REPORT

UNLOCKING THE ENERGY TRANSITION

Guidelines for Planning Solar-Plus-Storage Projects

ESMAP
Energy Sector Management Assistance Program

WORLD BANK GROUP
THE WORLD BANK IBRD • IDA
IFC International Finance Corporation
MIGA Multilateral Investment Guarantee Agency

FLAGSHIP REPORT

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Amit Jain
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ABOUT ESMAP

The Energy Sector Management Assistance Program (ESMAP) is a partnership between the World Bank and over 20 partners to help low- and middle-income countries reduce poverty and boost growth through sustainable energy solutions. ESMAP's analytical and advisory services are fully integrated within the World Bank's country financing and policy dialogue in the energy sector. Through the World Bank Group (WBG), ESMAP works to accelerate the energy transition required to achieve Sustainable Development Goal 7 (SDG7) to ensure access to affordable, reliable, sustainable, and modern energy for all. It helps to shape WBG strategies and programs to achieve the WBG Climate Change Action Plan targets. Learn more at: https://esmap.org

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Abbreviations

AC	alternating current
ASPIRE	Accelerating Sustainable Private Investment in Renewable Energy
BESS	battery energy storage system(s)
CSP	concentrated solar power
DC	direct current
EPC	engineering, procurement, and construction
ESMAP	Energy Sector Management Assistance Program
ESS	energy storage system(s)
FiT	feed-in tariff
GW	gigawatt(s)
GWh	gigawatt hour(s)
IFC	International Finance Corporation
IFRS	International Financial Reporting Standards
IPP	independent power producer
kWh	kilowatt hour(s)
kWp	kilowatt peak
LDES	long duration energy storage
MW	megawatt(s)
MWh	megawatt hour(s)
MWp	megawatt(s) peak
O&M	operation and maintenance
PPA	power purchase agreement
PV	photovoltaic
RMI4P	Risk Mitigation Independent Power Producer Procurement Programme
RTC	round-the-clock
SCADA	Supervisory Control and Data Acquisition
SIDS	Small Island Developing States
SRMI	Sustainable Renewables Risk Mitigation Initiative
TW	terawatt(s)
VRE	variable renewable energy

All currency is in United States dollars (US$, USD), unless otherwise indicated.

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Foreword

"And what do we do when the sun doesn't shine, and the wind doesn't blow?" This has been the recurring, main concern, of our colleagues at energy ministries and electricity utilities around the world, when we discuss the fact that solar and wind generators can provide the cheapest kWh in most power systems.

This fundamental question has been holding back the expansion of clean energy. As a result, too many countries are still exposed to vulnerabilities associated with fossil fuels for electricity generation. But thermal 'dispatchable' power generation often results in very expensive electricity, locking many of the world's poorest countries into a vicious cycle of power sector deficits that prevent investments, and heavy subsidies that lead to fiscal stress and further indebtedness.

With this report, the World Bank begins to address the anxieties of 'intermittent' solar and wind. We introduce a complete framework that outlines how modern battery energy storage systems can be effectively deployed and alleviate the variability of renewables. Moreover, the paper is accompanied by a Power Purchase Agreement template that can serve as a practical tool to bring private sector investments in the power sector–going beyond solar, or wind parks, with variable output.

The World Bank estimates that technological developments, and the expansion of manufacturing, have made solar panels combined with battery storage directly competitive with thermal generation for many locations around the world. This approach can reduce fossil fuels dependency in the power sector, provide affordable electricity, and at the same time reduce harmful global and local emissions.

Building on our global experience at the World Bank, and with invaluable support from our Energy Sector Management Assistance Program (ESMAP), this report brings together our knowledge, thinking, and experience, on business models for modern energy storage systems. We hope that it will be helpful to our energy sector colleagues around the world in their efforts to accelerate clean energy investments and manage costs.

Going forward, we will work with our global knowledge partners to prepare tailored training programs (battery energy storage systems academies), where we will elaborate on how to use this report and the accompanying Power Purchase Agreement, to help address the needs of specific countries and electricity systems.

We acknowledge that this is an area where technology is moving fast, costs are dynamic, and where there is relatively limited knowledge and experience. So, this is not our final word on the subject, but rather a beginning. We plan to further advance our understanding and update the content in the coming months and years. We welcome comments and suggestions that can further improve our answers to what do we can do to keep the lights on when the wind is not blowing, and the sun is not shining – without burning fuels.

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Key Findings

- **Many developing countries are exposed to vulnerabilities associated with energy imports, volatile prices, and fuel dependency.** Fossil fuel-based thermal generators have deepened the fiscal crisis in many countries, leading them into debt distress while perpetuating a vicious cycle of power sector poverty traps.
- **Deploying solar and integrating it with energy storage is a viable, cost-competitive alternative that has the potential to reduce the dependency on thermal generation, especially when leveraging private investments.** Solar-plus-storage projects share several technical and commercial features commonly associated with thermal generation such as dispatchability, firmness (i.e., constant availability) of supply, capacity payment mechanisms, among others.
- **This report distills the global experience of the World Bank and other players with projects that combine solar energy generation with energy storage systems and provides a framework for planning and executing them.** The proposed project planning tools aim to streamline the adoption of various business models for utility-scale solar-plus-storage projects, especially in countries where fuel dependency is draining limited public resources and deepening the sovereign debt crisis.
- **The report outlines three business models for solar-plus-storage power purchase agreements (PPAs):** a two-part contract for capacity and energy, a capacity contract, and a blended contract. Case studies illustrate each business model and identify challenges and opportunities. The risk allocation and technical configuration requirements of the off-taker and system operator informs the selection of the appropriate model.
- **Several developing countries have used the two-part contract, while the suitability of the business model depends on the local context.** The two-part contract model can be especially suitable in settings where electricity markets do not exist, dependence on fuel for generation is high, and only partial firmness and dispatchability is needed. Most Sub-Saharan Africa and Small Island Developing States meet these conditions. The choice of the business model depends on different variables association with the local context of and application.
- **A four-phase guided framework is proposed for planning solar-plus-storage projects.** The framework covers several requirements, from conducting the preparatory studies on the long-term least-cost plans, grid-integration, and demand forecasts, to selecting and adapting the suitable business model based on the contextual requirements, and finally implementing the project through competitive procurement methods. The selection of the relevant model is facilitated by a decision-tree. The framework is complemented by a PPA and term sheet template, which can be adapted based on the business model and use-case applied. A sample PPA and term sheet for a

two-part contract is provided. With the help of technical and transaction advisors, it can be adapted to meet the requirements of specific projects.

- **The report's ready-to-use planning framework, the decision-making tree, sample business models, and the PPA template aim to streamline the adoption of solar-plus-storage projects that leverage private investments in countries where fuel-dependency is putting stress on limited public resources.**

Solar-plus-storage contractual modalities are at an earlier stage than solar-only PPAs. The business models outlined in this report are therefore likely to continue to evolve. Practitioners and decision makers are advised to engage relevant technical and transaction advisors who can provide the necessary technical, legal, and commercial guidance on planning and implementation of solar-plus-storage power projects.

The term hybrid generation (or hybrid projects) refers to a broad set of technical configurations combining different power sources, including fossil-based generation, various renewable energy sources (wind and/or solar), and storage. This report focuses primarily on the solar-plus-storage segment of hybrid projects, specifically on solar photovoltaic systems and battery energy storage systems (BESS). The terms storage and BESS are used interchangeably in this report.

Executive Summary

Many developing countries face vulnerabilities associated with energy imports, volatile energy prices, and fuel dependency. Expensive fuel-based thermal generators have contributed to fiscal crises in many countries, pushing them into power sector debt traps.

The integration of renewable energy with energy storage systems is a cost-competitive option that can enhance the flexibility of the grid while providing several benefits, including dispatchability, firm supply, and ancillary services. This has the potential to reduce dependency on fuel-based thermal generation, especially when it leverages private investment under a long-term power purchase agreement (PPA) with independent power producers (IPPs).

While still representing a small share of the market, the number of renewable energy projects that are integrated with a battery energy storage system, especially solar-plus-storage projects, is growing rapidly. This report seeks to help developing countries plan and implement such projects as integral components of their renewable energy programs, thereby unlocking private capital and reducing dependence on public finance. The report focuses primarily on utility-scale solar-plus-storage, whether through the case studies or the business models proposed.

Challenges Facing Solar-Plus-Storage Projects

Transitioning from thermal to solar-plus-storage projects is challenging. These projects are more complex than traditional energy projects because they integrate different technologies, each with its own operational parameters, maintenance needs, and performance characteristics.

Solar-plus-storage projects can be designed in various ways, depending on the characteristics of the products and services to be delivered, the preference for dispatchability versus energy firmness, and the allocation of risk between buyers (the utility, grid operators, or the government entity) and sellers (developers or IPPs). The variety of options results in different business models, PPAs structure, and procurement mechanisms; it adds complexity to project design and its technical configuration; and it makes it challenging for stakeholders and utilities in developing countries to make decisions without expert guidance. Given the complexities of these projects and the need to attract private financing, it is important to develop a comprehensive framework for structuring and planning successful operations. This report attempts to do just that.

The trend toward storage, including solar-plus-storage, is gaining momentum. Energy storage enjoyed another record in 2022, adding 16 gigawatts (GW)/35 gigawatt hours

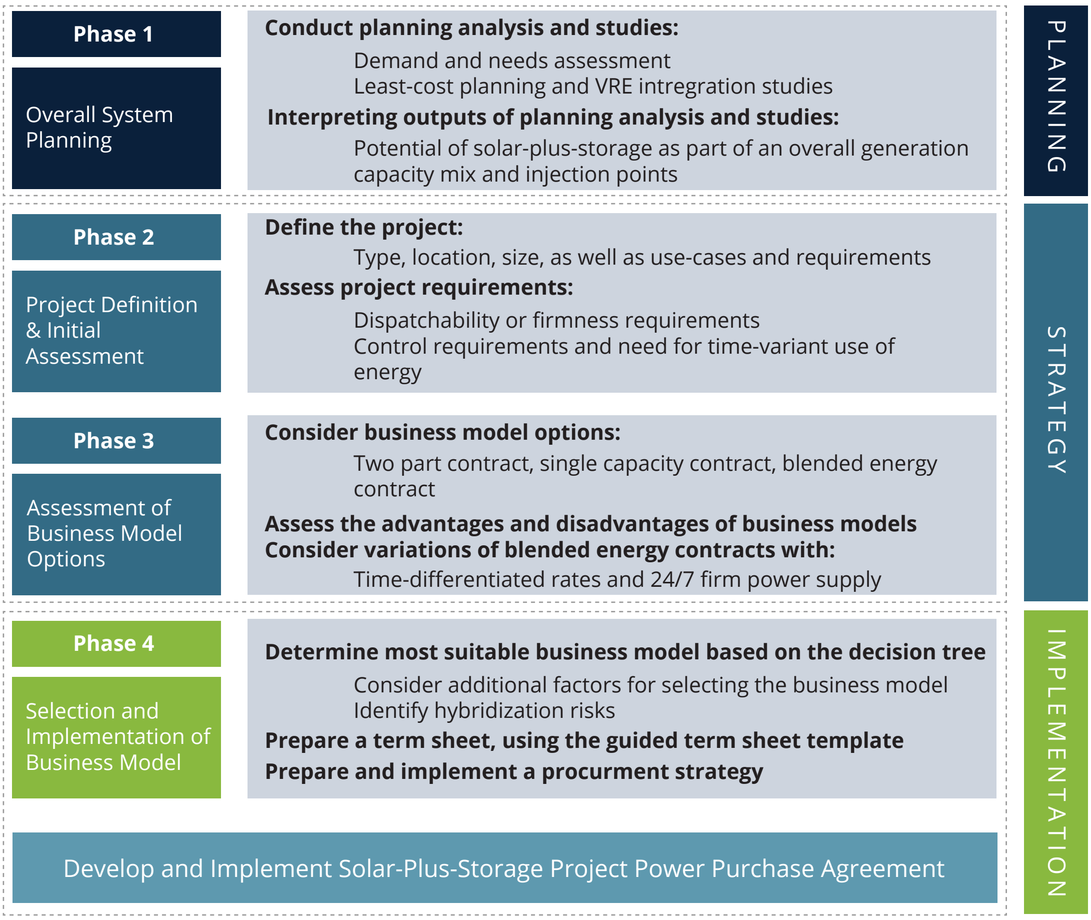
(GWh) of capacity, up 68 percent from 2021. By the end of 2030, global cumulative energy storage capacity will reach 508 GW/1,432 GWh, according to projections by Bloomberg. As these projects continue to evolve and gain momentum, regulations and policies are needed to support solar-plus-storage adoption. Regulatory constraints in many countries limit revenue streams, making it difficult to justify the high upfront costs of storage. However, the need for robust commercial structures and updated regulations and policies to support growth is becoming increasingly apparent.

The Four-Phase Framework

This report presents a four-phase framework for planning solar-plus-storage projects (Figure ES.1).

FIGURE ES.1

The Four Phases of Planning Solar-Plus-Storage Projects



The first phase focuses on overall system planning. It includes technical plans, such as least-cost planning and renewable energy integration studies, that help a country determine its potential for solar-plus-storage as part of its future energy and grid needs.

The second phase defines the project based on a detailed analysis of the country's power system needs and expansion plans. This phase characterizes use cases, the sizing of the project, and the system requirements in terms of dispatchability and energy firmness.

The third phase identifies business models that meet project-specific requirements and highlights differences among them through examples. Structuring bankable solar-plus-storage projects is key to financing clean energy projects and ensuring their long-term viability. The choice of model depends on the desired risk allocation and technical configuration requirements of the off-taker and system operator.

The report describes three main business models (outlined in Table ES.1): (1) a two-part contract that charges an energy payment based on energy used and a capacity payment; (2) a single capacity contract that charges based on a joint solar and storage capacity; and (3) a blended contract, which includes several variations. It identifies the challenges and opportunities associated with each model and provides case studies for each. It also identifies procurement options that spur competition, leading to better service and lower rates.

The fourth phase provides a decision tree to help practitioners evaluate the trade-offs involved in selecting a business model (Figure ES.2). During this phase, project designers need to identify and allocate the risks associated with the project.

TABLE ES.1

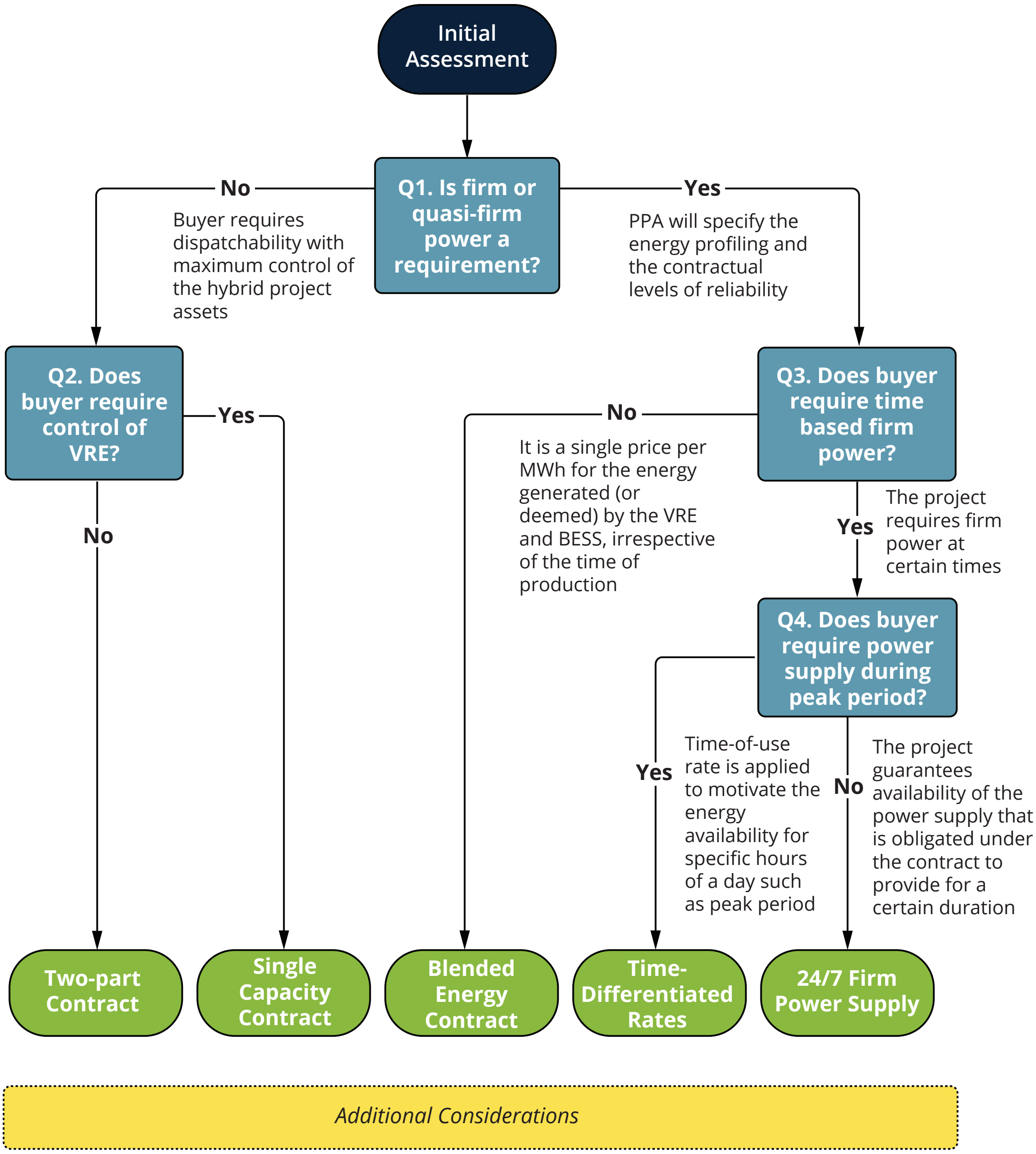
Three Business Models for Solar-Plus-Storage Projects

FEATURES	CONTRACT TYPE		
	TWO-PART CONTRACT (SOLAR PV-PLUS-STORAGE)	SINGLE-CAPACITY CONTRACT	BLENDED ENERGY CONTRACT
Involved Entities	A state utility, likely the grid operator	A state utility, likely the grid operator	A state utility or a central procurement agency, reassigning contracts to utilities
Renewable Energy and Storage Remuneration	Single contract, two types of payment: • Payment for PV is for energy produced ($/MWh) • Payment for storage is for capacity made available ($/MW/month)	Single contract, single fixed payment based on available capacity ($/MW/month)	Single contract, single fixed payment based on energy produced ($/MWh); no explicit capacity payment[a]
Variations	N/A	N/A	• Simple blended • Time-differentiated rates (peak and off-peak) • 24/7 firm power supply
Emphasis	Dispatchability	Dispatchability	Firmness
Dispatch Decision Maker	Buyer	Buyer	Seller or system operator
Operation and Maintenance	Separate O&M entity	Separate O&M entity	Separate O&M entity or the seller
Suitability of Storage Services	High	High	Low, as the seller has control of the storage assets
Risk Allocation: Resource Variability	On seller	On buyer	On seller
Risk Allocation: Curtailment	On buyer	On buyer	More on buyer
Risk Allocation: Market Variability	On buyer	On buyer	On buyer
Commercial and Technical Similarities to Thermal-Generation PPAs	Very high	High	Low for commercial characteristics; some similarities based on technical specifications of the solar-plus-storage project
Procurement/Award Criteria	Two products, simultaneous auction award possibly based on levelized cost of electricity (LCOE)	One product, award based on lowest $/MW	• Blended simple and 24 × 7: One product award based on lowest $/MWh • Time-differentiated: Two products, simultaneous auction, average peak/off peak price

[a] This pricing assumes that all resource variability, fuel costs volatility and market risks have been transferred from the seller to the buyer. Power purchase agreements (PPAs) in other jurisdictions may have more nuanced pricing structures whereby some of risks remain with the buyer, and a fixed plus variable payment structure is advisable.

FIGURE ES.2

Decision Tree for Selecting a Business Model



The Term Sheet and Power Purchase Agreement Templates

To provide a more granular illustration, one of the business models the report highlights is the two-part contract model. It provides a term sheet and a PPA template for this business model with guidance for use and implementation.

The term sheet template delineates the rights, obligations, and expectations of all parties, thereby reducing ambiguity and potential disputes and facilitating discussions with potential investors. It is particularly important given the nascent stage of many solar-plus-storage project financing structures.

The PPA template describes key clauses that should be included in a PPA under one type of business model. It is designed as a starting point, not a document that should be used as is. All PPAs will need to be customized, with the help of expert legal advisors.

The Potential of Solar-Plus-Storage Projects to Facilitate Transformational Change

Solar-plus-storage projects have the potential to revolutionize the energy landscape by reducing dependency on imported fossil fuels and enhancing energy security, particularly in Small Island Developing States and Sub-Saharan Africa. With increased energy system resilience and the mobilization of private investment, solar-plus-storage through a competitively procured IPP model can free up public resources to be redeployed for other essential services and development initiatives, supporting economic stability and growth.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2
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About this Report

Purpose of this Report

Energy storage is a key component in the transition from thermal to renewable energy-based power systems. It allows excess electricity generated from variable renewable energy, such as solar and wind, to be stored for use during periods of high demand or low sunlight, increasing the reliability and availability of renewable energy. By reducing reliance on fossil fuels, a hybrid project—a system that combines renewable energy with an energy storage system—facilitates the transition to a cleaner, more stable, and more cost-competitive energy system.

This report provides a guiding framework for planning and implementing utility-scale solar-plus-storage projects while leveraging private investments. The framework includes four phases, which cover the (1) identification and planning of a project, (2) selection of a business model from pre-set configurations, (3) adaptation of the model, and (4) use of a PPA template in a competitive procurement process. The report aims to streamline the adoption and deployment of privately owned solar-plus-storage projects, especially in countries where reliance on thermal generation is deepening their vulnerability and deficits, and limited public resources are drained in a vicious cycle of fuel dependency. The report also provides procurement options that can lead to competition and optimal tariffs.

Structure of this Report

This report is structured as follows:

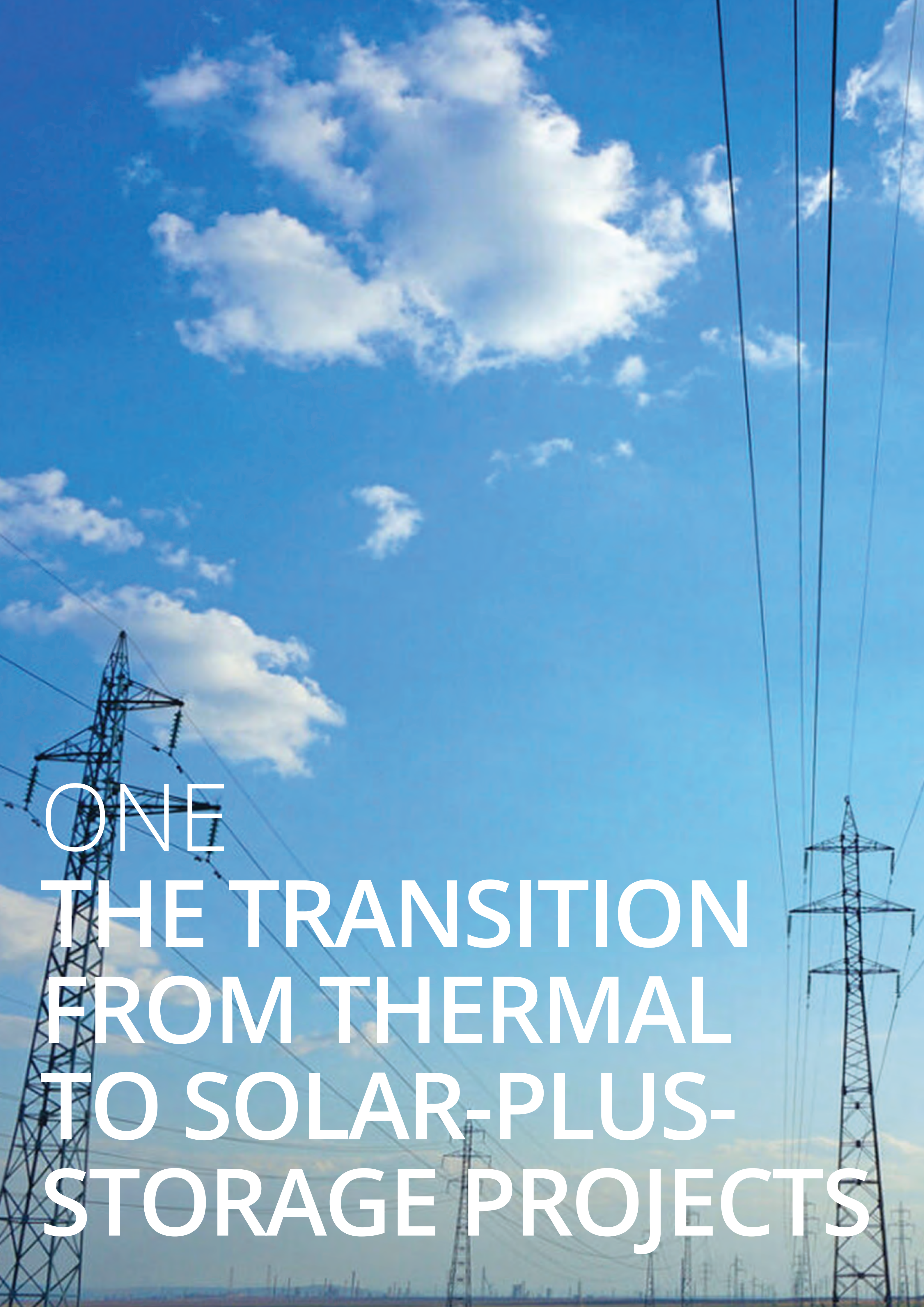
- **Chapter 1** presents the rationale for the transition from thermal to renewable energy projects combined with energy storage. It highlights how specifically solar-plus-storage projects can help to decarbonize power systems.
- **Chapter 2** introduces the business-as-usual scenario of publicly owned solar-plus-storage projects and the global trend toward IPPs owned projects.
- **Chapter 3** presents a four-phase framework, consisting of overall system planning and guidelines for selecting a business model, understanding the advantages and disadvantages of the selected model, and preparing a term sheet and PPA.
- **Chapter 4** provides guidelines for the competitive procurement of a solar-plus-storage project.
- **Chapter 5** discusses the guidelines and conclusions of the report.
- **Appendix A** presents a comprehensive list of the advantages and disadvantages of each of the three business models and their variations.

- **Appendix B** provides a template term sheet for a two-part contract business model. It provides guidance on how to structure the term sheet to ensure that all necessary components are included and properly addressed.
- **Appendix C** provides a link to a PPA template developed for the two-part contract business model considered in this report.
- **Appendix D** provides additional details on complementary knowledge resources from the Energy Sector Management Assistance Program (ESMAP) to facilitate the energy transition, especially resources on scaling up renewables and energy storage.

This report builds on several other World Bank publications, including *Scaling Up to Phase Down: Financing Energy Transitions in the Power Sector* (World Bank 2023b), the Sustainable Renewables Risk Mitigation Initiative (SRMI) framework's *A Sure Path to Sustainable Solar, Wind, and Geothermal* (World Bank 2022), *Deploying Storage for Power Systems in Developing Countries: Policy and Regulatory Considerations* (ESMAP 2020), and *Guidelines to Implement Battery Energy Storage Systems under Public-Private Partnership Structure* (Gamarra et al. 2023). Annex D provides details on these resources.

Endnote

1. The term hybrid generation (or hybrid project) refers to a broad set of technical configurations combining different power sources, including fossil-based generation, various renewable energy sources (wind and/or solar), and storage. This report focuses on the solar-plus-storage segment of hybrid projects, specifically on battery energy systems (BESS). The terms storage and BESS are used interchangeably.



ONE
THE TRANSITION FROM THERMAL TO SOLAR-PLUS-STORAGE PROJECTS

A wave of change is sweeping across the energy sector, driven by the need for cleaner, decarbonized, and more efficient energy generation and consumption. This shift from thermal to solar-plus-storage projects represents a transformative phase in the global energy paradigm. It reflects not just the emergence of new technology but a societal shift. Change is bringing modern sources of power to previously unserved populations and helping countries meet their climate targets.

Electricity demand in developing countries is rising; demand in these countries is expected to grow more rapidly than anywhere else in the next 20 years. By 2040, electricity will supply 31 percent of the world's ultimate energy needs, mostly by replacing fossil fuels in buildings, industries, and transport (IEA 2022).

Enhanced electrification, the widespread use of renewables, and increased energy efficiency measures are the three main components for decarbonizing the power sector. Each faces unique challenges.[1] The potential of solar-plus-storage projects can address several of the challenges.

Transitioning directly from thermal to renewable energy presents challenges, particularly in regions with small and weak power (grid) systems. Renewable energy resources are climate neutral, sustainable, and produce no greenhouse gases during operation, but their output is variable, making it difficult to ensure a stable and reliable power supply.

Solar-plus-storage can offer a more viable solution. They allow excess power generated during periods of high output of renewable energy to be stored for use when renewable energy output is low. The ability to store some of the power generated enhances the dispatchability and firmness of power generators, enabling them to supply power on demand while providing a more reliable and stable power supply.

This chapter examines the hybridization trend, compares thermal and solar-plus-storage generation projects, explores the adoption and economic viability of solar-plus-storage in developing countries, as well as the challenges embedded in the transition from thermal to renewable energy projects.

The Trend Toward Hybridization

The trend toward hybridization with solar-plus-storage is gaining momentum globally. According to the 2023 Bloomberg Energy Storage Market Outlook, energy storage enjoyed another record year in 2022, adding 16 gigawatts (GW)/35 gigawatt hours (GWh) of capacity, up 68 percent from 2021. Bloomberg projects that by the end of 2030, global cumulative energy storage capacity will reach 508 GW/1,432 GWh.

It estimates that energy storage installation in China alone will reach 175 GW/404 GWh in 2030, up 66 percent compared to the previous estimate. Hybrid projects are also gaining momentum in the United States. It is estimated that around 42 percent (285 GW) of all solar PV and 8 percent of all wind in interconnection queues are proposed as hybrid projects combined with storage. Solar-plus-storage currently dominates the hybrid development pipeline. (Bolinger, Gorman, et al. 2022).

In Morocco, the Noor Midelt project, commissioned in 2019, provides dispatchable concentrated solar power (CSP) for five hours after sunset for peak hours, showcasing the potential of hybrid projects in balancing grid demand (MASEN, 2022). The project achieved an impressive tariff of $71/MWh, demonstrating the cost competitiveness of hybrid renewables-plus-storage projects.

India has also made strides in adopting hybrid projects. A 2020 project provided 600 MW of firm power for peak hours for 6 hours and another 300 MW of firm power for 11 hours, with off-peak power at a fixed price (SECI 2022b). Another initiative, the Round-the-Clock (RTC) III project, tendered in 2022, added 2.25 GW, with requirement of maintaining 90 percent availability, demonstrating the cost effectiveness and reliability of hybrid renewables-based projects. India's 2023–24 budget provides funding for 4 GWh of grid-scale batteries (Indian Ministry of New and Renewable Energy 2023).

In 2021, South Africa tendered about 2 GW of technology agnostic, emergency capacity, under the Risk Mitigation IPP Procurement Program (RMI4P) to be 100 percent dispatchable between 5:00 a.m. and 9:30 p.m. Of this amount, about 1.2 GW came from natural gas generation capacity and 0.8 GW from hybrid projects (Republic of South Africa 2022).

These examples reveal the global trend toward hybrid projects, driven by their potential for improved grid stability, cost competitiveness, and enhanced utilization of renewable energy resources. As technology continues to advance, and regulatory frameworks evolve to better support these systems, hybrid projects, particularly solar-plus-storage will play an increasingly central role globally.

Comparing Thermal with Solar-Plus-Storage

Fossil fuel-based thermal projects may have lower capital costs than solar-plus-storage projects. Thermal generation is supposed to provide predictable and stable energy output, with relatively high dispatchability and responsiveness to demand. Stationary thermal plants in many countries have been poorly maintained, reducing the functionally available capacity for the system operator. Frequent breakdowns and poor performance, coupled with very high costs (especially for diesel- and heavy fuel oil-based generation) and associated price volatility, resulted in energy vulnerabilities in many countries. This reliance on expensive diesel and heavy fuel oils places a strain on these countries' public finances, increasing their deficits. Addressing the drawbacks of thermal generation, solar photovoltaic (PV) paired with storage is potentially a superior option. Even though the capital costs of these projects are higher, their operational costs are much lower—with no dependence on fuel imports. The shift to solar-plus-storage projects can free up public resources for other essential services and development initiatives, increasing economic stability and growth, especially when developed through a competitive IPP-owned model based on long-term PPAs.

Solar-plus-storage projects offers more flexibility to the system operator, because it can provide a range of ancillary services. They allow solar generation to be optimized to discharge power to the grid during periods of peak emissions intensity, reducing the need for fossil fuel-based energy sources and supporting broader decarbonization efforts. These projects can also facilitate grid balancing, by leveraging flexible capacity for system-level optimization even when it is not needed for load-matching requirements. This approach enables more effective decarbonization of the electricity grid and helps support the transition to a low carbon future.

Solar-plus-storage projects also have several other technical advantages over thermal plants. Unlike thermal generators, they operate without any minimum load requirements, enhancing their operational flexibility. Unlike thermal generators, which constantly burn fuel to stay synchronized, solar-plus-storage projects maintain grid synchronization even when not actively generating power. This difference results in substantial fuel savings and reduces environmental impact.

Solar-plus-storage projects have quick startup times, enabling them to promptly respond to demand and frequency fluctuations without burning fuel. These projects also maintain consistent efficiency at all output levels.

Solar-plus-storage projects also address the phenomenon known as the duck curve. In power grids with high levels of installed solar capacity, large imbalances can occur between electricity supply and demand that result in a drop in net demand during midday hours, when solar generation is high, followed by a sharp increase in demand as the sun sets and solar generation decreases. Battery storage in solar-plus-storage projects can help mitigate the duck curve by storing excess solar energy generated during the day and then discharging it during evening peak-demand periods. Doing so allows utilities to better balance electricity supply and demand, reducing the need for other sources of electricity, such as fossil fuels. Storage can also provide other ancillary services to the grid, such as frequency regulation and voltage control, which can improve the stability and reliability of the electric grid. All of these advantages make solar-plus-storage projects a compelling alternative for countries seeking to transition away from thermal-based power systems.

Competitiveness of Solar-Plus-Storage with Thermal Generation

In many countries that import fuel for electricity generation, tariffs can be very high, because of import costs, inefficiency of generation, and associated challenges. Such energy expenditures often drain public funding and raise the costs of many goods and services. For example, electricity tariffs in many Pacific Island countries range from $0.20/kWh (Fiji) to $0.50/kWh (Vanuatu and the Cook Islands). In the Caribbean Islands, tariffs are $0.20/kWh in Belize and St. Lucia, around $0.40/kWh in Cayman Islands, and about $0.60/kWh in Bermuda. Similarly, in many Sub-Saharan African countries, fuel-based thermal generation is one of the main sources of electricity; tariffs there are comparable to those in the island countries in the Pacific and Caribbean (Islam and Al Mamum 2017). In both categories, solar-plus-storage projects are already very cost competitive and can meet the technical operational requirements and commercial features commonly offered by fuel-based thermal generation.

The Hawai'i's Barbers Point solar-plus-storage project was awarded a PPA with a tariff of $0.112/kWh, under a single-capacity contract model that would integrate 15 MWp of solar with four-hours of storage capacity at 15 MW/60 MWh. However, the project is being revised due to financial and technical challenges, and a new bidding process may be initiated. In Morocco, the Noor Midelt project, which combines solar PV with CSP and five-hour thermal storage, achieved a $0.07/kWh tariff, under a blended contract.

In India, Solar Energy Corporation of India (SECI) Peak Power Supply procurement for renewables-plus-storage project awarded two contracts that permit the integration of renewables (solar or wind) with storage capacity for firm power. The first contract awarded 900 MW to Greenko, at a tariff of $0.086/kWh for peak period and $0.04/kWh for off-peak period. The second contract awarded 300 MW to Renew Power, at a tariff of $0.096/kWh peak period and $0.04/kWh off-peak period.

Limitations and Challenges

Solar-plus-storage projects have the potential to reduce carbon emissions and reliance on fossil fuels in many countries. But completely replacing baseload thermal power generation (with maximum penetration) through solar-plus-storage is not always practical or economically viable, especially in the short to medium term. However, in many contexts where countries depend on fuel-based thermal generation, solar-plus-storage has already become cheaper than other sources, offering the same flexibility and reliability in the power system.

One of the disadvantages of solar-plus-storage projects is that in order to maximize the displacement of thermal power generation, they must be oversized to compensate for variations in resource availability. Adding solar and storage capacity increases the initial cost of a system.

Oversizing also presents operational challenges. During periods of high solar production and low demand, the excess generated power can exceed the storage capacity of the facility, necessitating curtailment of the PV output. This waste of potential energy is inefficient and decreases the return on investment of the system.

The lifecycle of the storage can also be a limiting factor. Over time, batteries degrade. Replacing or upgrading them adds to the operating costs of the system; failing to do so can jeopardize the consistency of the power supply. The solution is either to replace them or augment them, to ensure that storage availability continues to be within an acceptable range, as defined in the original agreement while meeting the technical requirements of the operator. South Africa's Risk Mitigation Independent Power Producer Procurement Programme (RMI4P) illustrates the challenges of implementing solar-plus-storage projects to provide energy with very high levels of energy generation firmness (i.e., the controllable and reliable ability to produce electricity and meet customer requirements at any point in time) to replace baseload generation (Box 1.1).

BOX 1.1

SOUTH AFRICA'S HYBRID POWER PROCUREMENT

South Africa is in critical need of new power generation capacity to close the supply gap (projected to reach about 6 GW in 2024), improve the investment climate through reliable power, and implement its plans to decommission coal. To address these challenges, the government organized a technology-agnostic procurement process via auctions. The Risk Mitigation Independent Power Producer Procurement Programme (RMI4P) auctioned 2 GW of capacity. Bids were submitted for 5,000 MW, demonstrating interest in the program. Winning prices in the auction ranged from $89/MWh to $115/MWh, averaging $97/MWh.

The request for proposal was designed to meet flexible dispatch. Power plants needed to be 100 percent dispatchable between 5:00 a.m. and 9.30 p.m. Run contracted capacity was set for 16.5 hours a day for 15 consecutive days, with interruptions of no more than 12 hours. Bidders considered this reliability run requirement very strict, particularly because the storage could not charge from the grid at night. Most of the winning bids were organized as hybrid projects combining PV, wind, and storage, with a diesel generator backup to meet the strict reliability requirements. Only one developer (Scatec) blended renewable energy with storage, which also made it eligible for climate concessional finance.

The reliability run requirement is the critical factor determining the sizing of renewable energy and storage capacity. When high levels of dispatchability are necessary using only clean energy sources, such as renewable energy and a storage, generation and storage assets must be oversized, resulting in a less competitive PPA.

(*continues*)

BOX 1.1 (*Continued*)

To achieve 150 MW of dispatchable capacity to meet South Africa's standards, Scatec will have to install 540 MW of PV capacity and 225 MW/1,140 MWh of battery storage capacity, at a total capital expense of $962 million (Scatec 2022). Scatec resulted in one of the highest tariffs, calculated at $115/MWh, as it did not include any thermal generation to meet reliability requirements, relying completely on solar power plus storage.

The RMIP4 case illustrates the challenges and high costs of replacing baseload generation (in this case coal plants) with renewables-only sources, particularly if high levels of reliability are required from every individual PPA rather than aggregated at the grid level. It is crucial to determine appropriate reliability criteria in such tenders, as typically thermal plants have a reliability requirement of 85 percent whereas RMI4P program had much higher requirements.

Sources: ADB 2021; Scatec 2022; Republic of South Africa 2022 (https://www.ipp-rm.co.za/).

Note: The award criteria and the payout for the RMI4P program in South Africa are more complex than a typical auction for a time differentiated PPA, in which bidders provide blended energy prices for peak and off-peak hours ($/MWh). For RMI4P, prices (tariffs) are used to select and award the winning bidders and determine the monthly payout. They are calculated by the auctioneer, based on technical and economic parameters informed by the bidders. The evaluation price is a weighted average of the calculated electricity tariff (ET) (95 percent) and the ancillary services tariff (AT) (5 percent). The ET considers several cost components, including energy, fuel costs (if applicable), capital recovery for the dependable capacity (50 percent for non-dispatchable and 100 percent for dispatchable generation sources), and capital recovery costs of mandatory ancillary services. The economic assumptions provided by the bidders were compared with domestic and international benchmarks and adjusted as needed. The ET is calculated based on 70 percent and 100 percent load factors; the two figures are averaged to calculate the final evaluation price. Once the tariff is calculated, bidders are given the option to submit a best and final offer. The total payment in a billing period includes cost recovery for capacity, fixed and variable operations and maintenance (O&M), commercial energy payment, start-up costs, carbon taxes, and ancillary service cost, which are calculated based on economic assumptions provided by the bidders. Evaluation prices and tariffs are calculated separately for each technology. The methodology used to determine prices bears some resemblance to a traditional cost-plus scheme but introduces price competition.

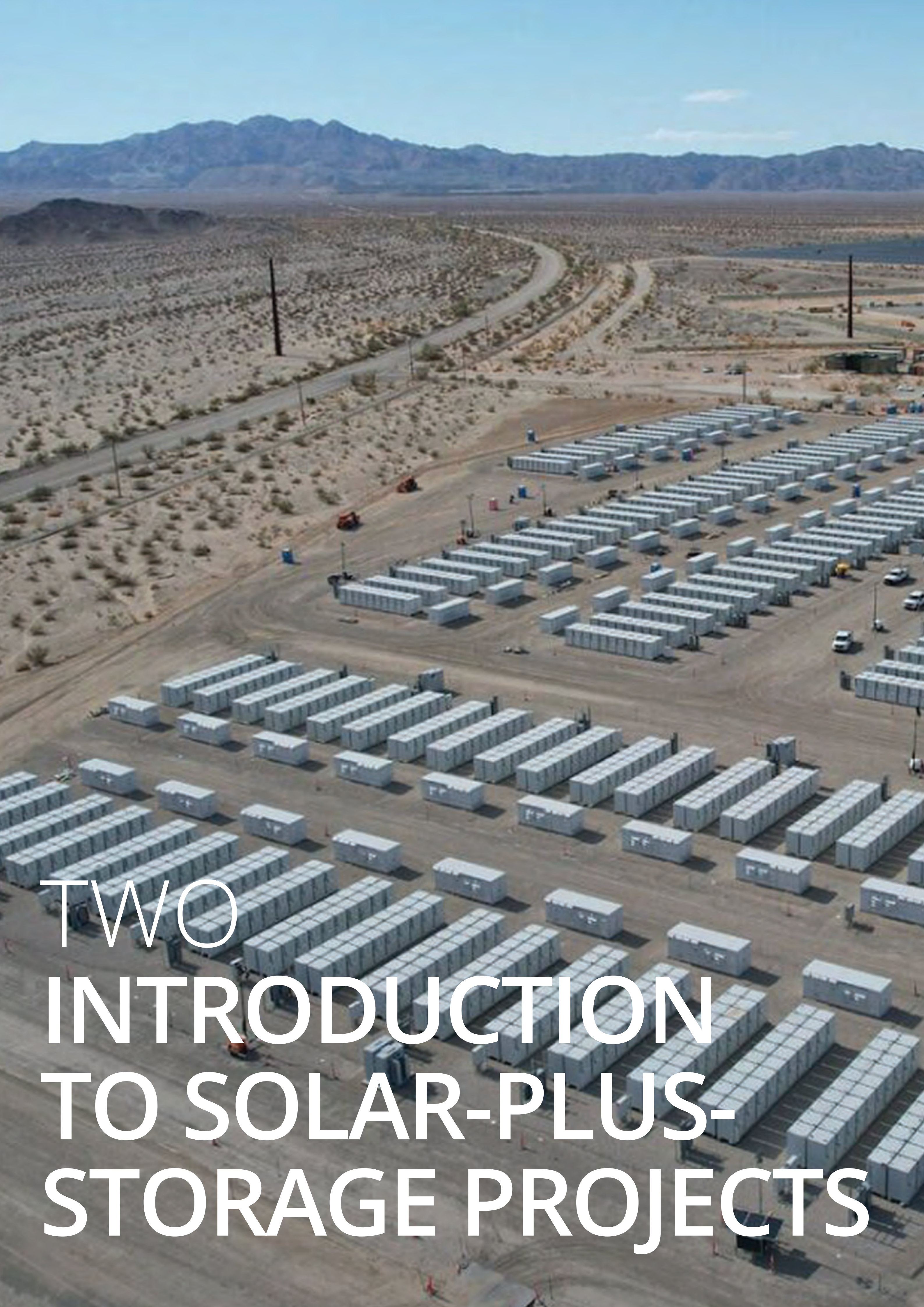
Barriers to utilities implementing solar-plus-storage projects include the complexities of operational control, the lack of automated infrastructure for Supervisory Control and Data Acquisition (SCADA) systems, and the limited technical capacity of the system operator. To work around these challenges, solar-plus-storage projects could be designed to provide autonomous services that do not rely on local measurements of metered real power, reactive power, voltage, and frequency. Technically, such power plants can function effectively without requiring supplementary inputs from the system operator. In conjunction with autonomous control, the utility can provide power schedules, voltage setpoints, or curtailment signals to finetune the dispatch of solar-plus-storage projects. The primary advantage of autonomous controls for solar-plus-storage projects lies in their capability to provide services without complex utility software and communication systems to control the resources. The best approach is a blend of autonomous control and utility-provided control signals.

These challenges can be constraining, but the potential benefits of solar-plus-storage projects are significant. The process of transition may be gradual and require overcoming barriers. It will need supportive policy and regulatory frameworks, capacity building, and innovative financing mechanisms. With the right strategy, these challenges can be addressed, especially when considering adequate technical configurations that are consistent with the control and operational capabilities of the utility while meeting the grid's requirements for reliability and flexibility.

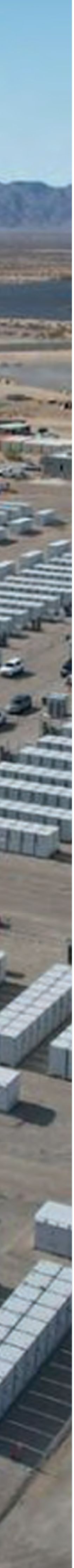
It is important to approach the energy transition with a balanced, multifaceted strategy. Thermal power generation may still have a role to play, particularly in providing baseload power and ensuring the stability of the grid. The goal should be to find the optimal mix of energy resources that best meets the needs and contextual conditions of each region and country.

Endnote

1. Enhanced electrification is the process of expanding the use of electricity across sectors to reduce reliance on fossil fuels, for mobility, heating, or other applications.



TWO
INTRODUCTION TO SOLAR-PLUS-STORAGE PROJECTS



Value Stack Services

The economic viability of solar-plus-storage projects depends on various factors, including technology costs, operational characteristics, and regulatory frameworks. Over the past decade, the costs of PV panels have decreased significantly. Storage costs followed a similar trajectory, which was interrupted by the COVID crisis and supply disruption. It is expected that storage costs will continue to decline, thanks to economies of scale, reducing overall costs and making solar-plus-storage projects more competitive.

Solar-plus-storage projects offer several benefits over standalone solar power projects that can significantly affect the technical and economic feasibility of a project:

- **Energy shifting:** Energy shifting involves storing excess solar energy generated during the day and using it during periods of high energy demand (price arbitrage). During times of peak solar generation, the excess energy can be stored in batteries instead of being curtailed for later use. It can then be dispatched when demand for electricity is high, such as in the evening hours. Energy shifting can maximize the use of renewables while contributing to grid stability and resilience, making renewables a valuable alternative to fossil-based generation. Energy shifting is considered the primary use case of energy storage, representing 54 percent of global deployments in 2022 (BloombergNEF 2023).
- **Commercial and residential use:** By integrating solar PV with storage systems, businesses and homeowners can generate renewable energy on-site, reducing their reliance on the grid and decreasing electricity expenses. Excess energy generated during low demand periods can be stored and used during peak hours, reducing electricity bills and avoiding peak demand charges. In addition to the benefit of shifting power use from peak demand charges, solar-plus-storage systems can provide backup power during power outages. Solar-plus-storage systems in commercial and residential settings provide cost savings, energy independence, and enhanced resilience, making them valuable solutions for businesses and homeowners seeking sustainable and reliable energy solutions. Commercial and residential use cases accounted for 28 percent of global deployments in 2022 (BloombergNEF 2023).
- **Ancillary services:** Solar-plus-storage projects can provide more than just electricity generation. They can also supply grid support services, such as frequency regulation, voltage control, and spinning reserves. The addition of storage greatly enhances these capabilities, by allowing for greater control over power output. The ability to provide these services to the utility or operator can potentially generate additional revenue streams for the project, increasing its economic viability. Even if no electricity market exists where ancillary services are priced and monetized, as in the case in many developing countries, such services can still be utilized as operational functions of the solar-plus-storage assets. The cost per megawatt hour of adding four-hour battery storage to a utility-scale solar renewable project is $5 to $20 per MWh, depending on the battery-to-PV capacity ratio, according to a report by the Lawrence Berkeley National Laboratory (Bolinger et al. 2022). Ancillary services accounted for 13 percent of global deployments in 2022 (BloombergNEF 2023).

- **Deferral of upgrades to transmission and distribution:** Solar-plus-storage projects can reduce the costs of upgrading the grid. Solar combined with storage can smooth fluctuations common in solar-only plants. This consistent power output can reduce the need for certain grid upgrades. Project developers can reduce project costs by consolidating solar plus storage assets at the site by sharing equipment and reducing interconnection and integration issues. Placing solar power and storage together at the utility scale could result in up to 8 percent cost savings, according to a study by the National Renewable Energy Laboratory (Denholm et al. 2019).

Public and Private Asset Ownership Models

The renewable energy sector has seen significant growth and transformation over the past decade. This evolution is reflected not only in the technology and energy sources used but also in the financial models and contract structures adopted to facilitate this growth. There has been a gradual shift from the publicly owned model deployed through turnkey engineering, procurement, and construction (EPC) contracts in the early days of the solar transition, to the increasingly popular IPP-owned model that leverages private investments. The mobilization of private investments can have different variations in the context of storage-only and solar-plus-storage generation.

The initial transition to storage was based on a publicly owned EPC model. Under a turnkey EPC contract, a single contractor is responsible for the EPC of the energy project. This model gained popularity because of its simplicity and the centralized control it offered utilities, which was critical in the early stages of the solar transition.

Recently, there has been a slow shift toward the IPP model, which allows private capital to be unlocked, thereby leading to greater economic efficiency and better use of resources. For storage-only deployments in many developing countries, the case for having the assets publicly owned and operated continues to be strong, mainly due to the lack of developed electricity markets, where storage services can be monetized in competitive settings. Business models for private sector owned storage-only solutions where grid services are offered requires further development for them to become attractive.

With the increasing penetration of renewables and the decentralization of energy systems, many utilities are transitioning from being primarily electricity suppliers owning generation assets, to managing energy networks and balancing supply and demand. This shift frees them to focus on their new roles, leaving the operation of electricity generation to IPPs. This model also promotes competition, innovation, and efficiency, as multiple independent entities are involved.

Two categories of solar-plus-storage projects can be distinguished: (a) solar-plus-storage projects that are planned as a combined system and (b) storage-only projects that are coupled with existing solar energy plants.

Hybrid energy generation can take many forms. It can include thermal with renewable energy (without storage) or solar PV and wind hybrid generation, to name only two examples. In this report, *hybrid* refers primarily utility-scale solar-plus-storage projects. Storage-only projects involve the installation of a storage without a new generation source; the storage is used to store excess electricity from existing renewable energy. Storage-only projects are often used to improve the stability and flexibility of the grid, especially in areas where a significant amount of renewable energy is already being generated.

The choice between an IPP-led model and an EPC model depends on a variety of factors. An IPP-led model may be more viable and feasible in scenarios in which the government or the utility lacks the necessary capital or technical expertise to implement the project. The attractiveness of the IPP model transcends the traditional bounds of capital and expertise, however, making it an appealing choice for countries at different stages of economic development. The strategic allocation of public resources to areas where private sector contribution is limited or nonexistent can create a compelling case for an IPP-led model, not only in developing countries but in high-income countries, as well. An IPP brings not only investment but also technical know-how and experience in managing projects. IPP-led models also harness the efficiencies of the private sector. The market competition inherent in IPP-led models encourages the pursuit of cost-effective solutions and operational efficiencies, potentially reducing the cost of energy. The framework proposed in this report focuses primarily on IPP-led models for solar-plus-storage projects.

Pricing Models

As the energy sector evolves, the complexity and sophistication of pricing structures must keep pace. In an era of hybrid solar-plus-storage projects, pricing models must accurately reflect the distinct and multifaceted value these systems provide.

Projects provide two kinds of services: energy services and capacity services. Energy services are priced in terms of energy generation ($/MWh). This pricing model is based on the actual amount of energy produced, providing an intuitive and straightforward pricing mechanism. This model has worked well for conventional power systems, in which energy production is relatively constant and predictable.

Solar-plus-storage projects also offer additional value through capacity services—the system's ability to maintain energy availability and rapidly respond to load changes, ensuring grid stability and reliability. These services are typically priced in terms of capacity ($/MW/month). The capacity services pricing model recognizes the value of available power capacity.

The transition to solar-plus-storage projects requires a pricing model that values both energy and capacity services. This combined pricing model provides a comprehensive approach to valuing the services solar-plus-storage projects provide. The different business models outlined in the report provide a range of possibilities for how the energy and capacity services are remunerated in an IPP-owned solar-plus-storage project.

Potential in Sub-Saharan Africa

Sub-Saharan Africa has many different energy landscapes, dictated by a complex mix of geographic, socioeconomic, and political factors. Some countries in the region have substantial fossil fuel resources; others rely heavily on traditional biomass or are progressively capitalizing their abundant renewable energy potential.

A critical issue confronting many of these countries is their rising dependency on imported fuel, especially heavy fuel oil, for power generation. The volatility of global fuel markets and the short-term nature of contracts often lead to high electricity tariffs.

Solar-plus-storage projects could help these countries tap into their immense potential for renewable energy generation, particularly solar PV. Implementing solar-plus-storage projects is challenging in Sub-Saharan Africa, where energy infrastructure is often weak, and the regulatory and financial environments are uncertain or complex.

In many Sub-Saharan African countries, the policy and regulatory framework may not be conducive to the deployment of solar-plus-storage projects. Issues include a lack of clear guidelines for grid interconnection of solar-plus-storage projects, uncertain or unfavorable tariff structures, and barriers to private sector participation in the energy sector. In addition, the technical expertise required to design, install, and maintain these solar-plus-storage projects may not be readily available. This lack of local capacity can lead to reliance on foreign experts and companies, increasing costs and potentially leading to systems that are not optimally designed for local conditions. A comprehensive policy and regulatory framework on overall planning may be required.

Potential in Small Island Developing States

Small island developing states (SIDS) possess unique energy landscapes, shaped largely by their geographical characteristics and size. They often have small-scale power systems and high dependence on imported fossil fuels for electricity generation, which creates significant challenges and vulnerabilities. Most SIDS have high solar irradiance, making them ideal for the integration of renewable energy systems.

Solar-plus-storage projects have the potential to revolutionize the energy landscape in SIDS. These systems can harness renewable resources and offer a stable, reliable, and more sustainable solution to the energy needs of SIDS. Solar-plus-storage projects reduce these islands' dependency on imported fossil fuels and enhance their energy security. Some SIDS encounter many of the challenges faced in Sub-Saharan Africa. As in Africa, the potential for solar-plus-storage projects in SIDS is high.

Maldives is highly reliant on imported fuels for electricity generation. This dependence results in high electricity prices and supply disruptions, hampering economic development and affecting the quality of life (Box 2.1). To address the problem, the government has set ambitious targets for renewable energy deployment and aims to achieve net-zero emissions by 2030. Given the country's tropical climate, abundant sunlight, and scattered islands, solar power generation coupled with energy storage systems presents a compelling opportunity.

BOX 2.1

MALDIVES' TRANSITION FROM THERMAL TO SOLAR-PLUS-STORAGE PROJECTS

Maldives consists of nearly 1,200 coral islands in the Indian Ocean. With a population of about half a million people, the country has high human development indicators and is a top tourism destination. It is also highly dependent on fuel imports and threatened by rising sea levels.

Its transition to renewable energy began in 2012, with the Scaling up Renewable Energy Program (SREP) Climate Investment Plan (CIP). The CIP identified key interventions, such as scaling up renewable energy in Greater Male and the Outer Islands and supporting capacity building. The project led to the development of the World Bank-funded Accelerating Sustainable Private Investment in Renewable Energy (ASPIRE) and Accelerating Renewable Energy Integration and Sustainable Energy (ARISE) projects, which will establish 53.5 MW of solar capacity and 50 MWh of battery storage, reducing the country's import bill by $30 million a year.

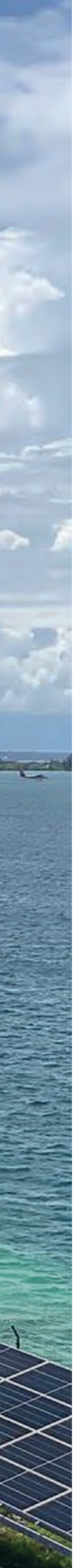
To support the transition to renewable energy, Maldives is implementing solar-plus-storage projects. It will build three solar PV arrays with a combined capacity of 36 MW and a 40 MWh storage to improve the integration of solar PV into the national grid. By offering ramping, spinning reserves, and frequency response that adheres to the utility SCADA dispatch signal, the storage aims to enhance the integration of solar PV into the country's electrical grid. To reduce curtailment and ensure seamless integration of renewable energy into the system, Maldives chose one-hour storage units to avoid PV curtailment instead of discharging the batteries during peak hours to reduce peak demand (peak-shaving).

Sources: World Bank 2023; Maldives Energy Authority 2019; ESMAP 2019.

The Maldives is an excellent test case for demonstrating the feasibility and benefits of transitioning from thermal generation to solar-plus-storage projects in SIDS. Successful implementation of solar-plus-storage projects there could serve as a blueprint for other SIDS facing similar energy challenges, offering valuable lessons on the practicalities of such a transition.

THREE

THE FOUR-PHASE PLANNING FRAMEWORK

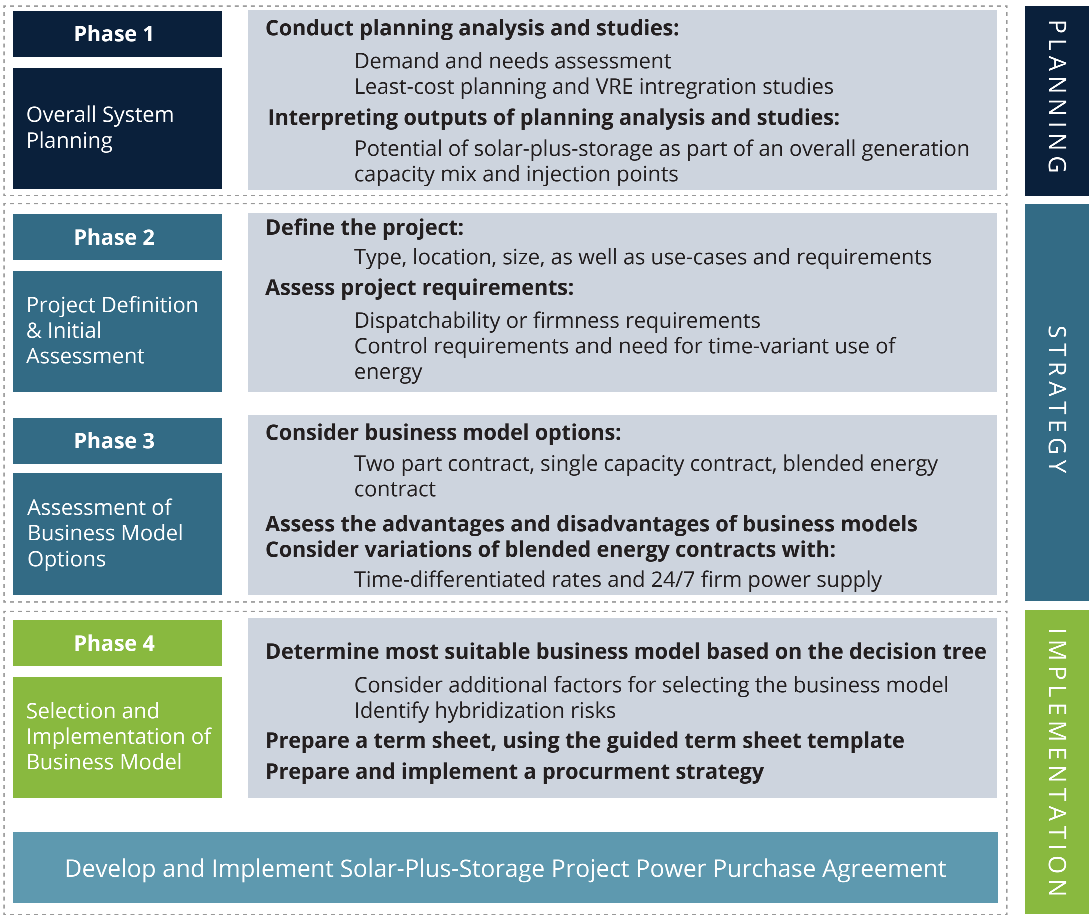


Solar-plus-storage projects are more complex than traditional renewable energy projects. They involve integrating different technologies, each with its own operational parameters and functions, performance characteristics, and maintenance needs. Given the complexities of these projects and the need for private financing, it is important to have a comprehensive planning framework.

This chapter presents a four-phase framework for structuring and planning solar-plus-storage projects (Figure 3.1). It provides guidelines for determining and selecting the appropriate business model based with a focus on privately financed modality (IPP-owned projects). The framework is aligned with the three-phase approach presented in the *Renewable Energy Deployment Guidelines* for privately financed sustainable renewable energy projects prepared under the Sustainable Renewables Risk Mitigation Initiative (SRMI) (World Bank 2022). The framework's primary objective is to help practitioners streamline the adoption and deployment of solar-plus-storage schemes in developing countries, while leveraging private investment. The framework may be applicable for planning other forms of hybrid projects, although certain adaptations would be required.

FIGURE 3.1

The Four Phases of Planning Solar-Plus-Storage Projects



In the first phase, corresponding to the SRMI planning phase, technical plans, such as least-cost planning and renewable energy integration studies, are prepared to determine the potential for solar-plus-storage systems as a part of the country's future energy needs. In the second phase, corresponding to the SRMI strategy phase, the solar-plus-storage projects are defined, with an initial assessment based on the clear characterization of use cases, the sizing of the project, and the system requirements in terms of dispatchability and energy firmness. The third phase, also corresponding to the SRMI strategy phase, identifies business models that meet the project-specific requirements and examines the differences among them through examples. In the fourth phase, corresponding to the SRMI implementation phase, a business model is selected, a term sheet is prepared, and a procurement strategy is developed and implemented.

Phase 1: Overall System Planning

The overall system planning phase reflects the guidelines provided in the World Bank's SRMI framework. The initial phase focuses on preparation studies and technical plans, such as demand and needs assessment, least-cost capacity planning, and renewable energy integration studies. The purpose of this phase is to evaluate and determine the potential for solar-plus-storage as part of the power system plans. These studies also inform technical and economic viability, optimal location and sizing, and associated grid upgrades needed for integration. While such studies would be necessary for a comprehensive view of the power system when planning solar-plus-storage projects, it is possible to have combined streamlined analysis for techno-economic feasibility, which can be completed in a shorter timeframe.

Several considerations generally guide the formulation of these studies, including the following:

- What is the projected power demand, based on different scenarios, and what generation capacity will be required to meet them?
- How would development of large-scale renewable energy facility affect net demand and the potential for a solar-plus-storage project?
- What are the limits of the large-scale renewable energy penetration, and what role can storage play in its flexibility?
- What grid and dispatch reinforcements are needed, and when do they need to be made?

Effective power development planning provides governments with ownership over policy implementation and limits the risks of bilateral negotiations with private developers. A comprehensive set of planning studies helps policymakers select the best strategies and projects and build the necessary transmission infrastructure in anticipation of future generation projects. From the perspective of IPPs, these studies lower the perceived risks of project cancellations or to grid integration issues leading to power curtailments.

De-risking the infrastructure development process through informed studies also reduces the cost of capital, leading to more economically viable investments and projects.

The following is a brief overview of the key studies required under this phase.

Demand and Needs Assessment

The major objective of power development planning is to outline the approaches for meeting existing and future load demand. It is highly dependent on forecasted demand. The main parameters of a demand assessment include the following:

- Socioeconomic trends, such as population and economic activity forecasts (growth rates, sectoral dynamics, etc.) and the locations of grid-connected and off-grid areas
- Electricity needs for domestic and productive uses and time horizons for forecasts
- The geographical distribution of demand growth and current loading for substations at distribution and transmission networks

Assessments need to address the demand expected from new connections to the grid, reflecting electrification plans that provide timelines for new connections and their associated demand.

It is important to consider how demand might be affected by increased energy efficiency, demand response, the installation of decentralized rooftop PV systems, and the accelerated deployment of electric vehicles. Improvements in energy efficiency can affect the volume of electricity needed by single customers and alter overall system demand. Significant scale-up of rooftop PV production can lead to a significant drop in net load during midday (when solar generation is high), followed by a steep increase in the evening (when solar generation diminishes and demand peaks). Such a pattern is referred to as the duck curve. It is crucial to plan separately for both energy requirements using renewable energy and peak capacity requirements using storage.

Least-Cost Capacity Planning

Once demand forecasts are derived, the next step is to determine how best to meet demand. Determining the optimal generation solution requires developing least-cost expansion plans for off-grid and grid-connected areas.

In order to match grid-connected demand and power supply, two intertwined plans need to be prepared by the government and/or the state utility: (1) a least-cost generation plan that determines a cost-optimized electricity mix that can meet demand at any time and (2) a least-cost transmission plan. These capacity expansion models simulate investment in generation and transmission capacity given assumptions about future electricity demand, fuel prices, technology cost and performance, and policy and regulations. The variation in hourly and monthly renewable energy resource availability can be analyzed to optimize the value of electricity injection to the grid, given the hourly load in the electrical grid net of renewable energy generation and the type of other power plants.

Inputs into these two plans include the following:

- A grid flexibility analysis that will determine where the renewable energy will be connected to the grid and how much of it can be integrated into the grid given its current configuration
- A demand forecast that reflects the objectives set in the electrification plan
- A list of committed and existing generation projects
- An assessment of domestic solar, wind, and other renewable resource potentials, plus energy storage potential as part of the national energy generation capacity (and ESS for transmission and distribution capacity)

In specific scenarios, a country may adopt a strategic approach to undertake a solar-plus-storage project by incorporating de-risking measures. These measures could involve various financial incentives, such as viability gap financing and other instruments aimed at encouraging private sector investments and facilitating the project's successful implementation. Even at a time when a solar-plus-storage project may not be the least cost based on conventional modeling functions, its strategic deployment for renewable energy targets and optimizing renewable energy penetration may require the aforementioned strategic approach. Such an approach would be relevant when considering nationally determined contributions (NDCs), climate financing associated with renewable energy, and limits associated with carbon emissions.

Grid Flexibility Analysis

Two key analyses for determining grid flexibility are simulating dispatch capabilities and renewable energy integration studies.

Simulating Dispatch Capabilities

Evaluating the flexibility of a grid requires assessment of its technical constraints. Does it, for example, lack a centralized data, automated control, and dispatch system (e.g., a SCADA system)? Does it have automatic generation control or a type of generation that by its nature is not highly reactive? It is also important to integrate commercial constraints, such as take-or-pay PPAs, grid code requirements for how much support a generator must provide the grid, and key performance indicators for utility-owned generators, all of which can inhibit the smooth integration of renewable energy.

Renewable Energy Integration Studies

Power flow studies and stability assessments are conducted and their results assessed as part of the economic analysis conducted for the least-cost expansion plan that looks at the following requirements, among others: the solar PV and storage capacity that can be accommodated while guaranteeing grid stability and the reliability of power, considering storage capacity, reserve needs, and ramping reserve requirements.

The output of the least-cost capacity planning and grid flexibility will help quantify the potential of solar-plus-storage systems as a part of overall system needs. Considering the regionalized demand forecast developed, and the least-cost power system planning performed with grid flexibility and renewable energy integration analysis, it is important to determine the optimal position on the grid for the solar-plus-storage projects.

High-Level Locational Study

Once the preliminary capacity of a solar-plus-storage project has been determined, it is important to identify the optimal injection points into the grid and what power plants can do to support it. The locational study allows multicriteria analysis of renewable energy resources (e.g., solar irradiation for solar generation); land availability; the capacities of existing grid infrastructure (e.g., lines, substations) for power evacuation; the proximity of demand centers to supply; and social acceptability. These results inform transmission and distribution plans, identifying places where the grid infrastructure needs to be upgraded.

Defining clear grid service rules helps cover several risks, for both grid operators and IPPs. Updating the national grid code with international best practice for interconnecting solar-and-storage will ensure that grid management will be as easy and inexpensive as possible.

At the end of the planning stage, governments will know where best to locate projects and what investments are needed to improve their grid integration capacity. The government may wish to set up common infrastructure (e.g., solar and wind parks) to reduce the time and cost risks of land acquisition and interconnection approval by private developers. For more detailed medium- or long-term planning and preparation of solar-plus-storage projects, practitioners may adopt the World Bank's SRMI framework.

Streamlined Techno-economic Feasibility Analysis

In some contexts where there is relatively low penetration of renewables and high dependency on imported fuels for electricity generation, accelerating a streamlined approach for solar-plus-storage projects may be possible.

In parallel, a technical-economic study—pre-feasibility for multiple sites and feasibility for short-listed sites—can be performed. The core elements required for the study include: (a) grid-integration analysis to order to identify the immediate grid-upgrade requirements for optimal integration of the asset and (b) renewable energy resource analysis. A techno-economic analysis would inform the development of the competitive tender and auction documentation, and build private sector confidence regarding participation. A streamlined and expedited approach could build on the guidelines and framework proposed in this report, facilitating the adoption of relevant business models (e.g., two-part contract) together with adaptation of the key documents (i.e., the PPA and the term sheet).

Phase 2: Project Definition and Initial Assessment

The second phase lays the groundwork for selecting the business model of a solar-plus-storage project. The project definition and initial assessment, which builds on and complements the planning phase, aims to determine the following:

- The intended use cases for both the solar and the storage assets
- The location of the project and the sizing of the solar and storage assets[1]
- Whether the project will be part of a larger solar-plus-storage project

The initial assessment addresses two key aspects that differentiate business models for solar-plus-storage projects—the need for dispatchability versus firmness and the requirement of full or partial control over the solar PV asset. The need for dispatchability or firmness determines the buyer's grid requirement for a solar-plus-storage project. The need for full or partial control evaluates the level of operational control the buyer requires over the solar-plus-storage power plant, based on the existing technical capacities for the utility and grid operator.

What is the Priority: Dispatchability or Firmness?

Dispatchability reflects the prerogative ability of the utility/system operator to:

- Have some control over the storage use (cycles, depth) in order to optimize the limited resource base (where existing resources, including reserves, are not enough to keep the lights on) and reduce the variable costs of diesel generation
- Have ample control over and flexibility of the storage to dispatch for use cases (peak shift, reduced load-shedding, provision of ancillary services, and so forth)
- Have maximum control of the solar-plus-storage assets, to provide a full range of services, including the services described above as well as voltage control and reactive power production by underscheduling solar PV production

Firmness reflects the prerogative ability of the utility/system operator to:

- Have firm or quasi-firm energy provided by the seller, based on an agreed energy profiling and with a certain level of availability (daily, monthly, yearly) [2]

- Hold the seller responsible for sizing, locating, and selecting technologies and operating the system
- Accept having less control (dispatchability) of the system, whereas the seller must fulfill its contractual obligations but not necessarily provide ancillary services upon demand (except for the ones specified by the grid code) and can choose to monetize the ancillary services in other markets

In the absence of the necessary automated control infrastructure and SCADA to dispatch the storage assets, it is not possible to manage a dispatchable system. However, the solar-plus-storage project dispatched by the seller can offer quasi-firm or firm capacity solutions to the buyer.

Partial, Full, or No Control?

Three types of control are possible for the buyer in a solar-plus-storage project: full control, partial control, and no control. If the buyer needs more control, the PPA should provide more dispatchability. If the power system needs more firmness, the buyer will have less control over how the assets are dispatched.

Full control means that the buyer has complete control over the dispatch rights of both assets.[3] The entire renewable energy plus storage portfolio is offered to the buyer, who makes decisions about how and when to use the storage, which will provide ramping, spinning reserve, and frequency response services by following the utility SCADA dispatch signal. The buyer also has full control over the renewable energy asset. Although the resources are considered non-dispatchable, the buyer can still make decisions about when and how much to underschedule the renewable energy to provide some ancillary services, such as voltage control.

Partial control means that the buyer has control only over the dispatch rights of the storage. The buyer can control the storage within its technical limits, with a daily cycling limit set forth in the agreement. Renewable energy is usually controlled by the seller. However, the seller has no obligation to firm up energy.

No control means that the buyer does not control the assets for the delivery of energy, but the seller has obligations to prepare the system, dispatch the assets, and deliver the energy to the buyer per the requirements in the agreement. No control by the buyer usually leads to more firmness over the dispatchability requirement by the buyer; the readiness of the system to deliver firm capacity is usually the seller's responsibility.[4]

Determining the level of control possible and required, based on the technical capacities of the utility and the grid operator, informs the possibilities around dispatchability and firmness for the project—and by extension the business model for the solar-plus-storage project.

Phase 3: Assessment of Business Model Options

After the project's technical configuration and requirements are determined, based on buyer needs and the local context, then the appropriate business model is selected. The models presented in this chapter cover a variety of case studies, based on a survey of projects and interviews conducted with companies and stakeholders in different countries.[5] The list is not exhaustive; future projects or companies could use different models or variations of the models presented.

Every country has its own set of needs and requirements; the most suitable business model may vary even within a single country. The model's suitability model is informed by the following questions:

- Which entities are involved, and how are risks allocated among them?
- What service obligations are imposed (and on whom)?
- Who owns the assets (generation, transmission, and distribution)?
- How are the assets controlled, and what are the capacities of the utility and grid operator?
- How is pricing handled and payments made?

Table 3.1 compares the three business models.

The following sections give an overview of the three main business models and discuss their potential advantages and disadvantages. Examples are provided for deployment in different countries, in addition to in-depth case studies that outline the main features of applied business models.

Two-Part Contract (Solar and Storage)

The two-part contract ensures that both the energy and capacity components of a solar-plus-storage project are appropriately priced and compensated for. One part of the contract is for the output of a solar PV plant in a given period. The second is for the storage capacity made available in a month.

In a two-part contract model, specific service obligations are imposed on different entities. The seller owns and ensures the provision of electricity from the solar PV system and the availability of the storage capacity. The buyer (typically a state utility or grid operator) enters into an agreement to purchase the energy and access the storage capacity without owning the assets.

The solar PV plant is remunerated based on the energy it produces.[6] A fixed monthly payment per megawatt is made for the storage capacity, adjusted for unavailability if necessary. Compensating the storage through a capacity payment recognizes the value of its storage capabilities, which provide flexibility and stability to the grid, enabling the buyer to manage energy demand more efficiently. For example, a 10 MW storage with a capacity payment of $9,000/MW/year with a maximum of one cycle per day would receive a fixed (unadjusted) payment of $90,000/year ($9,000 * 10), or $7,500/month ($9,000 * 10/12), if fully available. Both parts of the contract are part of a single contract signed by the seller. Solar is compensated on a per kilowatt hour (kWh) basis.

TABLE 3.1

Features of Business Models Used in Solar-Plus-Storage Project Contracts

FEATURES	CONTRACT TYPE		
	TWO-PART CONTRACT (SOLAR-PLUS-STORAGE)	**SINGLE-CAPACITY CONTRACT**	**BLENDED ENERGY CONTRACT**
Involved Entities	A state utility, likely the grid operator	A state utility, likely the grid operator	A state utility or a central procurement agency, reassigning contracts to utilities
Renewable Energy and Storage Remuneration	Single contract, two types of payment: • Payment for PV is for energy produced ($/MWh) • Payment for storage is for capacity made available ($/MW/month)	Single contract, single fixed payment based on available capacity ($/MW/month)	Single contract, single fixed payment based on energy produced ($/MWh); no explicit capacity payment[a]
Variations	N/A	N/A	• Simple blended • Time-differentiated rates (peak and off-peak) • 24/7 firm power supply
Emphasis	Dispatchability	Dispatchability	Firmness
Dispatch Decisionmaker	Buyer	Buyer	Seller or system operator
Operation and Maintenance	Separate O&M entity	Separate O&M entity	Separate O&M entity or the seller
Suitability of Storage Services	High	High	Low, as the seller has control of the storage assets
Risk Allocation: Resource Variability	On seller	On buyer	On seller
Risk Allocation: Curtailment	On buyer	On buyer	More on buyer
Risk Allocation: Market Variability	On buyer	On buyer	On buyer
Commercial and Technical Similarities to Thermal-Generation PPAs	Very high	High	Low for commercial characteristics; some similarities based on technical specifications of the solar-plus-storage project
Procurement/Award Criteria	Two products, simultaneous auction award possibly based on levelized cost of electricity (LCOE)	One product, award based on lowest $/MW	• Blended simple and 24 x 7: One product award based on lowest $/MWh • Time-differentiated: Two products, simultaneous auction, average peak/off peak price

Note: Appendix A provides a comprehensive list of the advantages and disadvantages of each model. n.a. = Not applicable.

[a] This pricing assumes that all resource variability, fuel costs volatility and market risks have been transferred from the seller to the buyer. PPAs in other jurisdictions may have more nuanced pricing structures whereby some of risks remain with the buyer, and a fixed plus variable payment structure is advisable.

The operation and maintenance (O&M) of these assets are generally handled by a separate entity, ensuring optimal performance and availability in accordance with the contract. The buyer, however, retains the authority to make dispatch decisions, determining when and how to utilize the energy from the PV system and the capacity from the storage.

In a two-part contract model, the seller typically bears the variability risk associated with the solar resource, including fluctuations in PV energy production. If the resource output is lower than expected, the seller absorbs the associated risk. The buyer assumes the risk of curtailment, which means it is responsible for managing and mitigating the risk of reducing energy output because of grid limitations or other factors.

The advantages of a two-part contract include the following:

- The private sector owns, develops, and finances both the PV and storage assets.
- The buyer (utility or grid operator) has the flexibility to dispatch the storage to meet various requirements, such as peak-shaving, mitigation of PV curtailment, and reduction of load-shedding.
- The model is suitable for providing ancillary services with storage, such as frequency regulation, voltage regulation, reserves, and among other services.
- As many important risks, such as resource volatility, curtailment, and market risk, remain with the buyer, the project can be highly de-risked for the private sector, enhancing its bankability. This feature is important in a nascent industry, where financiers are still getting acquainted with storage as a new asset class.

The disadvantages of a two-part contract include the following:

- Sellers are not obligated to firm up the energy delivered. The buyer must do so with its own portfolio or resources, such as plants, contracts, and reserves.
- The model may not be able to attract funds earmarked for financing storage only.
- Competitive procurement is slightly more complicated than in a traditional solar PV PPA, because the award seeks the lowest cost solution for two simultaneous products opened for bidding in the auction—energy for the PV and capacity for the storage.

Several countries have adopted two-part contracts, in order to improve renewable energy integration, increase renewable energy penetration, and enhance grid stability (Table 3.2 and Box 3.1). A project in South Andaman, India, for example, both smooths variable

TABLE 3.2

Examples of Projects that Adopted Two-Part Contracts

PROJECT	LOCATION	SYSTEM SIZE	
		SOLAR PV	STORAGE
Boulder Solar and Storage	Nevada, United States	128 MW	58 MW/232 MWh
Ambatolampy Solar Park with Storage	Ambatolampy, Madagascar	40 MW	5 MW/5 MWh
South Andaman Solar and Storage	South Andaman, India	20 MW	16 MW/8 MWh

generation and regulates the frequency (frequency response) to improve the stability of the grid (renewable energy ramp control).

Single-Capacity Contract

A single-capacity contract model combines solar PV and storage in a single contract and remunerates both assets based on the capacity the combined system makes available to the buyer. The seller has the sole obligation to provide the specific energy capacity agreed upon in the contract. The buyer relies on the seller to ensure the availability of the contracted capacity.

This model resembles a tolling agreement used in thermal generation, where the seller owns the assets and receives fuel from the buyer for processing. In a single-capacity contract model, the seller owns the assets, while a separate entity is responsible for the O&M functions, based on the contracted capacity to the buyer on behalf of the seller. The buyer's role is to receive the contracted capacity and utilize it within the grid system or distribute it to end consumers. The sizing of the storage capacity in relation to the solar PV asset varies, as per the examples outlined in Table 3.2.

The basic payment is made on a cost per megawatt per month ($/MW/month) basis. The capacity payment ensures that the asset owners receive a fixed payment whether or not the assets are called upon to provide electricity. Therefore, in a single-capacity contract model, the buyer typically assumes the key risks associated with resource variability, curtailment, and market fluctuations.[7]

The advantages of single-capacity contract include the following:

- The model allows buyers (utilities or grid operators) to jointly optimize assets to provide energy and ancillary services. It is more likely to capture the "value stack" of storage services with PV, because of the high control capability.
- Remuneration based on a fixed payment for the capacity of PV and storage shifts much of the risk from the seller to the buyer.
- The model gives full control of solar-plus-storage assets to the buyer while mitigating the financial risk associated with curtailment for the seller.[8]

The disadvantages of a single-capacity contract include the following:

- The model is relatively new. Experience with it is therefore limited.
- Buyers and regulators may feel uncomfortable with this unusual risk allocation profile and form of remuneration. In a rate case, it may be difficult to justify to regulators that the model is cost effective and maximizes benefits to end-users.
- The model requires secure and uninterrupted communication between the dispatcher and the assets to fully utilize their dispatchability remotely.

Several projects in Hawai'i have adopted single-capacity contracts (Table 3.3 and Box 3.2). This kind of contract can be optimal in some island grids that have limited resources to generate electricity and cannot be connected to a neighboring grid.

Box 3.3 represents an unconventional example of single-capacity contract for a special-use deployment.

TABLE 3.3

Examples of Projects in Hawai'i that Adopted a Single-Capacity Contract

PROJECT	SYSTEM SIZE	
	SOLAR PV	STORAGE
Kamaole Renewable Dispatchable Generation Project	40 MW	40 MW/160 MWh
Kahana Renewable Dispatchable Generation Project	20 MW	20 MW/80 MWh
Barbers Point Renewable Dispatchable Generation Project	15 MW	15 MW/60 MWh

Source: Hawai'ian Electric 2023.

Blended Energy Contract

The blended energy contract model consists of a single agreement in which the buyer (typically a state utility or central procurement agency) enters into a contract with the seller for blended energy. This arrangement generally encompasses both solar PV and storage, although it can also involve a portfolio with additional nonrenewable energy assets. The seller is compensated based on the energy generated ($/MWh), without any explicit capacity payment.[9] If, for example, a solar PV plant produces 12.5 MWh in a particular day, of which 2 MWh are stored and 10MWh are provided directly, the buyer pays the seller for 12 MWh per day. The remuneration rate is agreed upon in the contract. The time of the energy delivery does not change the energy rate. The seller or the independent asset operator is responsible for O&M.

The advantages of blended energy contract include the following:

- The model is less complex than other models, with single pricing on a cost per megawatt hour ($/MWh) basis. The seller pairs renewable energy assets with storage but trades firm or quasi-firm power on an energy-only (MWh) basis.
- The seller has more control over the operation of the storage and makes dispatch decisions to ensure that the firm or quasi-firm contracted amounts are delivered. The seller has more autonomy to make decentralized decisions, including islanding, leading to a more resilient system.[10]
- Several sources of power generation and storage are able to be blended into a single contract.

The disadvantages of blended energy contract include the following:

- The buyer has less flexibility to manage storage assets, which is not advisable in small or weak systems with limited reserves.
- There are more risks to sellers to comply with contractual obligations to deliver the agreed upon load profile. In smaller grids, or in case of spot market absence,

the seller will have fewer options to combine resources/contracts to meet its contractual obligations.

- Projects are more complex for sellers to manage because sellers assume some of the volatility risks and make decisions on the optimized use of the assets.

Several projects have adopted a blended energy contract (Table 3.4 and Box 3.4).

A single-pricing blended energy contract gives the buyer less flexibility to manage assets; it is the seller who makes dispatch decisions to ensure that the firm or quasi-firm contracted amounts are delivered. Such contracts will not work well with applications such as shifting solar generation to supply peak demand, unless specific dispatch hours are provided and agreed upon between stakeholders.

Burkina Faso's least-cost generation plan has the dual objective of facilitating greater PV penetration while reducing the need for new diesel or heavy fuel oil plants. The World Bank is working with the government of Burkina Faso to deploy 300 MWp solar PV paired with 100 MW/300 MWh of storage across two sites. The storage sizing was defined based on a financial analysis requiring the overall blended PPA tariff to be lower than imports from Côte d'Ivoire ($0.10/kWh). With that price target, the two projects were sized at 300 MW of PV and 100 MW of storage with a three-hour duration.

The project's technical structure is designed so that the storage is charged only from solar PV during the daytime. The intended primary operational function of the storage is to shift solar energy generation to the time of day when demand is highest. The storage would also provide some (modest) smoothing of PV production, given the sizing of the battery. The overall goal is to maximize the utilization of renewable energy sources and reduce dependence on nonrenewable energy sources. Box 3.5 provides more details on the planned solar-plus-storage PPA approach in Burkina Faso, which reflects the time-differentiated variation of the business model.

TABLE 3.4

Examples of Projects that Adopted a Blended Energy Contract

PROJECT	LOCATION	SYSTEM SIZE	
		SOLAR PV	STORAGE
Golomoti Solar-Plus-Storage Project	Malawi	28.5 MW	5 MW/10 MWh
Lawai Solar-Plus-Storage Project	Kauai Island, Hawai'i	28 MW	20 MW/100 MWh
Floating Solar-Plus-Storage Project	Andaman, India	4 MW	2 MW/1 MWh

Source: SECI 2020; Hawai'ian Electric 2023.

BOX 3.1

EXAMPLE OF A TWO-PART CONTRACT: NEVADA'S NV ENERGY BOULDER SOLAR AND STORAGE PROJECT

Context: The Boulder solar plus energy storage project is one of three projects NV Energy plans to build in southern Nevada, to produce a total of 478 MW of solar PV and 338 MW of energy storage. NV Energy achieved the ambitious 1,000 MW storage target set by the utility and the regulator in Nevada. It plans to store low-cost solar energy during the day and deliver it to its customers during the evening, bringing NV Energy closer to meeting its long-term goal of serving customers with 100 percent renewable energy.

Business Model: The buyer pays for the product, capacity rights, and renewable energy benefits on all energy during the term of the contract. It takes delivery of the net energy, including any excess energy, discharging energy at the delivery point. The product rate is applied to net energy from the generating facility (except storage); storage is paid for at the storage rate applied to the contract capacity. The storage facility is mandated to maintain a certain level of availability for a month during peak hours. The supplier pays the buyer replacement costs and penalties in case of shortfall. The buyer reserves the right to adjust charging and discharging notices on a real-time basis.

System Size: The project includes 128 MW of solar PV and 58 MW/232 MWh of lithium-ion storage. The duration of storage depends on the use cases. Load shifting typically requires four hours of storage. Smoothing out intra-day PV variations and the provision of ancillary services requires a smaller storage capacity, ranging from 0.5 to 2 hours. Therefore, four hours of storage is enough to meet most of the system requirements.

Tariff: The applied product rate is $22.45/MWh, including net energy, capacity rights, renewable energy credits, and benefits. The storage capacity rate is $6,800/MW/month.

Salient Points: The two-part contract PPA applied by NV Energy is simple. Renewable energy resources and storage facilities are charged separately based on their technical characteristics. The seller can sell all of the renewable energy generated and is paid for the availability of storage capacity.

BOX 3.2

EXAMPLE OF A SINGLE-CAPACITY CONTRACT: THE MAUI ELECTRIC RENEWABLE DISPATCHABLE GENERATION POWER PURCHASE AGREEMENT

Context: This PPA is based on a renewable dispatchable generation contracting mechanism, which allows for better utilization and integration of the project's renewable resources while mitigating the financial risk associated with curtailment for sellers. The PPA was introduced as an improvement over the energy-only compensation mechanism, which limited the ability to use resources for grid services and hindered growth in renewable energy opportunities. The fully dispatchable (single-capacity) PPA model provided the flexibility required to increase renewable penetration and control over the planned grid with 100 percent renewables by 2045.

Business Model: The PPA gives the buyer dispatch rights over the renewable energy facilities (both solar PV generation and energy storage). In exchange, the seller receives a fixed monthly payment (lump-sum payment), which is subject to adjustment based on the availability and performance of the facility. The target availability is 95 percent, subject to penalties for nonperformance.

System Size: Maui executed several projects with the same PPA. One is the Kamaole Renewable Dispatchable Generation project, with 40 MW solar PV and 40 MW/160 MWh storage.

Tariff: The seller is paid a lump-sum payment for the buyer's right to dispatch, subject to agreed performance metrics and availability. The lump-sum payment is adjusted based on the unit price. If the seller fails to achieve one or more of the performance metrics, it must pay a liquidated damage amount.

Salient Points: The PPA gives the buyer full dispatch rights over the facility, allowing it to adjust its operation based on grid requirements. This right is essential for an island grid committed to increasing the use of renewables. The seller is paid a fixed lump-sum payment for these dispatch rights, reducing the risks of operating under loss for grid services.

Source: Hawai'ian Electric 2023.

BOX 3.3

CONTAINERIZED RENEWABLE LEASE SOLUTIONS WITH CONCESSION CONTRACTING

Several utilities and other commercial and industrial users in Sub-Saharan Africa have rolled out containerized renewable solutions. Modular mobile redeployable solar PV plus battery storage units allow utilities to quickly increase power generation capacity at a competitive tariff through a simple standardized lease agreement that allows them to harness modular solar PV technology without the complex concession/PPA-based contracting mechanism that is the norm in IPP procurement. These solutions provide quick access to competitively priced renewable energy while paving the way for future private sector investment and well-structured, large-scale, competitive procurement programs.

Lease terms include the following:

- lease period of three to five years, with an option for the utility to extend for an additional term (at reduced tariffs)
- mobilization of equipment subject to payment of mobilization and demobilization fee by utility and issuance of letter of credit covering 12 months of payment
- plant performance parameters, including guaranteed availability for PV and battery components, performance ratio (subject to seasonal adjustment and annual degradation), PV plant yield (kWh/kWp), and expected power production (MWh) based on a P50 curve guaranteed by the lessor (P50 indicates that there is a 50 percent probability that actual production will be equal to or exceed the predicted solar yield).
- monthly rental payments paid by the lessee (the off-taker) based on available capacity (per MW), to be adjusted downward if less than the guaranteed amount of electricity is made available.

The straightforward lease agreement means that negotiations and project awards can be finalized within three to four months. Installation of the preassembled modules, which are transported in standardized containers, can be completed within four to six months. Subject to land availability and permits, full deployment—from the start of negotiations to the initial production of electricity—can be achieved within nine months, including a provision for contingencies.

BOX 3.4

EXAMPLE OF A BLENDED ENERGY CONTRACT: HAWAI'I'S LAWAI SOLAR AND ENERGY STORAGE PROJECT

Context: The Lawai Solar and Energy Storage Project delivers roughly 11 percent of Kauai's power, increasing the Hawai'ian island's share of renewable power to more than 50 percent. The project claims to be the world's largest solar-plus-storage plant to provide capacity during peak hours (referred to as a *peaker plant*). It is backed by power producer AES Corporation and the not-for-profit Kauai Island Utility Cooperative (KIUC). The project uses 28 MW of solar PV to charge the 100 MWh Li-ion battery, which supplies sustained power to the grid for five hours.

Business Model: Tariffs are paid on the supply of net energy at the delivery point corresponding to the contracted capacity. A shortfall in expected annual energy output is compensated at the applicable energy tariff. Excess generation is paid based on a fixed pre-defined tariff. The seller has dispatch rights to the storage.

System Size: The project consists of a 28 MW solar PV and a 20MW/100 MWh five-hour duration energy storage system.

Tariff: Under the 25-year PPA, KIUC will purchase power from the facility at $0.11/kWh.

Salient Points: A blended PPA is simpler to understand and manage between stakeholders compared to other PPAs because payment is based purely on the MWh produced and contracts awarded based on the lowest price per MWh.

BOX 3.5

BURKINA FASO'S SOLAR-PLUS-STORAGE PROJECT BUSINESS MODEL APPROACH

Burkina Faso is considering combining solar PV and storage into a single blended PPA with time-differentiated rates, providing incentives for the IPP to shift electricity production to the 4-hour peak period (7:00 – 11:00pm.); the main period of energy delivery is 12 hours (7:00am – 7:00pm), for a total of 16 operational hours. Two sites of 300 MWp of solar PV with 100 MW/300 MWh of storage are planned to be tendered in a phased approach.

The buyer is not meant to have any control over the PV or storage assets. The seller would make all dispatch and charging decisions, in accordance with the parameters set in the PPA. Energy provision is autonomously delivered because it does not necessarily require a market or any signal from the utility. The provision of ancillary services to the system, such as frequency regulation, operating reserves, or voltage stabilization, are not included as part of the scope of the PPA.

Remuneration for the energy produced from the solar-plus-storage project is based on the total MWh delivered to the grid. Elaborate operational rules have been proposed defining the conditions under which the seller has an obligation to deliver. They include (a) the yearly generation to be dispatched during the evening, (b) the storage minimum capacity level, (c) the number of days the PV plant is not available, and (d) the number of days the storage is not available. Penalties would be imposed for non-delivery of energy during designated peak hours, which entails some risks for the sellers.

The project is under development. The tender is scheduled to take place between 2023 and 2024.

Variation 1: Time-Differentiated Rates

Like the standard blended energy contract, the time-differentiated model combines solar PV and storage or a portfolio of assets into a single contract remunerated on a $/MWh basis. However, the price of energy and the volume of energy varies by time block. The contracted product typically involves energy with a profile that differentiates between peak and off-peak prices.

The advantages of a blended energy contract with time-differentiated rates include the following:

- Pricing can be differentiated based on when the electricity is used. Different prices are applied for peak and off-peak power delivery or in accordance with different time blocks based on the needs of the buyer.
- The buyer's requirements are meet more effectively, in accordance with actual demand and load, allowing for more efficient management of energy resources, as the system can respond to changes in demand and supply in real time and adjust the output accordingly.
- The most expensive (and polluting) thermal generators are dispatched to meet peak load only.

The disadvantages of blended energy contract with time-differentiated rates include the following:

- The buyer has less flexibility to operate solar PV and storage assets than in other models. It has limited control to specify PV and storage sizes and storage duration.
- The procurement process is more complex than in other models, as it entails more than one product via auctions (e.g., peak, valley, off-peak). The selection process must reflect the optimal combination of prices and quantities among multiple bidders.
- The resource volatility and seller's obligations to deliver fixed quantities in certain time blocks make contractual obligations more rigid and more difficult to satisfy, subjecting the seller to contractual penalties.

Several projects have adopted a blended energy contract with time-differentiated rates (Table 3.5 and Box 3.6).

TABLE 3.5

Examples of Projects that Adopted Time-Differentiated Rates

PROJECT	LOCATION	SYSTEM SIZE
Risk Mitigation IPP Procurement Program (RMI4P)	Multiple sites, South Africa	About 2 GW
Solar Energy Company of India (SECI) Peak Power Supply PPA	Multiple sites, India	1,200 MW firm power
Noor Midelt Solar (PV and CSP) Power Project	Midelt, Morocco	800 MW CSP–PV

CSP = concentrated solar power; PV = photovoltaics (solar)

BOX 3.6

EXAMPLE OF A BLENDED ENERGY CONTRACT WITH TIME-DIFFERENTIATED RATES: THE SOLAR ENERGY COMPANY OF INDIA'S PEAK POWER SUPPLY POWER PURCHASE AGREEMENT

Context: Increased electrification and reduced load-shedding by distribution companies in India have resulted in a steep increase in peak energy demand, which companies meet at significantly higher than average costs. Under this PPA, a storage charges during off-peak hours and supplies power during peak hours at a higher peak tariff. The net difference between peak and off-peak tariffs is critical to the project's commercial viability.

Business Model: Tariffs are paid on supply at the delivery point of energy corresponding to the contracted capacity. The power procured is allocated on a pro rata basis; the seller has dispatch rights. On shortfall of energy during peak and off-periods, the developer must pay compensation at the applicable energy tariffs. Excess generation is paid based on a fixed 75 percent of the off-peak tariff.

System Size: The system provides 1,200 MW of renewable energy plus storage, with guaranteed peak power supply for six hours a day (the morning peak [7:00–9:00 a.m.] and the evening peak [6:00–10:00 p.m.]).

Tariff: Greenko won 900 MW with pumped hydro storage at the peak tariff of Re 6.12/kWh ($0.0765/kWh); ReNew Power won 300 MW with the storage at peak tariffs of Re 6.85/kWh ($0.0856/kWh). For both companies, the off-peak tariff was fixed at Re 2.88/kWh ($0.0360/kWh).

Salient Points: A time-differentiated PPA resolves the issues of mismatch between demand and solar PV generation peaks. Such solar-plus-storage projects can replace thermal generators, serving as peakers.

Source: SECI 2022b.

In May 2019, Morocco auctioned the world's first advanced solar-plus-storage combining concentrated solar power (CSP) and PV. The 800 MW CSP-PV Noor Midelt plant is designed to provide dispatchable solar energy during the day and until five hours after sunset for a record low tariff at peak hours of DH 0.68/kWh ($71/MWh) (MASEN 2022).

In a blended energy contract with time-differentiated rates, the sizing of the renewable energy and storage combination must be calibrated to satisfy specific demand requirements within designated time frames. In the 800 MW Noor model in Morocco, the requirement is 11 hours (MASEN 2022). In India, it is divided into two separate peak periods with a cumulative duration of six hours (Institute for Energy Economics and Financial Analysis and JMK Research & Analytics 2020).

South Africa adopted a variation of the blended energy contract under the RMI4P program with time-differentiated rates to procure emergency capacity of about 2 GW to address the demand and supply gap and avoid rolling blackouts. The request for proposal (RFP) required a power plant with 100 percent dispatchability between 5:00 a.m. and 9:30 p.m., with a contract capacity of 50 to 450 MW. Nine bidders were announced in 2021, totaling 1,996 MW. The Scatec projects (3 × 50 MW) were the only projects relying exclusively on renewable energy. Scatec had to oversize the solar (3 × 180 MW) and the storage (3 × 75 MW/ 380 MWh). The bid tariff for RMI4P (at the time of the bid) ranged from $89.1/MWh to $115/MWh. The three Scatec projects were the first projects to reach financial close in July 2022. Other bidders used thermal generators as a back-up to avoid the risk of non-delivery.

Allowing the seller to offer a portfolio of assets, as South Africa's RMI4P program does, can partially mitigate the risk of non-delivery. Diversifying the assets within the portfolio can reduce the risks associated with delays or underperformance of renewable energy. This approach provides a reliable, cheaper, and consistent energy supply that meets unpredictable energy needs and enhances overall resiliency of the energy system.

Variation 2: 24/7 Firm Power Supply

The 24/7 firm power supply model combines solar PV, a storage system, and, in some cases, other nonrenewable energy assets to provide higher levels of firmness to the buyer. Such PPAs are typically energy-only contracts remunerated based on megawatt hours delivered. Although the name suggests 24 hours a day, 7 days a week, these contracts do not necessarily provide continuous supply. The phrase means that the product being contracted is the energy that is available with a high level of firmness (e.g., 70–80%).

The concept of 24/7 is related to the sellers' ability to deliver reliable power, using a portfolio of technology-agnostic assets, such as renewable energy resources, storage, thermal plants. It is not a proxy for the content of green energy in the PPA.

In 2022, the Long Duration Energy Storage (LDES) Council released an innovative study proposing a new methodology to assess the carbon dioxide content of corporate PPA, in which a corporation is the off-taker. This concept can also be applied to PPAs in which the off-taker is a utility company or the grid operator. LDES and McKinsey (2022) propose a categorization of PPAs based on the actual level of clean energy produced. This metric would measure the degree of "green firmness." The concept calculates the matching of demand and "green" supply on a very granular basis (hourly and in the same electric zone).[11]

The advantages of a blended energy contract with 24/7 firm power supply include the following:

- There is a high level of energy firmness, which depends on system requirements. In remote areas not or poorly served by the utility, for example, requirements may be very high (up to 100%); in large systems with abundant reserves, systems sometimes provide just 70 to 80 percent of requirements. Another example is mini grids that are completely isolated from the main grid and supply a small, localized group of customers with a distribution network, which is different form the use-case of this business model variation.
- The seller has discretion to combine a variety of assets and contracts, optimizing resources in the grid and fostering creativity to provide energy at the lowest possible price.
- The model can contribute to the deeper decarbonization of the grid system. Typical renewable energy corporate PPAs lead to only 30 to 40 percent decarbonization. A blend of resources and long-term energy storage is key to competing with and displacing fossil fuel-baseload generation (although achieving 100% green PPAs is exponentially more costly, as reported by LDES and McKinsey).

The disadvantages of a blended energy contract with 24/7 firm power supply include the following:

- The seller assumes most of the risk of delivering a high level of energy firmness. This risk can be mitigated, if the seller has access to a combination of assets/contracts that can be blended.
- The model may require adding nonrenewable energy sources, such as complementary thermal generation, to meet the level of energy firmness agreed to, reducing the greenness of the PPA.

The PPA may be traded in a large power system, where the grid operator decides which power plants have to be dispatched (or not), exposing sellers to dispatch risk. To mitigate this risk, market rules must compensate the PPA's underlying assets when the plant is not dispatched because of transmission constraints (constrained-off operation). As an example, India adopted a blended energy contract with 24/7 firm power supply to meet the round-the-clock (RTC) baseload requirement without the need for external balancing (Box 3.7).

BOX 3.7

EXAMPLE OF A BLENDED ENERGY CONTRACT WITH 24/7 FIRM POWER SUPPLY: THE SOLAR ENERGY COMPANY OF INDIA

Context: Solar Energy Company of India (SECI) has released three tenders for hybrid projects with renewable energy resources and suitable storage capacity that can meet RTC baseload requirements without any need for external balancing. Per the latest RTC-III, the IPP is obligated to supply the contracted dispatchable power capacity in a round-the-clock manner, keeping at least 90 percent availability annually, at least 90 percent monthly for at least 11 months a year, and at least 90 percent during peak hours. At least 51 percent of energy supplied annually must be from renewable energy sources. RTC-III benefited from the knowledge gained from RTC-I, which was based on a capacity utilization factor rather than availability, and RTC-II, which required matching of the lowest tariff to secure contracts.

Business Model: Tariffs are paid on the supply of the energy at the delivery point corresponding to the contracted capacity. The power procured is allocated on a pro rata basis, and the buyer has dispatch rights. On shortfall of supply, the developer must pay for all liquidated damages at the applicable fixed tariffs, which are usually two to four times the energy tariff. Monthly energy billing is computed based on the applicable tariff, and payments are made based on the respective energy components (renewable and nonrenewable) supplied by the developer. Excess renewable energy is paid based on the ratio of excess energy to the contract energy.

System Size: RTC-I, issued in 2019, had a requirement of 400 MW. RTC-II, issued in 2020, had a requirement of 2,500 MW. RTC-III, issued in 2022, had a requirement of 2,250 MW.

Tariffs: Renew Power won the first RTC-I tender. It will provide 400 MW at a tariff of Rs. 2.91/kWh ($0.0364/kWh), with a 3 percent annual escalation, for 15 years. In RTC-II, Hindustan Thermal Projects emerged as the lowest bidder with tariff of Rs. 3.01/kWh ($0.0376/kWh) for 250MW project. Other bidders for RTC-II, such as Greenko Energies, quoted a tariff of Rs 3.18/kWh ($0.0397/kWh) to supply 1,001 MW, ReNew Samir Urja placed Rs 3.19/kWh ($0.0398/kWh) bid for 600 MW, Power Mech Projects quoted Rs 3.30/kWh ($0.0412/kWh) for supply of 550 MW, and JSW Neo quoted Rs 3.45/kWh ($0.0431/kWh) for 600 MW will have to match lowest tariff to secure the contract. As of October 2023, SECI had not released the results for RTC-III tender.

Salient Point: This type of PPA can partially replace less efficient thermal generators with a renewable energy resource while ensuring grid reliability.

Phase 4: Selection and Implementation of a Business Model

Phase 4 involves the selection of the business model that best meets the project requirements. A decision tree model is developed and applied based on the technical requirements of the solar-plus-storage project expected by the buyer. Other factors that should be considered include electrical connectivity, remuneration methods, operation and dispatch, functional requirements, and financing and bankability. Phase 4 also involves identifying the risks for the solar-plus-storage project, preparing a term sheet, and providing the basis for further developing a PPA that matches the business model and the contextual features identified, which can be applied through a competitive process described in the following chapter.

Using the Decision Tree Tool

The decision tree model outlined below provides a clear and structured way for the buyer and the decisionmaker to evaluate the different business models and determine which best suits their contextual needs and requirements (Figure 3.2).

The steps in the decision tree tool are developed from the perspective of the buyer, which may or may not be the same entity as the system operator. Depending on the project, sellers can also use the tool.

Question 1: Is Firm (or Quasi-Firm) Power a Requirement?

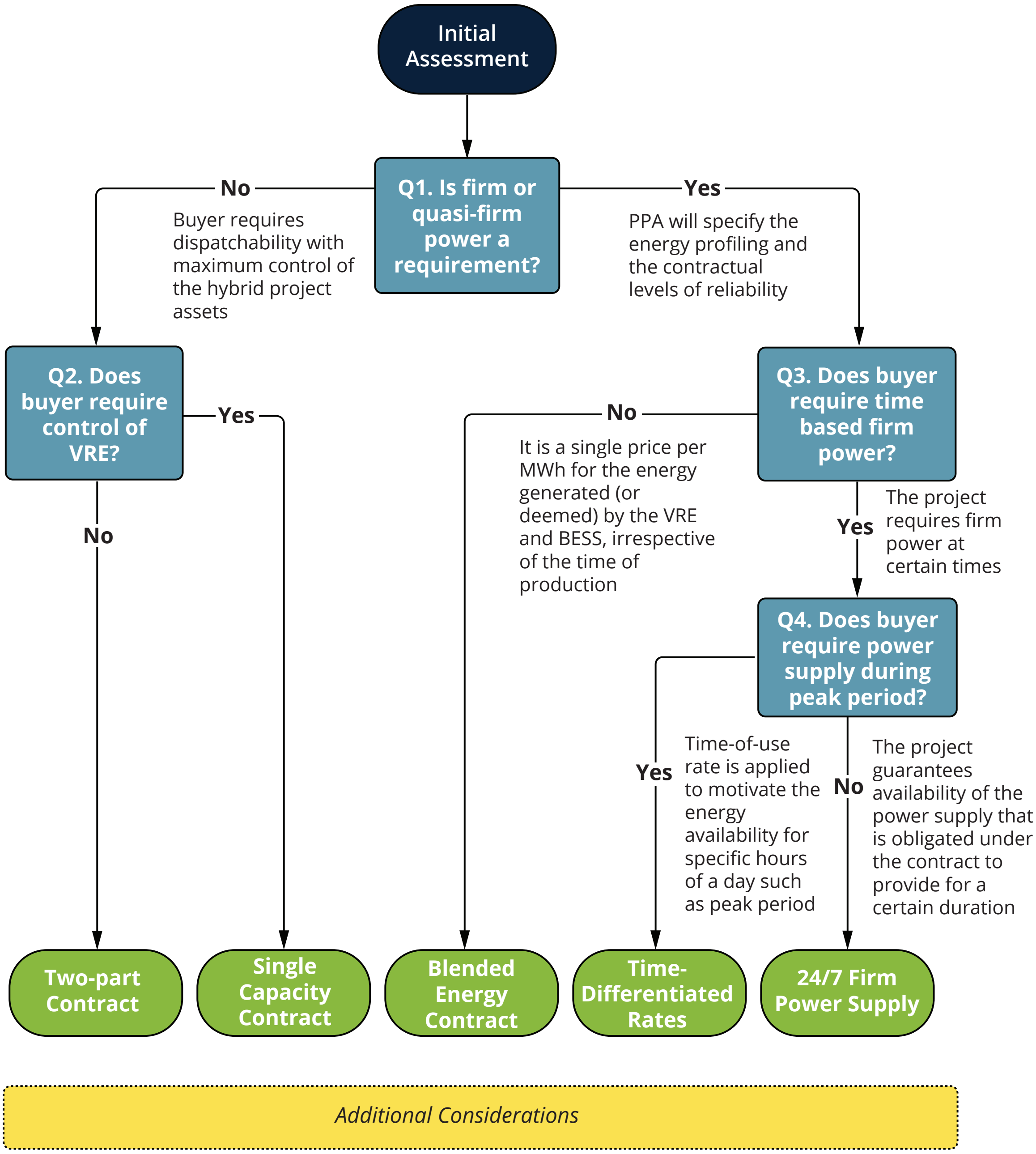
After the initial assessment, it is necessary to determine whether the buyer needs to have firm (or quasi-firm) energy supplied. If the answer is yes, the PPA will specify the energy profiling and contractual levels of reliability. If the answer is no, it means that the buyer prioritizes having dispatchability with maximum control of the solar-plus-storage project assets.

If a buyer needs to replace an existing thermal generator (or prevent the installation of a new peaker or baseload), the solar-plus-storage project needs to provide firm or quasi-firm capacity. These requirements are exemplified in the South Africa RMI4P program, where 2 GW of firm capacity was procured to address the demand and supply gap.

SIDS, which have low energy demand and relatively large-scale projects, would benefit from dispatchability to ensure grid stability. This need became apparent in Hawai'i, where PPAs were introduced granting the buyer full dispatch rights to adjust project operations based on grid requirements in light of the growing adoption of renewable energy sources.

FIGURE 3.2

Decision Tree for Selecting a Business Model



Note: This decision tree is merely indicative, intended to illustrate the main factors that lead to each model. In real life, there may be elements that are not reflected in the decision tree, particularly when the buyer also plays the role of the national system operator. In that case, the PPA may contain elements of firmness and dispatchability (that is, control of the assets).

Question 2: Does the Buyer Require Control of Renewable Energy?

If the buyer desires control over the output of both the renewable energy and the storage irrespective of time, the single-capacity contract may be the preferred option, as it grants full dispatchability rights to the buyer. This model offers operational flexibility, allowing the buyer to determine when and how much energy the solar-plus-storage project should generate. It is most suitable for buyers equipped with a well-established control infrastructure to meet their specific requirements.

If the buyer seeks partial control over the assets, the two-part contract is recommended. Under this model, the buyer has control over the storage output by managing its operations, and the seller remains obligated to provide energy from renewable energy resource. Solar-plus-storage projects could supply peak demand by shifting renewable energy production using a storage system. Such a solar-plus-storage project with control over the storage asset could also provide other utility-scale services, such as frequency response and ramping.

When a buyer intends to use the storage assets to shift renewable energy output to peak periods and provide some ancillary services, such as frequency regulation, a two-part contract is suitable, as it allows control over the storage assets. This need is illustrated by the South Andaman project in India, where a storage is used to smooth PV production and regulate grid frequency, enhancing grid stability alongside renewable energy integration.

If a buyer aims to reduce curtailments, enhance renewable energy integration, and offer spinning reserve services and a wide range of ancillary services, full control over both solar and storage assets becomes preferable. This requirement is illustrated by some projects in Hawai'i, based on a fully dispatchable (single-capacity) PPA. The buyer is granted complete dispatch rights to adapt project operations according to grid demands and thereby increasing penetration of renewables.

Question 3: Does the Buyer Require Time-Based Firm Power?

If the buyer does not require firm power, the blended energy contract is suitable. This contract offers a single price per megawatt for the energy generated by both the renewable energy and the storage, regardless of the production time. Essentially, the buyer pays for the energy as and when it is produced or deemed. A buyer with constant energy usage throughout the day may prefer a fixed energy rate that applies irrespective of the time of day. Having a fixed rates simplifies the energy procurement process and reduces administrative overhead. A blended energy contract allows the buyer to secure a stable energy rate, facilitating budgeting and long-term energy expense planning. Blended energy contracts are particularly well-suited where a buyer intends to establish a solar-plus-storage project that aims to consistently meet demand, utilizing storage to eliminate curtailments and optimize the utilization of energy generated from renewable energy sources.

Question 4: Does the Buyer Require Power Supply During Peak Hours?

If a buyer requires a guaranteed power supply during periods of peak energy demand, a modified version of the blended contract with time-differentiated variation may be appropriate. This type of contract entails structuring rates in a way that encourages energy availability during specific hours of the day, typically coinciding with peak demand periods. This approach motivates energy producers to ensure the provision of power during these high demand periods.

Some buyers need a high level of firmness in energy supply (such as 70% or higher) regardless of the time of day. The most suitable business model in this scenario would be a 24/7 firm power supply, which ensures firm power based on an agreed energy profile.

India's Peak Power Supply PPA implemented time-differentiated tariffs to bridge the mismatch between demand requirements and solar PV production. Solar-plus-storage projects like these have the potential to replace thermal generators that serve as peakers. For fulfilling baseload requirements, contracts guaranteeing 24/7 power supply with high levels of availability are most appropriate. An example is India's RTC power supply PPA, where IPPs are obligated to provide power with 90 percent availability round the clock, where other nonrenewable energy sources may be included.

Box 3.8 provides an example of the use of the decision tree.

Considering Other Factors in Selecting a Business Model

Additional factors not addressed in the decision tree tool should be considered before a business model is selected and a PPA drafted. They include electrical connectivity, remuneration methods and impact on bankability, and financing. Appendix A presents an in-depth evaluation of each model's advantages and disadvantages, including the additional factors outlined in this section.

Electrical Connectivity

The electrical connectivity and technical configuration of a solar-plus-storage project should be considered when selecting a business model. The necessary infrastructure must be in place to connect the solar PV, the storage, and the grid in a way that allows the

BOX 3.8

SELECTING A BUSINESS MODEL FOR A SOLAR-PLUS-STORAGE PROJECT IN MALDIVES

A project in Maldives involves the development of three solar PV arrays with a total capacity of 36 MW and 40 MWh of storage capacity. The decision model for the project starts with the question “Is firm or quasi-firm power a requirement?“ In this case, the answer was “no,“ because on the large island grid of the Greater Male region the dispatchability of the storage by the utility is more important than firmness, because the utility (STELCO) has other resources and wants to jointly optimize all of them to reduce operating costs.

The next factor to determine in the decision tree is whether the buyer needs control of solar in addition to control of the storage. The project requires control over storage to provide the selected services such as frequency regulation and peak-shaving but does not necessarily need control over solar as well to have full control of the system. Selecting the level of control is important for maintaining a reliable and stable power supply on the main island, where the grid can be subject to fluctuations and instability. These decision choices indicate that the most suitable business model for this application is a two-part contract, which provides the grid operator with the ability to control the storage asset, in order to maintain system stability and reduce reliance on the diesel generators.

With the two-part contract, the project will have an energy payment component that recognizes and compensates the value of the energy produced by the solar arrays. This remuneration criterion is important because it ensures that the project will not only provide capacity to the grid but also help meet energy demand by directly injecting solar energy or discharging energy stored in the storage.

The financing of the model then needs to be considered. Developing projects through private sector financing is an attractive way for the Maldives to accelerate the development of solar. Support from the World Bank has significantly improved the renewable energy investment climate in Maldives. Technical assistance and financing have been delivered under the World Bank’s ASPIRE project (ongoing since December 2014). A two-part contract is a suitable for the private sector to jointly develop and finance both solar and storage assets under one project. It has the flexibility to allow the buyer (utility) to dispatch the storage to meet use case requirements.

(*continues*)

BOX 3.8 (*Continued*)

A stable cashflow stream for sellers increases bankability. A two-part contract remunerates solar based on energy generated and remunerates the storage based on capacity availability, enabling the buyer to maximize the use of the storage across multiple use cases. Maldives is familiar with the structure of a thermal PPA, as it has depended on thermal generation capacity for decades. A two-part contract mimics the structure of a thermal PPA, with variable and fixed payments that can easily be understood by investors and policymakers.

A two-part contract is the best fit for Maldives, because it provides the buyer with some level of control over energy output while still allowing the seller to manage the risk associated with energy generation and storage. It allows for a balanced approach to the development of the solar-plus-storage project that benefits both the buyer and the seller.

system to operate effectively. Ideally, the solar PV and the storage should be co-located and have the same point of interconnection (POI). If they are not co-located or have separate POIs, they can be connected virtually. The contractual implications and prerequisites of virtual connectivity must be established. In the absence of a grid code and transmission tariff, a technical feasibility study of a model should be conducted.

Co-locating solar and storage assets can provide multiple benefits, reducing land use and grid connection costs. It can also increase the efficiency of the system, by reducing transmission losses (Bolinger et al. 2022). Reasons for co-location include cost savings, technical benefits, and regulatory considerations. Reasons for not co-locating assets include lack of suitable land, grid connection, technical feasibility, or the need to locate the storage closer to the load center to provide ancillary services, relieve congestion, and enhance reliability.

If the solar PV and storage assets are co-located, they can be designed as alternating current (AC) or direct current (DC) coupled system. This technical decision has ramifications in terms of the functionalities and operational flexibility. In AC-coupled systems, both PV and storage have their own separate inverters, which are then connected to the grid. The operation of solar PV and storage components is largely independent. In DC-coupled systems, the solar PV and storage outputs are mutually connected and share a common inverter, which transforms the DC into AC output to be connected to the grid. Operation of the solar PV and storage components is coordinated.[12] The DC-coupled set-up allows the battery to be charged from the PV system only. It offers more flexibility to the system operator and reduces solar PV production clipping. However, it requires more sophisticated controls and energy management systems to make smart decisions about when PV production should be used to charge the battery or be injected into the grid.

Regulatory Considerations

By optimizing the operation of solar-plus-storage projects to take advantage of both solar output and storage capacity, solar-plus-storage projects can lead to operational cost savings. How these potential cost savings are realized depends on the regulatory environment. *Deploying Storage for Power Systems in Developing Countries: Policy and Regulatory Considerations* (ESMAP 2020) examines ways to realize the value of storage solutions from a system perspective and reviews relevant considerations for frameworks that facilitate storage deployment.

Regulatory policies such as private-public partnerships (PPPs), PPAs, competitive procurement rules, and tax incentives can significantly improve the financial outlook for solar-plus-storage projects. Market structures that allow for the sale of excess power back to the grid or participation in ancillary services markets can also enhance the economic viability of these systems. Considering different technology options, such as long duration energy storage (LDES), could also help achieve cost-effective decarbonization of bulk power systems that can provide system flexibility and stability with the solar resources. According to the LDES Council, the total addressable market for LDES has the potential to reach 1.5 to 2.5 terawatt (TW) scale by 2040 by providing energy shifting and capacity, optimizing transmission and distribution, and providing other grid services (LDES Council and McKinsey 2021).

Remuneration and Bankability

The remuneration methods used in the project could be designed to compensate sellers for the investments and services they make available to the buyer and/or the grid operator. Payment for energy is suitable for projects that require a high level of firmness but low dispatch control. Payment for capacity is suitable when the buyer requires the dispatch rights of the assets to increase its level of control on the assets. The services provided by PV (energy) and the storage (capacity) can be priced separately (as in a two-part contract) or jointly (as in a blended energy contract). Remunerating the seller for each storage service separately may be complicated without sophisticated and mature electricity markets and separate pricing for each one of the stacked services provided by storage. Even in sophisticated markets, not all storage services can be monetized, such as voltage control and ramp-up/ramp-down. In countries with no market mechanism for capacity or ancillary services, it is reasonable to compensate a storage operator via a fixed payment per megawatt of capacity made available each month, as in a two-part or single-capacity contract.

Financing

Policymakers should consider the factors that affect the financing of the project, including the investment climate for private sector participation, regulations, the availability of funding, the cost of financing, and the creditworthiness of the buyer. The seller sets conditions that need to be met so that the project is attractive to investors for a typical limited-recourse finance project backed by a PPA. A country with a strong record of successful solar PV PPA projects may be more attractive for potential investors in a solar-plus-storage project. Few emerging markets have a strong record of storage projects, however. Therefore, both the strong presence of IPPs and a regulatory framework that recognizes energy storage as an asset are desirable. In the absence of some key regulations, the contract itself will be the vehicle to bridge this gap.

Identifying the sources of funding available for solar PV and storage projects can help determine the level of government support needed for renewable energy projects and the level of interest from private sector investors. It can also provide guidance on the ease of accessing funding for a solar-plus-storage project and the cost of capital involved. The nature of funding may also be a determining factor in the selection of the business model. If, for example, concessional financing is earmarked only for storage assets developed by government agencies, a two-part contract is no longer suitable. A mode where a utility-owned storage is integrated into an IPP-owned solar PV asset can be considered, in a hybridized technical configuration.

In the case of solar-plus-storage PPAs, new regulatory and legal requirements are necessary. It is imperative to assess a country's previous experience with IPPs and PPP models. This assessment can provide insight into the regulatory and policy frameworks that exist, which can affect a project's viability and potential risks. It is also crucial to consider the local legal framework's treatment of storage as an asset class. Clear guidelines on the ownership of and compensation for the power generated by a storage are essential for ensuring transparency and consistency in the investment landscape.

The World Bank Group has tools and instruments that can increase the bankability of projects while de-risking the overall environment:

- The International Bank for Reconstruction and Development (IBRD) and International Development Association (IDA) can offer partial risk guarantees to backstop payment and credit risks. It can structure payment guarantees for the IPP (through escrow accounts), if the off-taker is not creditworthy and unable to pay for the energy delivered. It can also offer credit guarantees to protect lenders, if the IPP defaults on its contractual obligations.
- The International Finance Corporation (IFC) can offer blended finance tools, sustainability linked bonds, and interest rate and currency hedging products.
- The Multilateral Investment Guarantee Agency (MIGA) can offer political risk guarantees to investors and lenders, covering the risks of expropriation, breach of contract, currency transfer restrictions, and the failure to honour sovereign financial obligations.

Accounting: On- or Off-Balance Sheet?

From an accounting perspective, a PPA can be classified as an on-balance sheet asset (a financial lease) or an off-balance sheet financing. This classification has major implications, particularly for the buyer. If the PPA is considered equivalent to a financial lease, the buyer must recognize assets and liabilities as part of its balance sheet.

Categorization of a solar-plus-storage project's PPA as a financial lease depends on several factors. One of the most important is how risks are allocated between buyers and sellers.

The business model selected, the PPA structure, and the risk allocation may affect the categorization of the PPA as a financial lease. If most risks are transferred to the buyer, the PPA is more likely to be categorized as an on-balance sheet transaction. PPAs in business models that involve payment for capacity—storage, PV, or both–are more likely to be classified as financial leases than PPAs in blended business models, in which the seller takes more performance risks. If having an off-balance sheet PPA is essential, the blended energy contract model and its variations with suitable structuring would be better options; the two-part contract or single-capacity contract should be avoided.

Practitioners should follow International Financial Reporting Standards (IFRS) 16, as suggested in Box 3.9, for the financial lease model, and consult lawyers, auditors, and accountants for compliance with these standards.

BOX 3.9

INTERNATIONAL FINANCIAL REPORTING STANDARDS 16

International Financial Reporting Standards (IFRS) 16 is an annual reporting standard set by the International Accounting Standards Board. Adopted in 2019, the standard affects the way PPAs are reported on the buyer's balance sheet. It may have undesirable consequences for the buyer's level of indebtedness and future ability to borrow. For the seller, this kind of reporting is not a critical issue, as most projects are structured as special purpose vehicle (SPV) entities, with nonrecourse or limited recourse finance. The ability to borrow depends on the quality of the project's cashflow streams.

Under IFRS 16, single lessee accounting model is treated as a financial lease. The standard requires a lessee (in a PPA, the buyer of the energy or capacity) to recognize assets and liabilities for all leases with a term of more than 12 months. A lessee is required to recognize the right of use of the underlying leased asset (that is, the PV plant and/or the storage) and a lease liability representing its obligation to make lease payments.

Including a PPA on the buyer's balance sheet may have undesirable consequences, because it increases the reported indebtedness and debt-to-equity ratio and limits the buyer's ability to borrow. Buyers would rather have the PPA reported as an off-balance sheet transaction, something IFRS 16 regulations do not permit.

Identifying Risks

Understanding the risks associated with solar-plus-storage projects can help practitioners develop strategies for mitigating them and making informed decisions about the feasibility and viability of the business model.[13] The framework identifies four types of risks that must be assessed for all solar-plus-storage projects:

1. **Curtailment Risk**. Curtailment occurs when an electricity-generating system or energy storage system stops exporting to the load or temporarily shuts down, wasting energy that could have been used. Electricity injection from the system can be curtailed for economic or grid capacity reasons. The lack of grid capacity to inject power from the system to the grid or load may occur to maintain the technical requirements of the power system operation. A system operator may decide to curtail power in order to protect the grid from harmful events.
2. **Variability Risks**. Variability is the extent to which a power source predictably fluctuates, such that an electricity generating system or energy storage system stops exporting to the load or even temporarily shuts down because too little capacity is available to meet the terms of the agreement. The seller bears some risks associated with variability, such as penalty on payments or even termination of the PPA when there is a need for a higher degree of firmness.
3. **Market Risks**. Market risk depends on the type of contractual structure. It is associated with the lack of monetization of storage services (e.g., voltage regulation, renewable curtailment mitigation, black start, etc.) in the current market structures in most countries. Once storage services are represented fairly in markets, this risk will be addressed. In most cases, the PPA energy volume should not be adjusted based on market conditions. In some cases, however, the seller bears this risk—as in a "full requirement" contract—in which every seller has an obligation to deliver energy on a 24/7 basis to fully meet load requirements.
4. **Capital Expenditure Risks**. Storage prices have not declined as steeply as prices for solar and wind power. Securing a price in a bid for a product to be delivered two years in advance entails a risk for sellers. This kind of risk pertains to solar-plus-storage projects; it is less relevant in typical solar PV PPAs. A price-tracking mechanism for the capital expenditure of the storage from real projects would help monitor the difference between expected and realized expenditure.

Every solar-plus-storage project is unique. Identifying the risks for the buyer and seller is important. Risk allocation between them in the contract reflects the trade-off between the price (that the buyer is willing to pay) and the risks (that the seller or buyer is willing to take to improve bankability). Consideration of the high-level contractual risk informs which mitigation instruments or provisions the buyer will provide to the seller and what the buyer can expect from the seller. The risk allocation depends primarily on three considerations:

1. **What is the use-case of the solar-plus-storage project that the buyer needs?** The answer determines which entity keeps control of the assets and the level of control

required. If the buyer requires a higher level of control, it should assume more risks associated with the project.
2. **Which entity is in a better position to manage the risks associated with the planned solar-plus-storage project?** Such consideration would allow implementation of more efficient solutions for solar-plus-storage projects.
3. **How to ensure that the risks are identified and priced to keep the project bankable?** Such considerations help determine the penalties associated with risk mitigation.

Based on the level of risk allocation on either buyer or seller, the risk can be allocated in various ways:

- **Minor Risk to Seller.** The buyer wants to have full control of system assets (as in a single-capacity contract), producing energy and ancillary services and overscheduling production if necessary. The seller is paid for the capacity it provides (regardless of production). Once the solar-plus-storage project is financed and built, the seller's only risk is in maintaining an agreed level of asset availability. The seller specifies the detailed technical characteristics of the renewable energy system, such as technology, panel efficiency, degradation, inverter efficiency, tracking requirements, and many others.
- **Modest Risk to Seller.** The solar-plus-storage project is self-dispatched, and the buyer has no control over production. Payment is based on a tentatively agreed upon level of megawatt hours delivered, as in blended energy contracts. The provision of ancillary services is likely to be bundled with energy in the same contract. It is the seller's responsibility to deliver the agreed upon level of megawatt hours, by making sure that the system is available and operational. The seller may bear some risk for not delivering the agreed upon energy volume (volatility risk). To mitigate this risk, the contract may include flexible provisions, such as allowing sellers to carry over production surpluses or shortfalls on a seasonal, yearly, or multiyear basis, depending on how the variability risk is to be assigned between buyers and sellers. If curtailment occurs for any reason, the seller is paid based on the deemed energy charge.
- **High Risk to Seller.** The solar-plus-storage project is self-dispatched, and the buyer has no control over production. Payment is based on agreed generation, set forth in contractual clauses. Contractual obligations may be time-differentiated/profiled, as in variations of the blended energy contract. Any deviations between physically delivered and contracted volumes are settled at the wholesale market price, if there is a market, or via penalties (a proxy for liquidated damages). The seller bears no market risk. However, curtailment is compensated through market rules or grid codes (constrained to be on or off). Provision of ancillary services is likely to be bundled with energy in the same PPA, unless there is a market in which the seller can monetize one or more ancillary services.

Preparing the Term Sheet

Once a business model is selected, a term sheet can be prepared. This nonbinding document prepared by the buyer describes the major terms of the agreement. It serves as a starting point for setting the business terms during the competitive procurement process.

The term sheet outlines the key terms and conditions of the agreement, which are used to draft the PPA. It includes the following categories:

- **General**: includes details about the buyer and seller, including their names, addresses, and contact information
- **Solar and Storage**: provides technical configuration details about solar and storage assets needed to ensure that the assets meet all requirements and specifications
- **Rates and Limits**: covers the charges and limits applied to the assets, including the terms and conditions of the agreement
- **Payment**: includes details on how to calculate the payment amount, including the payment schedule, payment terms, and penalties
- **Default**: defines the dispute resolution and termination clauses

Appendix B provides a sample term sheet for a two-part contract.

Drafting the Power Purchase Agreement

A PPA is a legally binding contract that governs the purchase and sale of the electricity generated by the solar-plus-storage project. It includes payment terms, delivery obligations, liability allocation, termination provisions, and the purchase price. Legal experts need to prepare the PPA, to ensure that it is binding and enforceable. This report does not cover legal guidance on PPA preparation. Appendix C provides a link to a PPA template for a two-part contract that is consistent with the term sheet. In actual use, the template should be modified based on the business case, sector, and country context.

The PPA template prepared by the World Bank was crafted for a greenfield, grid-connected, single-site solar PV power plant co-located with a storage awarded to the seller via a competitive tender conducted by the government. It was drafted under English law, because of its prevalence in many developing countries. It would need to be customized to comply with local governing laws.

The template assumes that there is a lack of an established IPP track record and no alternative for selling to the government utility. This situation emphasizes the essential need for a PPA.

In the scenario described in the template, the seller intends to sell and deliver to the purchaser all the electrical energy generated by the solar PV plant as well as all the available storage capacity of the storage (described in the PPA as the “complex”). The template assumes that the project would charge the storage with the electrical energy generated from the PV plant; however, the seller also has the right to charge the storage at any time, using the grid by paying the purchaser for any charging energy at the regulated tariff.

The template includes two primary features:

- The seller provides a certain number of hours of energy storage on a fully dispatchable basis, with remuneration provided at the capacity charge rate.

- The seller provides the energy generated from the solar PV plant to the purchaser, with remuneration provided at the energy charge rate.

The purchaser makes the following payments to the seller:

- A monthly energy payment amount based on the aggregate of the PV plant metered energy and the deemed generated energy
- A monthly capacity payment amount based on the aggregate of available storage capacity or deemed storage capacity, where applicable, provided the previous month
- Tax, interest, and adjustments; 50 percent of the expenses paid to the independent engineer; and fees paid to any escrow agent or the bank issuing the letter of credit

The purchaser pays the seller the capacity charge for the available storage capacity even if a permitted scheduled outage or permitted unscheduled outage occurs.

The seller designs, constructs, installs, and commissions the complex and the interconnection facilities. The use-case described in the PPA template assumes that the interconnection facilities are handed over to the purchaser before the commencement of commercial operations. The seller undertakes the O&M of the complex based on annual, monthly, and weekly planned maintenance schedules.

This PPA template serves as a starting point. It needs to be adapted to meet the specific requirements and circumstances of each project. Transaction advisors, technical consultants, legal counsel, and other relevant parties must review and adapt the PPA to ensure it aligns with local laws, regulations, and market conditions before it is disclosed, even in draft form, to potential bidders or stakeholders.

Endnotes

1. This framework assumes that the solar and BESS assets are co-located. It is possible to locate the assets in different places (virtually linked with a single commercial contract).
2. *Firm energy* refers to the actual energy guaranteed to be available at all times during the committed period, even under adverse conditions.
3. *Full control* does not imply unrestricted authority. The level of control is subject to technical and operational limitations agreed upon by the parties, including those specified by manufacturers and integrators to ensure that warranties remain valid and intact.
4. In all cases, it is assumed that the grid operator will provide instructions to the asset owners to ascertain that the system is dispatched in the most economic and reliable way (if the assets are dispatchable). In small power systems, the utility plays the dual role of both buyer and grid operator, implying that the two roles overlap. In this case, some level of the assets control will always be expected.
5. Storage-only projects are excluded because they do not fit into the strict definition of hybrids. However, some countries, including India and South Africa, have started to tender storage-only projects. Other countries that have invested heavily in PV in

the past may need to tender storage-only projects, creating a \virtual hybrid\ at the system level. Depending on the interest of its client countries, the World Bank may consider storage-only business models in the future.

6. Sometimes remuneration is based on deemed energy (the energy that would have been produced if not curtailed).
7. Other commercial PPAs\such as the power system planned in The Red Sea Project (\TRSP\) in Saudi Arabia and implemented by ACWA Power\are atypical examples of a single-capacity contract. These agreements also remunerate all the assets (BESS, back-up thermal generator, and even solar PV) based on capacity.
8. Interviews with the Kauai Island Utility Cooperative (KIUC) revealed that it initially implemented single-price PPAs with dispatch control to sellers but that those PPAs proved ineffective in preventing solar curtailments and grid control when there was significant solar. To mitigate this problem, KIUC moved to PPAs that use the renewable dispatchable generation model with complete utility control, considering their system needs.
9. There may be situations, such as the RMI4P Program in South Africa, where the tariff-setting process includes a factor for capital recovery and fixed O&M related to fixed assets. This process mimics what a developer would do when calculating a bid price in a typical auction. However, this cost element should not be interpreted as a capacity payment.
10. *Islanding* refers to the condition in which a portion of an electrical grid becomes isolated and continues to generate and consume electricity independently from the rest of the network.
11. The study proposes categorizing PPAs as green, silver, gold, or platinum. Green PPAs meet current industry standards for annual energy matching. They potentially achieve 40\50% decarbonization if backed by solar PV and 60\70% percent if backed by wind energy. Silver PPAs achieve 80%, gold 90%, and platinum close to 100% decarbonization. The study shows that achieving increasing levels of greenness becomes very expensive. A calculation carried out for the California grid for 2025 forecasts that the levelized cost of electricity (LCOE) (renewable energy and storage combined) increases from $69/MWh for silver PPAs to $119/MWh for platinum PPAs. This gap of $50/MWh is projected to fall to $26/MWh by 2040, as a result of improvements in technology, economies of scale, and supply chain efficiency.
12. The Lawrence Berkley National Laboratory refers to a system that is co-located and has coordinated operation of the solar PV and BESS subcomponents as a \fully hybrid\ arrangement.
13. This report does not cover all risks associated with the PPA. It focuses on risks specific to hybrid solar-plus-storage projects.

FOUR

PROCUREMENT

This chapter overviews the competitive procurement approaches for IPP-owned solar-plus-storage projects. It examines a few aspects specific to storage that affect the design of the procurement process.[1] It describes a simple approach for evaluating the rates for energy and capacity services provided by solar-plus-storage projects under each of the business models described in this report and suggests procurement strategies linked to each.

Auctions that lead to long-term PPAs have enabled renewable energy projects to secure affordable financing and achieve competitive electricity tariffs globally. More than 100 countries use auctions to procure renewable energy as dedicated resources in technology-agnostic procurement modalities (IRENA 2019).

Many PPAs and auction modalities have been adopted. The extensive body of knowledge on solar PV auctions accumulated in the past 10 years can be applied to solar-plus-storage PPAs.

Solar-plus-storage PPAs are more challenging than tendering renewable energy alone, because they contain energy (MWh), capacity (MW), and ancillary services. In contrast, a typical renewable energy PPA involves a single product (energy), with no capacity or ancillary services attached to it.

Since 2015, most countries have migrated towards competitive IPP selection practices in an open auction environment, resulting in very competitive tariffs compared with feed-in tariff (FiT) policies. As of 2021, Vietnam, Kenya, and Mongolia had FiT prices of $0.0935, $0.120, and $0.150 per kilowatt hour, respectively. In 2019, under competitive selection, Tunisia, Ethiopia, Zambia, and the Philippines announced PPA prices of $0.0244, $0.0256, $0.03900, and $0.0450 per kilowatt hour, respectively (GCF 2023). Noncompetitive procurement methods, such as FiT, unsolicited projects, and bilaterally negotiated deals, are not recommended for solar-plus-storage projects.

For the competitive procurement process, practitioners have two options. The first is competitive bids based on price and nonprice factors. Nonprice factors could include the experience and financial standing of the bidder; the quality of the project design; and the project's environmental impact, social benefits, job creation, and other factors. Bidders have latitude in the technical solutions they present. Selection is based on a parametric formula based on factors and weights defined in the tender documents.

The problem with this approach is that projects can vary widely. As the assignment of weights is subjective, it is difficult for buyers to compare projects. Key evaluation criteria should be the technical skills and financial capability of the potential project developer. Other aspects to be considered include environmental and societal concerns.

The second option is an auction, in which the award is based solely on the price submitted by prequalified bidders that submit firm offers. Most procurement of PPAs for solar, wind, biomass, and in some cases hydropower plants have relied on auctions.[2]

An auction requires a very well-defined product. The solar-plus-storage PPA terms and conditions must be clearly defined before the auction. Once defined, the solar-plus-storage

PPA becomes a standard document for all bidders.[3] There should be no room for negotiation after the bidder is selected and the PPA is awarded.

For some business models, particularly when the buyer is also the system operator, the PPA should specify not only the energy requirements but also the ancillary services that should be provided. In two-part PPAs or fully dispatchable PPAs, the buyer makes a fixed payment for the storage or solar-plus-storage assets and has the right to make the best use of the assets to provide different combinations of stacked services, such as capacity, operating reserves, and frequency/voltage control, among others. The intensity of use for each service is bound by the operating agreement, in a way that preserves the assets' integrity and does not violate any warranty clauses.

For other business models, such as blended PPAs, and in more sophisticated systems, the provision of ancillary services is not under the scope of the PPA itself, but it is regulated by the grid code or interconnection agreement. In some cases, the asset owner can potentially trade those services in the capacity or ancillary services market. Trading is rarely possibly in World Bank client countries, but it has occurred in more sophisticated power markets.

How ever the provision of ancillary services is handled, it is important that the PPA, the business model, and regulations ensure that the stacked benefits are maximized to make the investments in the storage system more cost effective to the end-user.

Auction Types by Business Model

The design of the auction depends on the business model used (Table 4.1).

TABLE 4.1

Auction Type and Primary Selection Criteria, by Business Model

MODEL	AUCTION TYPE	PRIMARY SELECTION CRITERION
Two-Part Contract	Separate bids for energy and capacity (same auction)	Lowest levelized cost of energy ($/MWh)
Single-Capacity Contract	Bid for given PV and storage capacity	Lowest bid ($/MW/month) for joint capacity
Blended Energy Contract	Bid for price per MWh (for given firmness level)	Lowest bid ($/MWh)
Blended Energy Contract with Time-Differentiated Rates (variation 1)	Different bids ($/MWh) for time blocks or a bid for peak hours and a fixed tariff for off-peak	Lowest cost for system or lowest ($/MWh) or the lowest calculated tariff
Blended Energy Contract with 24/7 Firm Power Supply (variation 2)	Typically technology-agnostic bid (given a firmness level)	Lowest levelized cost of energy ($/MWh)

Two-Part Contract (PV Plus Storage)

In a two-part contract, two products—energy (from the PV) and capacity (from the storage)—are auctioned simultaneously. Bidders submit a price for each product.

There are two possible approaches for the auction process. In the first, each bidder provides the entire solar PV and storage capacity for the bid. In this case, there will be a single winning proposal. In the second option, bidders are allowed to submit bids for the megawatts for PV and the storage, up to the total amount of PV and storage to be contracted. In this case, there may be more than one winner.

The first case is more straightforward. Award of the contracts is based on the lowest levelized cost of energy and storage combined. The second case is more complex, allowing different combinations of bids of solar PV and storage and prices, with the award based on the combination that results in the lowest cost to the power system. This simple optimization process may result in different bidders for solar PV and the storage, which may not be an acceptable outcome. These issues need to be carefully considered at the early stages of auction design.

Single-Capacity Contract

As only one product—joint solar PV and storage capacity—is tendered under the single-capacity contract business model, the approach for the auction is direct and relatively simple. It is based on capacity, although the auctioneer must define the desired proportion of solar PV and storage resources to make proposals comparable.

Blended Energy Contract

As only one product (blended $/MWh) is tendered in the blended energy contract business model, the auction is simple and direct. As in the single-capacity model, the auctioneer must define the desired proportion of solar PV and storage resources to make proposals comparable.

Special considerations apply to the two variations of this model. The auction design is more challenging for time-differentiated rates, because at least two products—peak and off-peak electricity—are tendered. The bidder must submit prices for each of the products.

There are several options for awarding a contract when two products are being auctioned:

- In Colombia, bidders may offer one or more products (peak and/or off-peak energy). Bids are ranked based on the results of an optimization algorithm run by the auctioneer that selects the bidders that offer the best price/quantity combination for the tender.

The Colombia auction did not involve a storage, but the case is a successful example of auctions for multiple products.

- Chile used a similar auction approach in which storage was optional.
- Bidders in India have to offer both products. To supply energy during peak hours, they must provide storage. Off-peak energy is priced at a predefined fixed rate, and bidders make their offers on peak energy prices. The lowest weighted-average price bidder wins the auction.

In the blended energy contract with 24/7 firm power supply, only one product (MWh) is tendered. The auction can therefore be direct and simple.

The Mechanics of Auction Design

Practitioners need to make important choices in designing auctions. Three options to consider at the early stages of auction design include the following, all of which have been used for auctioning both solar only and hybrid solar-plus-storage projects:

1. **First-Price Sealed Bid**. Bidders submit their prices in a sealed envelope. The lowest-price bidder wins. There is no possibility for bidders to reveal or review their prices as part of the process. Because of its simplicity, this mechanism is the preferred method among the options examined in this report.
2. **Dynamic Reverse Auction.** Bidders have the opportunity to revise their offers as they learn how much other bidders offer. Bidders are more likely to offer lower prices as they learn about prices provided by other bidders, because this mechanism limits the potential for the "winner's curse," in which the lowest-price bidder wins but its offer is significantly lower than the second-lowest bidder. India has used reverse auctions in multiple tendering processes for solar-only and solar-plus-storage PPAs. Auctions involving one product (MWh or MW) can adopt dynamic designs without necessarily increasing the complexity of the bidding and award process.
3. **Uniform versus Discriminatory Price Auctions**. In uniform price auctions, all winning bidders receive a single price. In discriminatory (or pay-as-bid) auctions, winning bidders receive the prices of each bid. Uniform prices are more common, particularly if reverse auctions are used.

Table 4.2 lists selected outcomes of competitive procurement. It includes a parameter called the "price adder," which represents the additional price of a solar-plus-storage project compared with a PV-only solution. The price adder depends on the duration of the storage capacity.

TABLE 4.2

Selected Outcomes of Competitive Procurement, by Business Model

BUSINESS MODEL	USE CASE	TECHNOLOGY	PRICE ADDER
Two-Part Contract	Nevada, United States (2018): Six renewable energy projects with total capacity of 1,000 MW, including 100 MW of storage (400 MWh)	PV plus storage	Storage cost of capacity, ranging from $6,110 to $7,760/MW/month
Single-Capacity Contract	Hawai'i, United States (2021): Two projects, at Barbers Point (to be rebid) and Kahana solar. Total of 35 MW PV, four-hour (140 MWh) storage	PV plus storage	Information on contract price not available.
Blended Energy Contract	Hawai'i, United States (2019): 255 MW of solar power and 1,055 MWh of four-hour battery energy storage; selected bids for PV with storage of $80–$90/MWh	PV plus storage	$40–$50/MWh (four hours of storage)
	Morocco (2019): 800 MW CSP-PV Noor Midelt to provide dispatchable solar for five hours after sunset for peak hours price of $71/MWh	Hybrid CSP plus PV	$47/MWh
Blended Energy Contract with Time-Differentiated Rates	India (2020): 600 MW firm power for peak hours at $86/MWh for 6-hour period and 300 MW of firm power at $96/MWh for an 11-hour period; off-peak power paid at fixed price of $40/MWh	Renewable energy (PV and wind) and storage	$61/MWh (peak, six-hour). $71 MWh (peak, 11-hour-period) (PV-only project $25/MWh)
	RMI4P South Africa (2021): About 800 MW of hybrid projects.	PV plus ESS and small diesel (225 MW)	Average of $65.2/MWh
		PV plus storage, Wind, and small diesel (203 MW)	Average of $73,4/MWh
		PV plus storage only (150 MW)	$90/MWh
			(All figures assume a PV-only cost of $25/MWh)
Blended Energy Contract with 24/7 Firm Power Supply	RTC II India (2020): 2.5 GW; prices of $40–$42/MW for 80% average guaranteed capacity utilization	Renewable energy plus storage plus thermal generation	$73–$25 = $48/MWh (assumes PV-only project at $25/MWh)
	Corporate Green PPAs (United States): Cost calculation (by LDES and McKinsey) of virtual corporate PPAs with different levels of greenness (price adder), defined as difference between green PPA and average wholesale market price	Renewable energy plus long-duration energy storage	$18/MWh for 80% green, $27/MWh for 90% green, and $34/MWh for 100% green PPA (higher figures if compared with renewable energy-only PPA)

Endnotes

1. For a discussion of renewable energy and hybrid procurement modalities and auction designs, see Elizondo and Barroso (2021) and Maurer et al. (2020).
2. In some countries, such as South Africa, the law mandates inclusion of nonprice factors. As most bidders meet the requirements, the process becomes de facto an auction.

3. Asking potential bidders to provide inputs to a draft PPA and draft tender documents enriches the process and can identify issues affecting bankability. The process should be transparent, and questions should be directed to the procurement team. The questions and answers should be shared with all participants before the competitive process begins. Some countries establish formal processes, such as public hearings or public consultations, to garner inputs about the PPA, the procurement methodology, and tender documents in general.

FIVE CONCLUSIONS

A global energy paradigm shift is taking place. Thanks to both changes in technology and the growing recognition of the need for cleaner, more efficient energy generation and consumption, countries around the world are replacing fossil fuels with renewables. Many are bringing modern sources of power to large swaths of their populations for the first time.

Using solar can improve the lives of people, especially poor people; spur economic growth; and help mitigate global climate change. The intermittency of variable resources makes it difficult to ensure a stable and reliable power supply. This feature of solar energy reduces its attractiveness, especially in regions with small and weak power systems, such as Sub-Saharan Africa and SIDS.

Solar-plus-storage projects address the variability problem by combining solar resources with storage that harness excess power generated during periods of high output for use when output is low. The ability to store power vastly increases the appeal of renewables-based systems.

Thermal power plants can produce electricity at any time, but they are expensive to operate. The high cost of importing the fossil fuels strains developing countries' public finances, increasing their deficits.

Solar-plus-storage projects have much lower operating costs and several technical advantages over thermal systems. Unlike thermal generators, which constantly burn fuel to stay synchronized, solar-plus-storage projects have no minimum load requirements, enhancing their operational flexibility. They maintain grid synchronization even when not actively generating power. Solar-plus-storage projects also have quick startup times, enabling them to promptly respond to demand and frequency fluctuations without burning fuel, and they maintain consistent efficiency at all output levels. Storage facilities can also provide other ancillary services to the grid, such as frequency regulation and voltage control, which can improve the stability and reliability of the electricity grid. The substantial fuel savings solar-plus-storage projects provide and their reduction of dependence on imports, the ancillary services they provide to the grid and their far lower impact on the environment explain why sales of such systems are soaring.

This report describes three main business models that can be used to transition to solar-plus-storage systems. It focuses on an IPP-owned modality, which unlocks private capital, allows risks to be shared by IPPs and utilities, and promotes resource efficiency and effectiveness.

The proposed framework for streamlining the adoption and deployment of solar-plus-storage system includes four-phases (see Figure 3.1):

- Overall system planning
- Definition and assessment of the potential for a solar-plus-storage project
- Assessment of potential business models
- Selection and implementation of the most appropriate of the three business models described

The framework builds on the World Bank's de-risking and integrated planning approach outlined in the SRMI framework as well as the World Bank's Energy Storage Program and Partnership.

The decision tree shown in Figure 4.2 helps practitioners choose the most appropriate business model and risk allocation scheme based on the conditions in their market.

The report also describes the competitive procurement of solar-plus-storage PPAs, including the design of auctions, and provides a term sheet and PPA template. Both are useful starting points for practitioners, who can customize and adapt them to local contexts.

Reliance on diesel, heavy fuel oil, and thermal generation contribute to fiscal deficits and debt distress in developing countries. Hybrid solar-plus-storage solutions present a technically viable and economically attractive value proposition that can help many developing countries break the vicious cycle of vulnerability and fuel dependence they face.

The knowledge resources provided in this report are based on international experience with projects that have succeeded and failed with solar-plus-storage applications. As experience with these systems grows and technologies mature, new practices and business models are expected to evolve and emerge. Practitioners therefore need to consult relevant professionals, consultants, and transaction advisors, to make sure that their choices reflect both the state of the art and the context, needs, and other requirements of their markets.

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APPENDIX A

Advantages and Disadvantages of Selected Business Models

Each of the business models described in this report has advantages and disadvantages.

Two-Part Contract

The advantages of the two-part contract include the following:

1. The model is suitable when the government wants the private sector to jointly own, develop, and finance both PV and storage assets. Private capital can be attracted to finance the entire solar-plus-storage project.
2. The model provides the buyer (utility or grid operator) with great flexibility to dispatch the storage to meet various requirements (peak-shaving, mitigation of PV curtailment, reduction in load-shedding, and so forth).
3. The integration of renewable energy with a storage facilitates better coordination of both assets. PV and the storage can be sized to suit customer needs in terms of energy, storage capacity, and duration, increasing flexibility for the buyer. As the buyer is typically the grid operator in a two-part contract, all joint services provided by PV and the storage can be part of the same PPA and benefit the grid as a whole.
4. Flexibility is highly desirable in small systems or when a system has few resources to manage demand/supply variability. A two-part contract permits co-location, which reduces land acquisition, siting, and interconnection costs.
5. Dual remuneration provides energy payment for the MWh produced (or deemed) and creates a stable cashflow stream for the seller on the storage component.
6. A fixed payment based on storage capacity is a better option than remunerating the storage for specific services provided, because most World Bank client countries lack markets for most services (capacity, frequency regulation) and some services (such as voltage regulation) cannot be monetized at all.
7. The simple remuneration process in this model is consistent with the fact the buyer has full discretion to maximize the use of storage assets, stacking as many services as possible. This process ensures predictable cashflow streams.
8. As many important risks (resource volatility, curtailment, and market) remain with the buyer, the project can be highly de-risked, enhancing its bankability—an important feature in a nascent industry with which financiers are still getting acquainted.
9. The fixed/variable payment remuneration resembles the traditional energy/capacity payment often used in thermal generation contracts, making the transition from thermal generation to a two-part contract less disruptive for buyers and sellers.

The disadvantages of a two-part contract include the following:

1. The seller has no obligation to firm up energy delivered; the buyer has to do so with its own portfolio or resources (plants, contracts, and reserves).
2. The model may not be suitable when funds are earmarked for financing storage and separation of ownership between PV and storage assets become necessary.
3. Competitive procurement is slightly more complex than in a traditional PV PPA, as the award has to find the lowest-cost solution for two products (energy for the PV and capacity for the storage) simultaneously put for bid in the auction.

Single-Capacity Contract

The advantages of a single-capacity contract include the following:

1. The model permits co-location, reducing permitting, land acquisition, and connection costs.
2. The model enables buyers (utilities or grid operators) to jointly optimize assets to produce energy and ancillary services. Thanks to its high control capability, a single-capacity contract is the most likely to capture the maximum benefits that PV plus storage can provide (value stacking).
3. For the storage, the model provides the same level of flexibility to the system operator as a two-part contract. For PV production, it offers maximum flexibility/dispatchability to the grid operator, as it allows buyers to use PV assets to provide energy, voltage ampere reactive (VAR), and voltage control.
4. Buyers can underschedule production to obtain certain ancillary services without paying any compensation to the seller. They can do so under a two-part contract, but doing so would require detailed clauses on the contractual arrangements for the loss of production.
5. Remuneration based on a fixed payment for MW of PV and storage shifts much of the risk from the seller to the buyer. The seller is not responsible for resource variability, which is typically assigned to the seller in most PV-only PPAs. Given that the PPAs are highly de-risked, projects should be very bankable.
6. Auction design and award are relatively simple, as remuneration is based on $/MW/month for both the storage and PV and the lowest $/MW/month bid is awarded the contract.

The advantages of a single-capacity contract include the following:

1. The model is relatively new, and very few projects have implemented it. The risk allocation profile is a little lopsided, as most risks are pushed to the buyer. Even PV production and resource variability risks, which are borne by the seller in a typical PV PPA, are pushed to the buyer.
2. The model does not require the seller to firm up energy; the buyer must do so with its own portfolio of resources (plants, contracts, and reserves).
3. Buyers and regulators may feel uncomfortable with this unusual risk allocation profile and form of remuneration, in which all assets receive a fixed capacity payment. In a rate

case, it may be difficult to justify to regulators that the model is cost effective and maximizes benefits to end-users.
4. The model requires secure and uninterrupted communication between the dispatcher and the assets to fully utilize the dispatchability of the assets remotely.

Blended Energy Contract

The advantages of a blended energy contract include the following:

1. The model is less complex than other models, with single pricing on a $/MWh basis. The seller pairs renewable energy assets with a storage but trades firm or quasi-firm power on an energy-only (MWh) basis.
2. The seller has more control over the operation of the storage and makes dispatch decisions to ensure that the firm or quasi-firm contracted amounts are delivered. The seller has more autonomy to make decentralized decisions, including islanding, increasing the system's resilience.
3. The model provides the ability to blend several sources of power generation and a storage into a single contract. Under a blended PPA, there is no capacity payment. Instead, remuneration is based solely on a single energy payment ($/MWh).

The disadvantages of a blended energy contract include the following:

1. The buyer has less flexibility to manage storage assets, which is not advisable in smaller and/or weak systems with limited reserves.
2. The buyer has less control to specify PV and storage sizes, in terms of MW of capacity and storage duration, because the seller delivers MWh and not a particular set of assets.
3. The model assigns more risks to sellers, to comply with contractual obligations to deliver an agreed load profile. In smaller grids and in the absence of spot markets, the seller will have fewer options to combine resources/contracts to deliver the contractual obligations.
4. Projects are more complicated for sellers to manage because they take some of the risks of volatility and make decisions about the optimal use of the assets.
5. To mitigate those risks and make projects bankable, the PPA has to specify the conditions under which the obligation to deliver is waived (e.g., several consecutive days with no sun).

Blended Energy Contract with Time-Differentiated Rates

The advantages of a blended energy contract with time-differentiated rates include the following:

1. Different prices are applied for peak and off-peak power delivery (or in accordance with different time blocks), based on the needs of the buyer.

2. Energy resources can be managed more efficiently, as the system can respond to changes in demand and supply in real time and adjust output accordingly.
3. The model helps displace the most expensive (and polluting) thermal generators units, which are designed to meet peak loads and have high capital and operating costs.
4. The model transfers risks to the seller with higher abilities for it to be managed, leading to more efficient investment and operational decisions.

The disadvantages of a blended energy contract with time-differentiated rates include the following:

1. The buyer has less flexibility to operate PV and storage assets. It has limited control to specify PV and storage sizes and storage duration. A blended energy contract with time-differentiated rates prioritize energy firmness over dispatchability. However, if the buyer is also the system operator (e.g., ESKOM under RMI4P in South Africa), the PPA may contain clauses specifying some levels of firmness, terms of dispatchability and provision of ancillary services (if applicable).
2. The model adds risks depending on the penalties for non-delivery during peak hours, and the peak/off peak remuneration ratio. One of these risks is the seller's obligation to deliver fixed and firm volumes of energy in certain time blocks at differentiated prices. It may be difficult for sellers to comply with this requirement, particularly if resource variability is high. Sellers may be heavily penalized for non-delivery, particularly if there is no organized market for sellers to procure the energy shortfall to fulfill their contractual obligations. These risks can be mitigated if the seller combines a portfolio of assets. For example, most bidders in the RMI4P in South Africa combined PV, wind, storage, and back-up diesel generation to meet the strict requirements of "dependable capacity."
3. If bidders are not able to hedge resource variability via a portfolio of assets, risks may reduce project bankability and/or increase the bid price. These risks need to be identified, assessed, and if necessary (re)-allocated to ensure project bankability.
4. As in a blended energy contract, the PPA trades energy only. It does not provide an explicit remuneration formula for ancillary services. If ancillary services are provided to the grid, they should be governed, priced, and paid for by the grid operator as part of the grid code or interconnection agreement, assuming that the jurisdiction has a grid code and a payment mechanism for the provision of ancillary services. Those payments do not assume the existence of markets for capacity or ancillary services; they are a simple arrangement between the system operator and any generator connected to the grid.
5. The procurement process is more complex than in other models, because it entails more than one product via auctions (e.g., peak, valley, off-peak). The selection process has to find the optimal combination of prices and quantities among multiple bidders. Some simplifications are possible, such as setting fixed rates for off-peak energy and procuring only peak energy competitively. The auction design needs special attention.
6. Resource volatility and the seller's obligations to deliver fixed quantities at certain time blocks make contractual obligations more rigid and therefore difficult to meet, subjecting the seller to contractual penalties. A blended energy contract with time-differentiated rates tends to be more attractive in relatively well-developed power sectors with some form of spot market.

Blended Energy Contract with 24/7 Firm Power Supply

The advantages of a blended energy contract with 24/7 firm power supply include the following:

1. The model provides a high level of energy firmness, which may vary depending on system requirements. In remote areas that are not served (or poorly served) by the utility, for example, requirements may be very high (up to 100%); in large systems with abundant reserves, 70 to 80 percent figures have been observed.
2. The seller has discretion to combine a variety of assets and contracts, optimizing resources on the grid and fostering creativity to provide energy at the lowest possible price.
3. The model can contribute to the deeper decarbonization of the grid system. Typical corporate renewable energy PPAs lead to only 30 to 40 percent decarbonization; a blend of resources and long-term energy storage is key to competing and displacing fossil fuel-baseload generation. This model is best able to achieve this objective (although achieving 100% green PPAs is exponentially more costly than achieving partial decarbonization).
4. The PPA can be designed in a way that achieves a good balance between the objectives of decarbonizing the grid and enhancing power system reliability with PPAs with high levels of firmness.
5. If some market rules and grid codes exist, projects are likely to be bankable, if the risks faced by the seller are clearly identified and hedging mechanisms exist.

The disadvantages of a blended energy contract with 24/7 firm power supply include the following:

1. The seller takes on most of the risks of delivering a high level of energy firmness. This risk can be mitigated if the seller has access to a combination/portfolio of assets/contracts that can be blended.
2. The model may require the addition of nonrenewable energy sources (complementary thermal generation) to meet the expected levels of energy firmness, reducing the greenness of the PPA.
3. In most cases, resources will not be co-located. Basic rules are needed governing the connection and use of the grid by third parties.
4. The buyer and grid operator are different entities. Therefore, specific payments for ancillary services should be provided (via market rules and grid codes)
5. The PPA may be traded in a large power system, in which the grid operator decides which plants have to be dispatched (or not). Sellers are therefore exposed to dispatch risks. To mitigate this risk, market rules need to be set that compensate the PPA’s underlying assets for constrained-on and constrained-off operations.

APPENDIX B
Term Sheet Template

The term sheet template presented in Table B.1 provides a comprehensive (but nonexhaustive) framework for the PPA based on a two-part contract. It guides practitioners through the key elements that need to be considered when entering into a PPA. The term sheet should use technology-agnostic language, in order to ensure flexibility and adaptability to evolving technological trends. (The term renewable energy encompasses PV technology without compromising the broader project definition.) All of the terms included are suggestions and can be redefined based on a project's requirements.

The term sheet reflects the following charges and payment methods:

- The energy charge is paid for each kWh of energy delivered to the delivery point from either renewable energy source. The amount of delivered energy is measured by the energy meters connected at the delivery point.
- The capacity charge in $/kW/month is paid for the average available capacity provided by the storage over a month. Average availability is determined by the storage' monthly self-reporting.
- Contracted energy is the annual estimated energy to be delivered to the delivery point from renewable energy. Failure to deliver the contracted energy causes liquated damages based on the shortfall energy charge that the seller shall pay the purchaser.
- To the extent an interruption, curtailment, or reduction pursuant to curtailment results from a transmission event, the purchaser shall pay the seller the deemed energy charge.
- The purchaser has dispatch rights over the storage (maximum limits on the number of cycles per day and cycles per contract year the purchaser has right to dispatch the storage).

TABLE B.1

Term Sheet Template

CATEGORY/SUBCATEGORY	TERMS
GENERAL	
Business model	Model: [_____]
Purchaser details	Name: [_____] Legal status: [_____] Country of incorporation: [_____] Address: [_____] Email: [_____]
Seller details	Name: [_____] Legal status: [_____] Country of incorporation: [_____] Address: [_____] Email: [_____]
Name of project	[_____]
Commercial operational date (The commercial operation date is the date on which the seller notifies the purchaser of the fact that the system [renewable energy plus storage] is mechanically and electrically complete and operational and providing PV output and storage output through the meter(s) to the delivery point.)	[_____]
Metering (The seller shall, at its own expense, procure, install, test, and commission the main meter and a back-up meter at the delivery point, both at the renewable energy in relation to the production of net electrical output and at the storage in relation to it net electrical output and charging energy [grid].)	[_____]
Evidence of insurance	Name of insurer: [_____]
RENEWABLE ENERGY	
Contract term	[_____] years
Location or site	[_____]
Address of delivery point	[_____]
Manufacturer and model	Manufacturer: [_____] Model: [_____] Certifications: [_____] Comments: [_____]
Inverter	Manufacturer: [_____] Model: [_____] Certifications: [_____] Product warranty: [_____] years Guarantee against manufacturing defects: [_____] years Comments: [_____]

(*continues*)

TABLE B.1

Term Sheet Template (*Continued*)

CATEGORY/SUBCATEGORY	TERMS
Mounting structures	Type: [_____] Manufacturer: [_____] Model: [_____] Comments: [_____]
Power transformers - for ratings above 2.5 Mega-Volt-Ampere [MVA] (outdoor, oil-filled type) and for ratings below 2.5 MVA (oil-filled type or dry-cast resin type)	Manufacturer: [_____] Model: [_____] Ratings: [_____] Type: [_____] Comments: [_____]
Contracted capacity	[_____] MW (AC)
Minimum guarantees	First-year degradation: Up to [_____]% Annual degradation in subsequent years: [_____]% Guaranteed power output: No less than [_____]% of initial nominal power after [_____] years
Capacity utilization factor (factor is fixed for contract term)	[_____]%
BATTERY ENERGY STORAGE SYSTEM (STORAGE)	
Contract term	[_____] years
Location or site	[_____]
Address of delivery point (if not co-located with renewable energy)	[_____]
Description	Technology: [_____] Manufacturer: [_____] Model: [_____] Minimum guarantee: [_____] years Guarantee against manufacturing defects: [_____] years Comments: [_____]
Inverters	Manufacturer: [_____] Model: [_____] Certifications: [_____] Product warranty: [_____] years Guarantee against manufacturing defects: [_____] years Comments: [_____]
Contracted capacity (Insert the contracted capacity of storage with the nameplate power in MW; expand the list until the end of the contract term.)	Year Capacity (MW) 1 [_____] 2 [_____] 3 [_____] 4 [_____] 5 [_____]

(*continues*)

TABLE B.1

Term Sheet Template (*Continued*)

CATEGORY/SUBCATEGORY	TERMS
Minimum storage capacity	[_____] % of storage contracted capacity
Depth of discharge	[_____] MWh
RATES AND LIMITS (ALL RATES ARE EXCLUDING VAT)	
Contracted energy (contracted capacity of renewable energy in MW multiplied by the capacity utilization factor [CUF] in percent multiplied by number of hours in a year [8,760])	[_____] MWh/year
Energy charge to be paid by purchaser to seller for energy delivered to delivery point pursuant to dispatch instruction	[_____] $/MWh
Deemed energy charge to be paid by purchaser to seller because of interruption, curtailment, or reduction in power provided	[_____] $/MWh
Capacity charge to be paid by purchaser to seller for making storage available to the purchaser for dispatch in accordance with dispatch instructions issued	[_____] $s/MW/hour
Regulated tariff to either (a) charge the storage or (b) for on-site consumption by the storage that the Seller shall pay the purchaser for any Net charging Energy (Grid)	[_____] $/MWh
Maximum cycles over contract year purchaser has right to dispatch the storage	Up to [_____] cycle per contract year
Maximum cycles per day of contract year that purchaser has right to dispatch the storage	Up to [_____] cycles per day of each contract year
Permitted outages per contract year	Permitted scheduled outage: [_____] hours Permitted unscheduled outage: [_____] hours
PAYMENT	
Currency	[_____]
Payment schedule	The seller shall submit a statement to the purchaser every [_____] months. The statement shall contain reasonably detailed calculations of the amounts payable under it, together with such further supporting documentation and information as the parties may agree. The purchaser agrees to pay the seller on or before the [_____] day following receipt of the invoice.
Annual interest rate charged for late payments	[_____]%
Energy payment (the amount that will be calculated in each statement to be paid by the purchaser to the seller for the energy delivery from the system)	The purchaser agrees to pay the seller for delivered energy to the delivery point from renewable energy multiplied by the energy charge.
Deemed energy payment (the amount that will be calculated in each statement to be paid by the purchaser to the seller for the deemed of the system)	The purchaser agrees to pay the seller for deemed energy multiplied by the deemed energy charge. No deemed energy payment shall be due in any given year unless and until the cumulative duration of the curtailments in such year exceeds [_____] hours.

(*continues*)

TABLE B.1

Term Sheet Template (*Continued*)

CATEGORY/SUBCATEGORY	TERMS
Capacity payment (the amount that will be calculated in each statement to be paid by the purchaser to the seller for the capacity availability of the storage)	The **purchaser** agrees to pay the seller for the average availability of storage capacity over a month multiplied by the capacity charge following the Commercial Operation Date (COD). If compliance with warranty conditions requires idle time for the storage, the storage will not be considered available for this period.
Liquidated damages for energy deficit	If the seller fails to deliver at least [______] % of the contracted energy, it shall pay the purchaser liquidated damages, calculated as [______] multiplied by the energy charge multiplied by the shortfall energy.
DEFAULT	
Force majeure	Any circumstance, event, or condition (or combination thereof) that is beyond the reasonable control, directly or indirectly, of the responsible party, including natural and political events
Dispute resolution	In the event of default, the parties shall attempt to settle the dispute in good faith. If they are unable to resolve their disputes through negotiation within [_] days of the dispute notice, either party may initiate proceedings to submit the dispute for arbitration. The seat of arbitration shall be [______].
Governing law	This agreement shall be governed by and construed in accordance with the laws of [______].
Termination	The agreement is terminated under the following conditions: • The seller fails to achieve completion of the project within [______] days after the commercial operation date (COD). • The seller fails to maintain the required insurance for a period of [______] business days. • The seller abandons construction. • The renewable energy and storage capacity demonstrated by the latest performance tests are less than the contracted capacity and the seller fails to cure such deficiency. • In any contract year, the energy delivered by the seller to the **purchaser**, together with any curtailed product, is less than [______] % of the contracted energy. • The seller goes bankrupt or commits an illegal act.

APPENDIX C
Power Purchase Agreement Template

The PPA template prepared by the World Bank and IFC is available at https://www.esmap.org/Unlocking_Energy_Transition. It was prepared for a greenfield, grid-connected, single-site solar photovoltaic power plant co-located with storage awarded to the seller via a competitive tender that has been conducted by the government.

The use case of the solar-plus-storage project in the template is:

- to provide a certain number of hours of renewable energy storage (e.g., between 1–4 hours) on a fully dispatchable basis with a capacity-based tariff, so as to provide the maximum dispatch flexibility to the off-taker and maximize the value of the storage in peaking power periods, and
- to sell energy generated from the PV Plant to the purchaser with an energy-based tariff. The practitioner should customize their PPA based on the use case of their project (e.g., two-part PPA, blended PPA and its variations), and to the specific requirement and characteristics of each country and power sector.

In the use-case described in the PPA, the Purchaser would pay the Seller:

- Monthly Energy Payment Amount in respect of the aggregate of the PV Plant Metered Energy and the Deemed Generated Energy and,
- Monthly Capacity Payment Amount in respect of the aggregate of Available Storage Capacity (or, where applicable, Deemed Storage Capacity) in respect of the previous month;
- Plus, tax, interest, adjustments, 50 percent of the expenses paid to the Independent Engineer, and fees paid to any Escrow Agent or Letter of Credit (LC) Issuing Bank.

It is important to note that the template PPA serves as a starting point and must be customized to suit the specific requirements and circumstances of each project. Transaction advisors, legal counsel and other relevant stakeholders should review and adapt the template PPA to ensure it aligns with local laws, regulations, and market conditions.

It is critically important to note that this template PPA serves only as a starting point and will need to be customized to suit the specific requirements and circumstances of each project, based on the chosen business and commercial modality. Transaction advisors, technical consultants, legal counsel, and other relevant stakeholders should review and adapt the template PPA to ensure it aligns with local laws, regulations, and market conditions before it is disclosed, even in draft form, to potential bidders or stakeholders.

APPENDIX D

Complementary Knowledge Resources

The following World Bank reports complement this one and could prove useful to practitioners:

- ***Scaling Up to Phase Down: Financing Energy Transitions in the Power Sector*** (World Bank 2023b) presents a framework that maps out steps developing countries can take—with the help of development partners—to scale up affordable, secure, and reliable clean energy and phase down coal-fired electricity generation. It outlines a six-step vision to help developing countries create a virtuous cycle to accelerate the clean energy transition.
- ***A Sure Path to Sustainable Solar, Wind, and Geothermal*** (World Bank 2022) presents a three-phase approach to scale up privately financed sustainable renewable energy projects. In the planning phase, technical plans are proposed to enable the country to develop informed renewable energy targets. During the strategy phase, a sustainable renewable energy program is developed. In the implementation phase, the national renewable energy program is implemented.
- ***Deploying Storage for Power Systems in Developing Countries: Policy and Regulatory Considerations*** (ESMAP 2020) examines the role of energy storage given trends in power systems, with an emphasis on developing countries. It identifies the ways in which storage can help meet policy objectives and overcome technical challenges in the power sector; provides guidance on how to determine the value of storage solutions from a system perspective; and discusses relevant aspects of policy, market, and regulatory frameworks to facilitate storage deployment.
- ***Guidelines to Implement Battery Energy Storage Systems under Public-Private Partnership Structure*** (Gamarra et al. 2023) provides guidance on how structures can be implemented to broaden the role of storage in developing countries.

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ESMAP
Energy Sector Management Assistance Program

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