grid is the major increases and falls in energy production from wind and solar depending on sudden climatic conditions. For example, clouds passing over a 100MW PV park will generate a significant fall in the electricity pushed into the grid. This generates major issues in frequency and voltage control. BESS operators can provide frequency and voltage control services (known as "frequency control" or "frequency regulation services") by being discharged quickly (sub seconds responses). This is the most relevant type of utilization for BESS. However, it is important to note that the level of renewable energy is the energy mix beyond which BESS would be warranted will depend on the specifics of the sector in terms of grid stability, type of baseload generation and responsiveness, and availability of imports, among other factors.

Peak shaving and time shifting: Relevant for PV park operators. Peaks in electricity demand usually occur in the evening hours, after sunset, while the PV park does not produce electricity. The ability of the BESS to charge during the day when demand is low, and discharge for a few hours (2-4 hours) during the peak evening time (peak shaving) is also a potential use of the BESS, providing additional revenues for the operator, and providing significant benefits to the off-taker (the best example is in California).

Capacity of the BESS: With the current technology, operating short duration BESS, paired with a RE park (wind park or PV park), with a total capacity of 25% of the overall RE park appears to be the most cost-effective model.

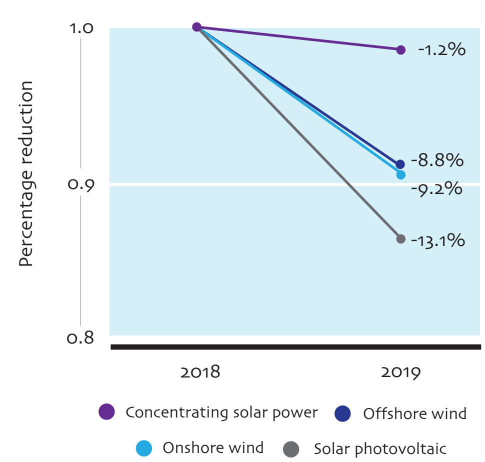
Location of the BESS: The BESS park does not necessarily have to be on the same location as the RE park, although there is an approximately 5%-10% economy of scale in doing so. What is important is to locate the BESS at grid points where the ancillary services are most relevant and where there is a potential for peak shaving.

Battery technology is expensive and not yet widely deployed in large-scale projects. The gap is particularly acute in developing countries, where wind and solar power have great potential, energy demand is growing, and where large populations often live without reliable, affordable electricity.

It should be noted that because of the high cost of the levelized cost of electricity (LCOE)[4] and the requirements for a minimum performance level of grid infrastructure, and the lack of regulatory environments that would allow the project to charge for its ancillary services, this RE+BESS model remains most relevant for developed and mid-markets. However, there are fast-developing market and technology changes that are increasing the viability of combining solar PV and batteries in a developing country context over the near- to mid-term:

- Electricity market growth and requirements for primary and secondary reserves
- Increased penetration of renewable energy in the generation mix of emerging market countries, requiring frequency and voltage control
- Increased investments and grid system stability,
- Market deregulation, market depth, and increased competition in the ancillary services market, and
- An overall increase in affordability by electricity users.

Figure 2: Global LCOE from newly commissioned utility-scale renewable power



Source: Renewable Power Generation Costs in 2019 report, IRENA, June 2020, p. 21

The World Bank Group (WBG) is supporting the roll-out of the PV + battery PPPs by combining the efforts of the different parts of the institution. For example, a joint World Bank-IFC team in India is developing one of the largest hybrid solar, wind and storage power plants in the world, while in South Africa, the World Bank is helping develop 1.44 gigawatt-hours of battery storage capacity, which is expected to be the largest project of its kind in Sub-Saharan Africa.[5] The World Bank Group has also launched an Energy Storage Program[6] and Energy Storage Partnership[7] to help developing countries to take advantage of hybrid solar + battery parks.

These efforts, combined with technological advances and the commensurate decrease in battery costs, are helping more emerging market countries to consider developing hybrid projects, including through using Public Private Partnership (PPP) structuring to align public and private interests and designing solutions that can be scaled.

PPPs and hybrid solar PV & battery parks

The ever-changing technology and performances of the BESS creates a compelling case for off-takers and public counterparts to leverage the expertise of the private sector to identify, procure, and operate the most relevant, economically and technologically viable BESS equipment. Public-private partnerships can be a highly effective way to structure these projects to most appropriately allocate risks and ensure that public sector objectives are met and the project is viable and sustainable for both parties.

How a PV+BES PPP can be structured: The private sector (the "Seller") designs, finances, builds, operates, and maintains the hybrid solar park and sells the energy generated to the off-taker (the "Purchaser"), usually a public utility or government agency. The Seller is typically paid for (i) the energy produced, and (ii) a monthly capacity charge for making the BESS available to the off-taker. This is currently the most common model in developed markets. Under this set up, the Purchaser has the ability to fully control the use of the BESS and decide to assign a usage for the purpose of typical ancillary services (for instance, frequency and voltage control) but also for other usages, such as peak shaving and time shifting if deemed financially relevant. In short, the Purchaser can elect when to charge and discharge the BESS, and where to charge it from (from the PV park or the grid). Under this model, governments and/or utilities retain significant control of the energy and can instruct the Seller on the time and amount of electricity to dispatch, subject to the contractually agreed technical limits, often using the dispatch operator control system.

It should be noted that a model allowing for the Purchaser's full control of the usage of the BESS does require a certain level of expertise and the adequacy of the tools, integration of software and resources of the dispatching function. It also requires an expertise by the Purchaser to assess, on a daily basis, the best economical use of the BESS against the market demand by benchmarking against the costs of imports, curtailment, etc.

Risk Transfer to the Private Partner: In a typical PPP setup, the private partner takes material responsibility for the availability and performance of the BESS, as long as the operations as instructed by the Purchaser falls within the contractually agreed technical limits (i.e mostly the throughput and/or number of daily and yearly full charge and discharge cycles). As a result, a contract would typically include penalties for the private partner in case the BESS capacity and availability fall below a contractually threshold, which would reflect a performance degradation curve.

The availability and capacity of the BESS can also be transferred by the BESS operator to the battery equipment supplier under a capacity agreement, whereby the latter commits to replace the cells and other key battery components to maintain a contractually agreed capacity.

While the technology to support wider adoption of utility-scale hybrid solar + battery parks is yet to bring costs low enough for large scale adoption in emerging market countries, the pace of innovation means it is only a matter of time before we see this on a global scale, with some estimates predicting the cost of battery energy storage systems falling by almost half over the next decade.

As noted in the IFC Battery Storage Primer, there are *"several factors that will continue to drive down costs, including technology improvements, manufacturing scale, competition between manufacturers, greater product integration ahead of installation, and greater overall industry expertise".*[8]

While hybrid solar + battery park technology is not yet viable for some developing countries, the pace of change and global efforts to ensure all countries can benefit from storage technology and a clean energy future, means it may not be out of reach for long.

As costs come down, new technologies will enable the deployment of energy storage solutions at scale, including through developing innovative hybrid solar + battery park PPPs. This, in tandem with strengthening grid infrastructure and relevant amendments to regulation, for example to enable market opening for the provision of ancillary services, will create more resilient power systems, allow for a higher degree of financial sustainability and less dependency on concessional finance, and bring cost savings to utilities and consumers in developing countries.

Comparison of the key terms of a PPP contract, between a typical PPP for a solar PV and a solar PV+BESS

SOLAR PV	SOLAR PV + BATTERY
Term ~25 years	Term ~25 years (may include a shorter period for the battery component (i.e. 8-10 years)
"Take-and-Pay": Price per kWh – energy only	Take-and-Pay + Payment for battery capacity and availability
Non-dispatchable	Dispatchable (i.e like a TPP)
No control from grid	Sometimes controlled by grid
Grid technical limits	Grid +battery technical limits (i.e. "throughput", number of cycles and cycle depths)
Typically, no ancillary services	Ancillary services (frequency, voltage, black start, needs to be broad)
Performance Guarantees	Performance Guarantees on both solar and batteries (capacity, availability, degradation curves etc.)

This article was authored by Bernard Atlan, Principal Investment officer and Industry Specialist at the International Finance Corporation, a member of the World Bank Group: ifc.org/ppp

1 Reliability and Degradation of Solar PV Modules—Case Study of 19-Year-Old Polycrystalline Modules in Ghana, Quansah, Adaramola, Takyi, and Edwin, Multidisciplinary Digital Publishing Institute, May 2017, pg. 2

2 For more information, see Floating Solar Photovoltaic on the Rise, Guido Agostinelli, IFC, May 2020

3 For more information, see Photovoltaics Noise Barrier: Acoustic and Energetic Study, Vallati, de Lieto Vollaro, Tallini, and Cedolac, Energy Procedia, Volume 82, December 2015, Pages 716-723

4 According to the International Renewable Energy Agency (IRENA), the LCOE of a given technology is the ratio of lifetime costs to lifetime electricity generation, both of which are discounted back to a common year using a discount rate that reflects the average cost of capital, Renewable Power Generation Costs in 2019 report, June 2020, pg. 20

5 Four Things You Should Know About Battery Storage, World Bank Group website, May 16, 2019, https://www.worldbank.org/en/news/feature/2019/05/16/four-things-you-should-know-about-battery-storage

6 For more information, see Energy Storage Program on the Energy Sector Management Assistance Program (ESMAP) website, https://www.esmap.org/energystorage

7 For more information, see Energy Storage Partnership (ESP) Factsheet, November 2020, https://esmap.org/sites/default/files/ESP/ESP-factsheet_Nov2020.pdf

8 Battery Storage: A Primer, Peter Mockel, IFC, May 2020, pg. 3