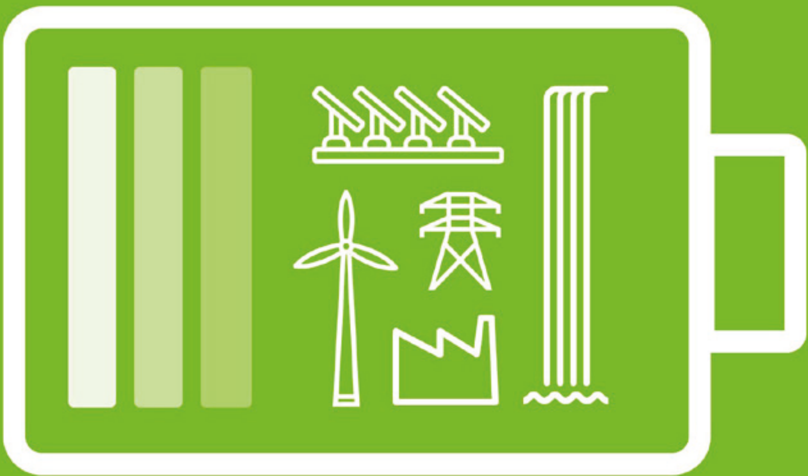
Understanding Energy Storage



UNITED STATES DEPARTMENT OF COMMERCE
Secretary of Commerce
Washington, D.C. 20230

Opening Letter for "Understanding Energy Storage" Handbook

Since 2013, the U.S. Government's Power Africa initiative, a whole-of-government effort, has marshaled technical, legal, and financial resources towards the goal of doubling access to electricity in Sub-Saharan Africa. The U.S. Department of Commerce is proud to have been a founding member and substantial contributor to Power Africa from the very beginning.

One of the Commerce Department's signature contributions to Power Africa has been the *Understanding* handbook series developed by its Office of the General Counsel's Commercial Law Development Program (CLDP). This open-source and plain-language knowledge library now includes six handbooks explaining a range of essential topics in power project contracts, financing, and procurement. In recent years, the *Understanding* series has expanded to focus on unique challenges in Africa's energy market, such as the complex nature of private participation in transmission projects. With 65,000 copies in print and tens of thousands more copies downloaded online, the *Understanding* series has become a trusted resource in Africa's power project community.

The most recent addition to the *Understanding* series, *Understanding Energy Storage*, comes at a critical time in both the development of the continent and the effort to combat climate change globally. It is my hope that this handbook will contribute to Power Africa's efforts to catalyze new energy storage investment as a core component of overall market development. This handbook supports the U.S. Department of Commerce's Renewable Energy and Energy Efficiency Advisory Committee's recommendations on (i) Clean Tech Export Competitiveness Strategy, (ii) Energy Equity, and (iii) Technology Risk Mitigation and Financing; and advances the U.S. International Climate Finance Strategy.

In developing the handbook, CLDP convened a group of international experts on energy storage, including engineers, lawyers, economists, and government representatives, with an understanding that this evolving technology has the potential to both expand energy access and accelerate decarbonization in Africa's energy market. These many authors collectively volunteered more than 1,000 hours to produce a resource that reflects their collective wisdom on how to meet the challenges of adapting and deploying energy storage capacity in Africa. I am deeply grateful for their contribution and for the essential role the U.S. Department of Commerce played in delivering this Power Africa resource to readers around the world.

Sincerely,

Gina M. Raimondo

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POLICY

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Introduction

Background

Power markets worldwide are experiencing a historic shift in how energy is produced, marketed, and consumed. This dynamic is also driving innovation in the technological design, financing, and legal structuring of power systems. Driven by the combination of greater emphasis on energy access, falling prices for renewable energy, increased attention to energy efficiency, and concern around climate change, the current energy transition represents both a challenge and an opportunity for the diverse set of actors in power markets.

Energy storage is one key to unlocking a future of the power sector that can be designed to be more flexible and predictable in terms of operating costs and the revenue streams that recoup capital costs. In recent years, many storage technologies have emerged that allow for short-duration, rapid-response energy storage and longer-duration applications that can economically shift energy to periods of high seasonal demand, such as scorching summer months, or low supply, such as during droughts. All signs indicate that new storage technologies will continue to emerge.

With the proliferation of renewable energy technologies, energy storage can also serve a role in decarbonising grids as it enables variable renewable energy (VRE) generation technologies to attain a level of total power system share that in years past was not technically feasible. Energy storage solutions can provide flexible daily renewable ramp rates, balance out power capacity changes during weather abnormalities, optimise renewable outputs to achieve maximum payback during peak periods, and enhance operations when these solutions integrate with existing assets to benefit the overall operations of a power network.

The Handbook

The rising adoption of energy storage systems (ESS) represents a perfect example of the co-existence of challenge and opportunity in the current energy transition. ESS is increasingly able to deliver, and in some cases improve, energy services for utility grids, behind-the-meter customers, and mini-grids at increasingly competitive prices. At the same time, the broad array of ESS technologies, scales, costs, and uses represents a significant challenge for utilities seeking value, developers seeking profits, and regulators seeking to maintain access to affordable and reliable power for the most important stakeholder in this space, the customer.

We hope that this handbook takes advantage of this unique moment in the evolution of energy storage. Never before in the history of power systems has it been possible to store electricity at the size, cost, and speed currently feasible. As grids become smarter and off-grid solutions burgeon, energy storage can be wielded to vault past the technical impediments of traditional power solutions. Most importantly, while the future of energy storage's role in the marketplace is not certain, there is enough collective experience (both around the world and within our community of authors) for a meaningful insight into the best practices for ESS development at the technical, financial, and legal levels.

Energy storage is a powerful tool that can change the pathways to power that sector decision-makers pursue. As is the case for any tool, foundational knowledge of the uses, basic principles, risks, and rewards is essential. This handbook is intended to provide the reader with an overview of each of these key issues around ESS in a balanced manner that does not advocate but rather empowers decision-makers at all levels of the power market to make more informed decisions as they evaluate this emerging technology.

A Guide to the Handbook

Who Is This Book For?

General knowledge of the different types of ESS is important as the technology and its diverse applications have not yet become well understood by practitioners within the power sector space due to the rapid pace of change. This book seeks to introduce to such practitioners some of the new capabilities of ESS and how these can be financed within both the public and private spheres.

The practitioners could include government officials, regulators, utilities, procurement departments, bankers, Development Finance Institution (DFI) officials, developers, and lawyers involved in the electricity sector. These groups, among others, are intended to take away from this handbook key concepts and applications of energy storage which may be used to begin planning for storage incorporation into their respective contexts by evaluating the needs of their systems, the state of their policies, and regulations, and the options available. With this information, the intended readers will ideally finish this book with a better command and comfort level of the topic.

What Is the Scope of This Book?

This handbook covers established practices and recent developments in the regulatory, policy, planning, finance, and contracting spaces to support ESS, as well as risks, challenges, and sustainability considerations.

In addition, this handbook provides examples of how regulation can be adapted to accommodate ESS, as well as a detailed list of use cases that describe how an ESS can be used. These use cases can be stacked to create even more value, and several case studies are provided as examples of this.

This handbook does not cover specific ESS technologies in-depth, nor does it purport to provide a comprehensive summary of all salient points related to energy storage. This handbook assumes that the reader has a general background knowledge of power systems and is focused on energy storage. However, this handbook describes many attributes of the various technologies that need to be considered when selecting a technology or preparing a tender to select such systems. It also provides a summary of points that the authors feel are particularly important when considering energy storage.

Who Are the Authors?

The authors represent a diverse set of practitioners within the broader energy sector, encompassing government officials, engineers, lawyers, academics, and financiers. This handbook thus seeks to capture much of their collective practical experience and knowledge rather than that of any one industry group, practitioner, or organisation. The book was prepared through a collaborative writing process that produced insights that were greater on the whole than possessed by any one individual. As noted throughout the text, there are added benefits as well as complexities to developing generation projects when including storage or when distributing it across a grid. The authors' varied areas of specialisation allowed the handbook to lay out these complexities in a digestible format while enumerating and categorising the inherent benefits of the technology and how it can optimise value creation and cost savings. The authors participated in the drafting and editing of this handbook on a pro-bono basis and are encouraged that its publication will make available a baseline of understanding about energy storage, its adoption, and its potential utility to markets and society.

How Does This Book Fit Within the *Understanding* Series?

This handbook is the sixth in the *Understanding* series published by Power Africa. This book references the other handbooks which are widely available in print and electronic formats, usually noting that a concept or area of subject matter has been more comprehensively explained in one of the other books. In these instances, that topic will not be explained in a detailed manner, and it will be assumed that the reader, if not familiar enough, can refer to the relevant handbooks.

How was this book developed?

The handbook was produced using the Book Sprint (*www.booksprints.net*) method which allows for the drafting, editing, and publishing of a complete product in just five days. Our journey began with a spirited discourse and quickly progressed to a furious pace of writing with occasional interruptions for the introduction of brilliant ideas and critical insights. There was a surprising amount of consensus on some topics and an unexpected level of debate on others. The outcome is a product that reflects this teamwork rather than the personal opinions of the authors or the institutions that they represent.

The authors would like to thank our Book Sprint facilitator Barbara Rühling for her patient guidance and unwavering leadership throughout the nearly 75-hour drafting process. The authors would also like to thank Henrik van Leeuwen for turning our rushed scribbles into beautiful and meaningful illustrations. We would also like to recognize the tireless work of BookSprints' remote staff Raewyn Whyte and Christine Davis (proofreaders).

The authors would like to recognize the following individuals and institutions that helped focus dialogue to build a consensus around the need for this handbook: Megan Taylor (Power Africa); Gadi Taj Ndahumba (African Legal Support Facility); Stephen Gardner (Commercial Law Development Program). Considerable planning and development went into the conceptualisation of the power project procurement handbook. In particular, our deepest appreciation goes to Elizabeth Clinch and Lydia Hollingsworth (CLDP). The authors would also like to thank the generous funding and logistics support from the United States Agency for International Development's Power Africa program and the African Legal Support Facility.

How may I use this book?

To continue the tradition of open-source knowledge sharing that is at the core of the Power Africa Understanding series, this handbook is intended to reflect the vibrant nature of the Book Sprint process and serve not simply as a reference but also as a jumping-off point for further discussion and scholarship. The handbook is issued under the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License (**CC BY NO SA**). In selecting this publication license, anyone is welcome to copy, excerpt, rework, translate and re-use the text for any non-commercial purpose without seeking permission from the authors, so long as the resulting work is also issued under a Creative Commons License. The handbook is initially published in English with French, and Portuguese editions soon to follow. The handbook is available in electronic format at *cldp.doc.gov/Understanding*, and print format. It can be used as an online interactive resource. Many of the contributing authors are also committed to working within their institutions to adapt this handbook for use as the basis for training courses and technical assistance initiatives.

Sincerely,
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Use Cases

Introduction

When considering storage applications in the context of a particular market, it is necessary to understand the various services that can be delivered and the different use cases for each one of them. Due to the sheer number of services and types of users, energy storage systems (ESS) are often viewed as complicated assets. The quantum of potential benefits that one storage system alone can provide should not overwhelm customers or system operators as these services or use cases can be categorised and articulated. Thus, based on the needs and constraints, the entity assessing the viability of a storage solution should evaluate the various energy storage technologies and the different services, functions, and the value offered.

Some of the use cases presented below lead to similar ESS operations. While these ESS operations may seem similar, they address different needs.

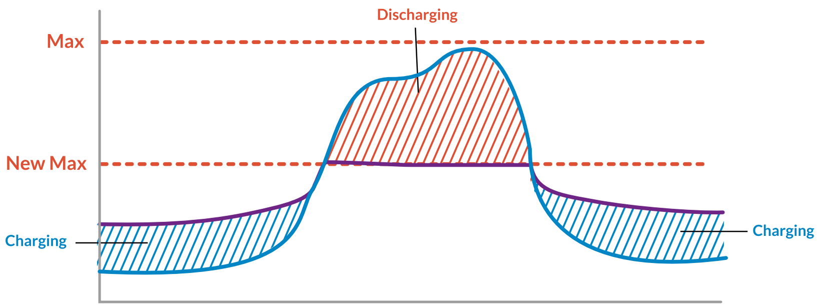
The use cases have been categorised into three sections, namely capacity services, energy services, and ancillary services. It should be noted that these lists are by no means exhaustive, and new use cases are emerging regularly.

Capacity Services

When it relates to ESS, capacity services are the applications by which an ESS helps maintain the balance between the electricity supply and demand in a given system. The point of balance rises and falls as various customers change their electricity consumption and power plants adjust their output, or as faults occur on the network.

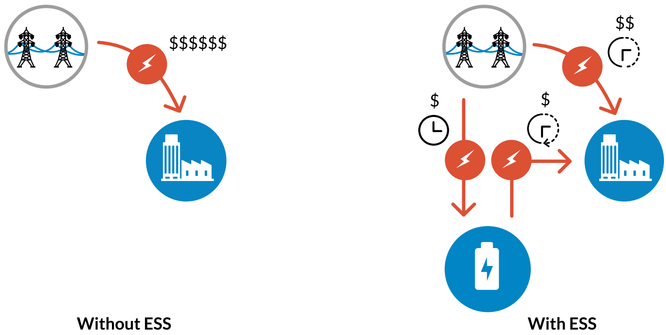
Peak Reduction

To prepare for rising electricity demand, many system planners and operators continually build new generation capacity to match the increase in the peak of their demand curve. However, it is possible to reduce the overall maximum system demand by charging storage assets during periods of low demand and then discharging them strategically during peak periods. At a system level, this approach is effectively 'shaving' off the top of the demand curve and reducing the need for traditional assets that are only operating during peaking time.



BESS allows the maximum peak to be reduced

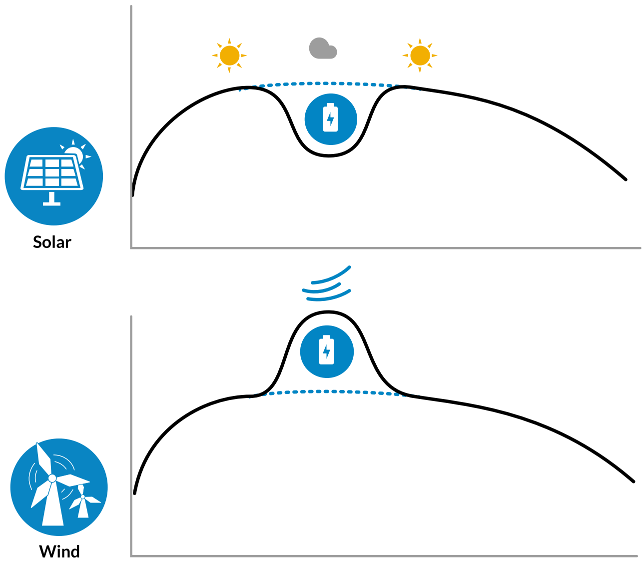
At the end-user level, large load points such as factories and data centres may have notified maximum demand charges. These charges are paid to utilities to essentially reserve the right to a planned maximum level of demand that a customer expects it will need for its operations. To reserve this right, a fixed fee is often required by the utility on top of the other charges for electricity consumed. The use of storage assets can allow large load customers to shave the peak off their power demand, reducing these fixed fees while keeping the same level of overall consumption.



The maximum demand charge is reduced due to the use of BESS

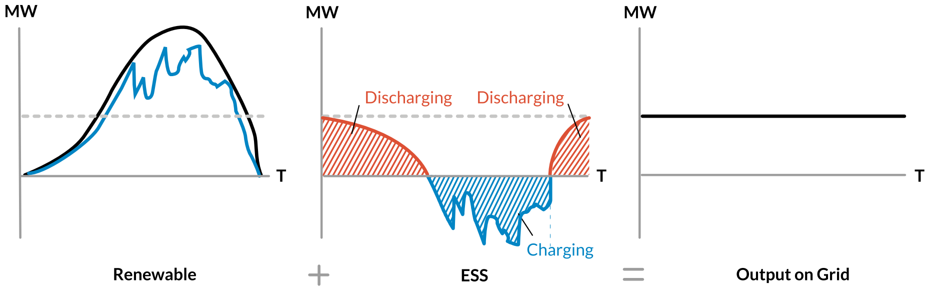
Capacity Firming

As the penetration of renewable energy increases across most electricity grids, a frequent problem is that most solar power plants in the same region simultaneously start producing when the sun rises or that generation from wind turbines begins dropping at the same time as the wind pauses.



The capacity of solar and wind power is made more predictable/firm

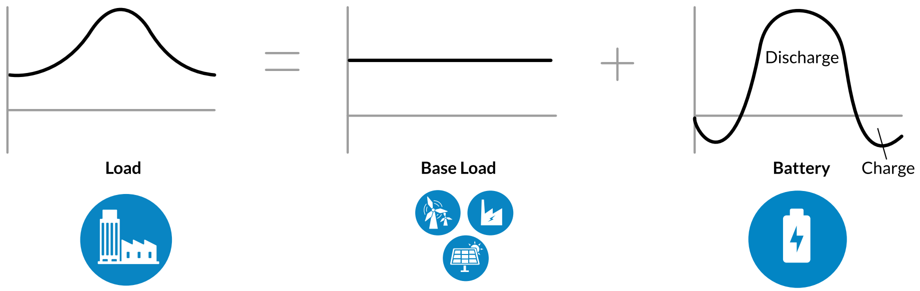
During these ramps and drops, an ESS can be operated to provide a smooth rate of increase or decrease, allowing time for the generation assets to ramp or reduce their production without affecting the stability of the grid. Alternatively, the ESS can also provide capacity cover drops or surges until the renewable assets return to expected operational levels. This prevents any abrupt changes to overall power quality and allows for a firm capacity to be derived from otherwise variable generation assets.



Firm capacity created from variable renewable energy and ESS

Load Following

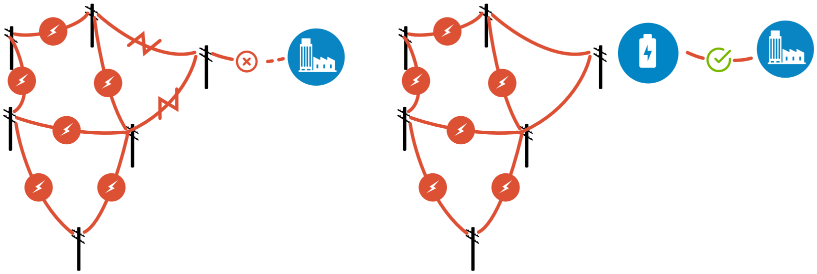
Another application of an ESS is to allow baseload generation assets to follow very dynamic demand profiles that shift faster than traditional power plants can manage. By charging off any excess generation, the ESS enables baseload plants to operate at a high-capacity factor well before load increases to match their production. They can also match temporarily elevated demand through simultaneous storage discharge and sustained baseload generation. In effect, this allows the baseload generation profile to remain relatively flat and running at an optimally efficient level, while the ESS follows the peaks and troughs of the demand as it fluctuates around this level. A similar application can be provided with a large storage unit or a series of smaller distributed units that follow a larger regional demand, often referred to as area regulation. This allows increased flexibility and efficiency for existing assets across the grid that incorporate ESS.



Storage load following for optimal generation efficiency

Network Congestion

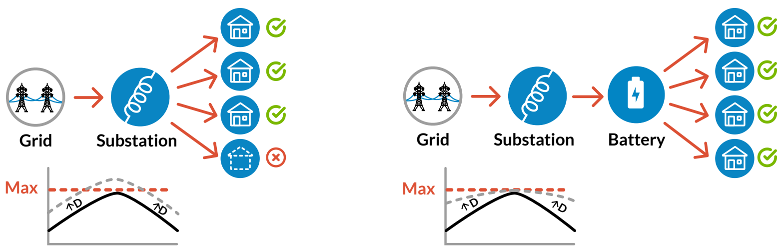
Elevated levels of demand can stress individual lines or nodes of a power system, creating network congestion that may result in increased line losses or even power outages. Before the availability of grid-scale ESS, new distribution lines and/or substations were built to provide alternate pathways for electricity and to de-stress high-traffic network corridors. With ESS distributed on the transmission and distribution network, this congestion can be reduced and power flows can be optimised within the existing network infrastructure.



ESS allows an otherwise congested grid to provide a load

T&D Deferral

Another important capacity service that ESS can provide is the ability for utilities to defer large-scale transmission and distribution investments by investing instead in strategically placed storage assets. Storage assets can allow for additional load on power lines and system substations, enabling a higher capacity factor or utilisation of these existing assets.



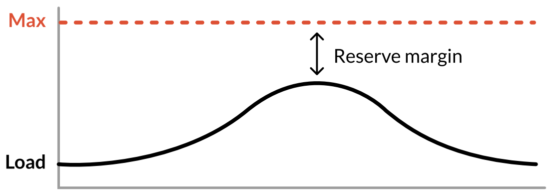
Additional customers connected without substation upgrade

Reserve Margin and Spinning Reserve

System operators require that the total power capacity on a grid includes a reserve margin to be available in case demand exceeds the maximum anticipated demand levels. This reserve margin can be met through building additional conventional generation assets. However, ESS is becoming a common alternative.

The reserve margin can at times be equal to double the ESS's rated capacity, as if the battery is charging at full power, it can be very quickly changed to discharge at full power, providing two times a change to its effect on the network.

Furthermore, ESS can provide a spinning reserve for the network as well. Traditionally provided by large rotating generators that could be dispatched to provide a buffer for the grid during unexpected spikes in demand, ESS can now serve this role as a fast, in some cases nearly instantaneous, response reserve asset. This function essentially acts as a backup for the grid that is inertial in its application.



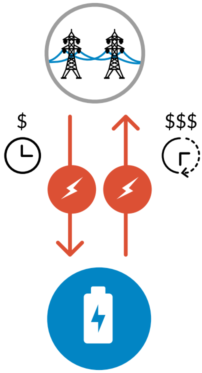
Reserve margin

Energy Services

Where capacity services respond to the demand needs of a network or a customer, the energy services focus on shifting, replacing, accommodating, or profiting from the energy (kilowatt-hours) produced by a generation asset. These services are therefore mainly focused on maximising the value of the energy that flows through a system for the benefit of various market participants such as a system operator, a consumer, a power producer, or even an energy trader.

Arbitrage

Energy arbitrage involves taking energy that is produced at one time, storing it in an ESS, and discharging it to the grid at another time. A common use of this practice is price arbitrage when the market conditions allow. For example, when the electricity market has different prices throughout a period (hourly, daily, yearly, etc.), the ESS owner will buy power to charge the storage asset during periods of low electricity pricing and discharge it back into the grid during periods of higher prices. This practice can also be adopted by private operators to generate revenue or by distribution companies looking to increase their profitability by buying power at an off-peak cost and serving their customers' demand needs with this same electricity at a later period of peak pricing.

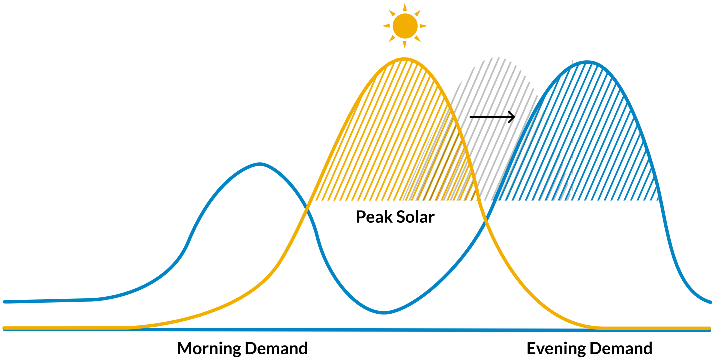


Arbitrage

Generation Shifting

Similar to arbitrage, on-site generation paired with storage may look to shift the energy it produces to when it is most needed to serve the in-house load. For example, a factory may install solar panels with an ESS for its energy consumption. The solar panels will provide electricity during the day for the energy needs while simultaneously charging the battery. The battery will then discharge during the evening and the night to respond to the energy needs during such time. Hence, the excess daily solar energy that had no value to the consumer without the ESS is made valuable by being shifted to the night.

Generation shifting can also serve non-financial, technical needs. In periods of uncertainty about the availability of energy, or when there will be insufficient generation over a series of minutes or hours, ESS operators can plan for these contingencies by storing energy at one time and releasing it at another to address their generation needs. This is specifically valuable in the applications of variable renewable energy power generation sources.

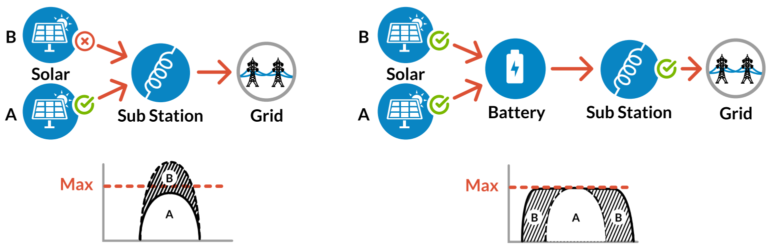


Energy generation shifting

This same practice can be applied over various timeframes (e.g., days, weeks, or months) with longer-duration storage technologies. The longest of these applications can allow operators to plan for season differences in load patterns or mitigate supply shortages anticipated in future months.

Renewable Energy Penetration

Storage assets are increasingly utilised to enable levels of renewable penetration that would otherwise be unfeasible in traditional grids and mini-grids. Storage not only allows operators and customers to capitalise on renewable energy that would have been curtailed without an ESS, but it also can allow VRE to attain a higher total percentage of the production. A system that has reached its operational limit in terms of variable energy can look to add VRE assets paired with ESS, whether co-located or distributed across the network, as the ESS allows for more predictable and smooth energy flows.



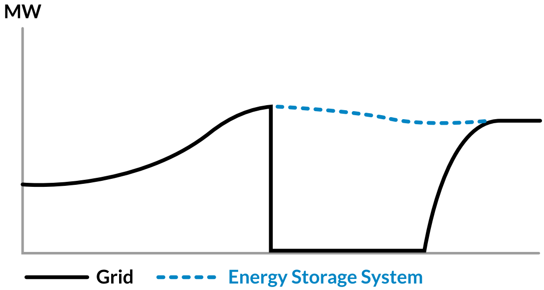
More solar installed despite substation limit

Asset Utilisation

ESS can be integrated to increase the efficiency of the generation assets designed to run optimally at a high load. Peaking units, for example, are dispatched as demand begins to exceed the supply from baseload assets already generating at full or close to maximum capacity. However, peaking units can be inefficient when dispatched at their lowest levels. Storage solutions can delay the need to activate peaking units by discharging electricity stored during an earlier period. This allows peaking units to run at a higher capacity from the moment they are activated to respond to an already higher demand that can even be raised by charging the battery at such time. By focusing on the efficiency of the existing assets, ESS can produce various benefits such as limiting the time during which a power plant runs at low capacity, which in turn improves fuel consumption and decreases the associated carbon emissions.

Backup Power

Backup power is a common ESS energy service. When sized to meet the load of an individual site or customer, ESS can power operations when there are unexpected disconnections from the network due to extreme weather events, load shedding, or entire grid blackouts. Storage assets can continue to power full or reduced operations until service is restored, mitigating what otherwise may be severe financial losses. Storage as backup power can also facilitate a smoother re-entry to grid services in the event of a total blackout, as described further in the ancillary services section below.



ESS provides backup power

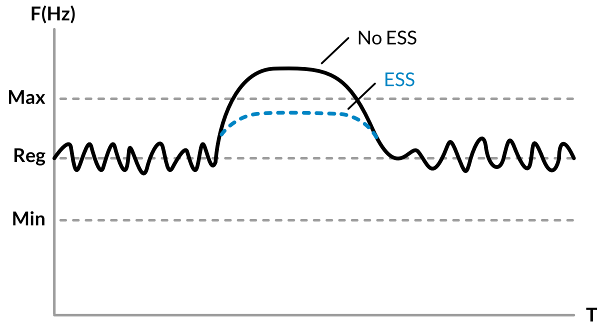
Ancillary Services

As described above, an ESS can improve capacity or respond to energy needs. In addition, an ESS can also address many very technical and specific use cases. These services, known as ancillary services, can add utility and value to a storage asset.

Frequency/Inertia Response and Voltage Regulation

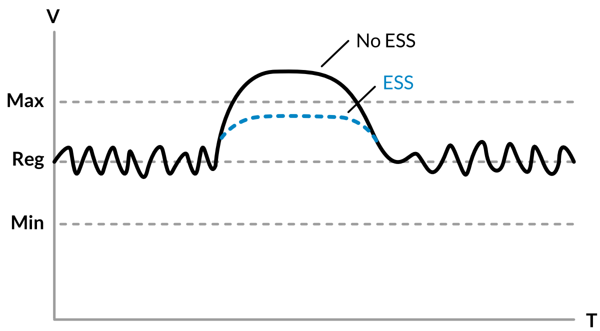
As the frequency of the grid must be kept as constant as possible, one of the primary roles of system operators is to balance the electricity inflows from the power plants with the outflows to the customer loads. Should there be too much generation, the frequency will start to increase. Should there be too much load, the frequency will start to decrease. Any imbalance will immediately impact the frequency and thus the system operator must be able to promptly respond to sudden events. ESS can provide fast response power balancing services to help stabilise the frequency.

Inertia is another important quality that is related to frequency control. The amount of rotating inertia of synchronous generators on a system affects how fast a change in load or supply will affect the frequency. Modern inverter systems, as part of an ESS, can now also provide such inertial response. Grid operators need to secure spinning reserve, i.e., inertial capacity in reserve to manage sudden changes in demand or generation. ESS can assist in providing spinning reserve in response to these rapid changes, often close to instantaneously.



ESS helps regulate frequency

It is a general requirement for grid operators to provide stable voltage to an end-user. However, the voltage can fluctuate due to several variables. ESS can be used to influence the voltage to provide better stability. Thus, ESS can provide a stable voltage and frequency for good electrical power quality.



ESS helps regulate voltage

Reactive Power

Reactive power, which can be considered a quality attribute of electricity, is an essential component of the energy system as it ensures smooth transport of electricity across the grid and can be used by the system operator for voltage regulation. Although this does not increase the amount of energy being consumed at the endpoint, if a consumer draws reactive power it increases the losses in the system. ESS can consume or provide reactive power as required, limiting these losses and aiding in voltage control for the system operator.

Power Factor Correction

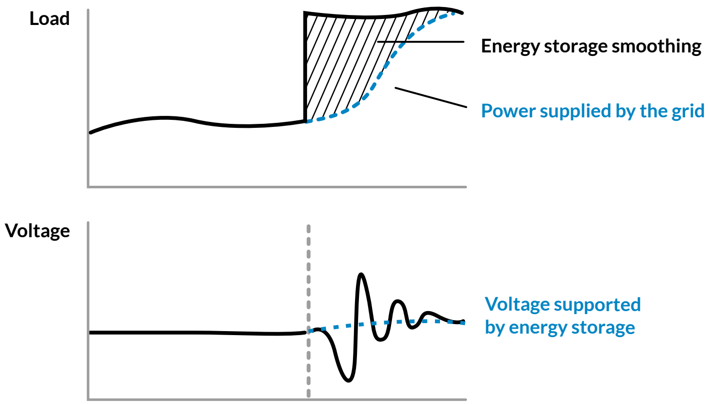
Consumers are typically penalised for drawing reactive power. The measure used to quantify how much reactive power is being drawn is called the power factor. A power factor of one means no reactive power, and 0 means 100% reactive power. ESS can be used to provide reactive power to correct the power factor as desired.

Ramp Rate Control

Ramp rate is the term used to describe how fast demand ramps up or down over time. The steeper the curve, the harder it is for system operators to meet the rate of demand change, as historically grid infrastructure includes a lot of slow-response baseload generation. ESS can assist with controlling ramp rates of conventional power plants by providing additional capacity during changes in demand and supply.

Step Demand Changes

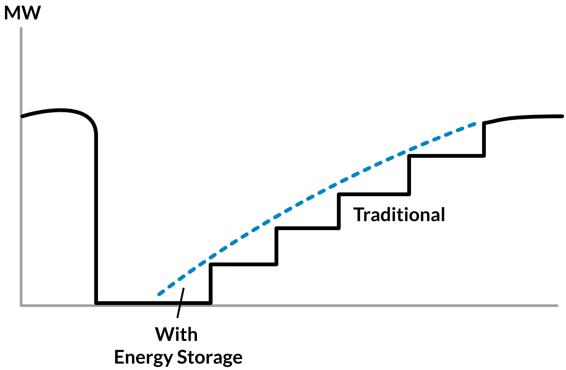
When a sudden increase or decrease in demand, known as a step change, occurs at the end of a long, low-power transmission or distribution line, it can cause significant voltage fluctuations that can be detrimental to equipment on a network. ESS can help smooth out the power and current step change experienced by the power line, providing a better quality of service.



Reduction of the voltage effects of load step change

Black Start

One of the worst events that can happen to a grid operator is a total power outage or blackout. To restart the network after such an event is difficult and time-consuming and requires bringing both generation and load back online in a stable, balanced manner. ESS can provide very flexible services to assist during a black start.



ESS helps black start

Technology Attribute Descriptions

ESS technologies are numerous, all with different strengths and weaknesses, depending on the use cases required. Moreover, new technologies and suppliers are constantly emerging. Rather than attempting to describe every technology available, and running the risk of becoming outdated almost immediately, this handbook describes the various attributes of ESS and their associated benefits and risks. During storage technology selection for a project, all appropriate technologies should be considered and modelled correctly from a performance and financial perspective.

Round-trip Efficiency

Round-trip efficiency describes how efficient a storage technology is during a single charge cycle followed by a discharge cycle. This can be influenced by how intensively the ESS is operated in terms of its charge and discharge rates and the depth of discharge during the cycle. For example, battery applications can also be quoted at the cell level, the DC battery level, or at the AC side, with or without inverter or transformer losses, and with or without auxiliary losses, such as cooling systems, pumps, management systems, or SCADA. Thus, when comparing technologies, it is important to make sure you compare like attributes with like attributes.

Degradation and Life Expectancy

Many storage technologies suffer from degradation, meaning that the capacity of energy they can hold decreases under certain conditions, or over time. The most common cause of degradation stems from the actual usage of the storage system. This loss of capacity is normally a function of how deep the system is discharged during each cycle and how fast this happens in terms of charge and discharge rate. For example, some systems may lose 20% of their capacity over 2000 cycles, if each cycle was a 50% discharge, whereas the same system may lose 20% of its capacity over 500 cycles if each cycle was a 90% discharge. This degradation rate can also accelerate over time. Thus, augmentation (or replacement) of system components may be required during the operational life of the system to maintain the same level of capacity, and these costs need to be considered in the initial financial models comparing storage technology options.

In addition, some technologies can also suffer from accelerated degradation or high auxiliary power consumption if left in a discharged or charged state for an extended period.

Maximum Charge/Discharge Rate

All storage systems have a limit to how fast they can be charged or discharged, and often their efficiency is a function of this rate. The maximum rate can also be a function of the state of charge, and for some technologies, the temperature of the system.

Response Time

This describes how fast a storage system can respond to a request to provide power or service. It is often quoted as the time for the system to go from 0 to 100% power. This can be as fast as milliseconds, for certain battery chemistries, or as long as hours for some large, long-duration schemes. Note that it can be quoted at either DC or AC system levels, as inverter technologies through their designs can significantly improve AC response times.

Temperature

Many storage systems have limits on the temperature range at which the battery can be safely operated. In extreme climate conditions, additional ambient cooling or heating may be required to keep the ESS within the correct operational parameters and these additional losses within the ESS need to be considered. It should be noted that even when operating within the nominal temperature range, the temperature can affect ESS performance in terms of efficiency and/or degradation rates.

Maintenance Downtime

Planned and unplanned maintenance can lead to long downtimes for part or the whole of the ESS, depending on the time to repair and/or availability of parts, and the modularity of the components of the solution. This should be considered when selecting the most optimal ESS.

System Segments

The use cases described above demonstrate how energy storage can be used to perform a variety of functions that are useful to power systems. This section discusses how those functions are used in practice in various segments of power systems (which we will refer to as system segments). In the Utility Grid Segment, the customer is a utility that owns a transmission network (or grid). In the On-Grid Segment, the customer is a private (or public) generator or consumer of energy whose generation facilities or loads are connected to the grid. In the Off-Grid Segment, the customer is a private (or public) generator or consumer of energy whose load is not connected to the grid.

Utility Grid Segment

In the Utility Grid Segment, a utility that owns and operates a transmission network may install energy storage at (or close to) a substation for various capacity, energy, and ancillary services such as:

- Capacity services;
- Grid congestion relief;
- The deferral of other investments in the power network; and
- On-site backup power at a substation to enhance the reliability of the network.

These energy storage systems may be owned and operated by the transmission utility or by an Independent Energy Storage Producer (IESP) who will provide the services.

On-Grid Segment

Generators

In the On-Grid Segment, a generator may co-locate an energy storage system at a generation facility for services such as:

- Generation shifting;
- Renewable penetration; and
- Ancillary services to the grid, both when energy is being generated and when energy is being withdrawn from storage.

ESS that is co-located at a generation facility is typically owned and operated by the same company that owns and operates the generation asset.

Loads

Energy consumers with a connection to the grid may co-locate an energy storage system on their site to:

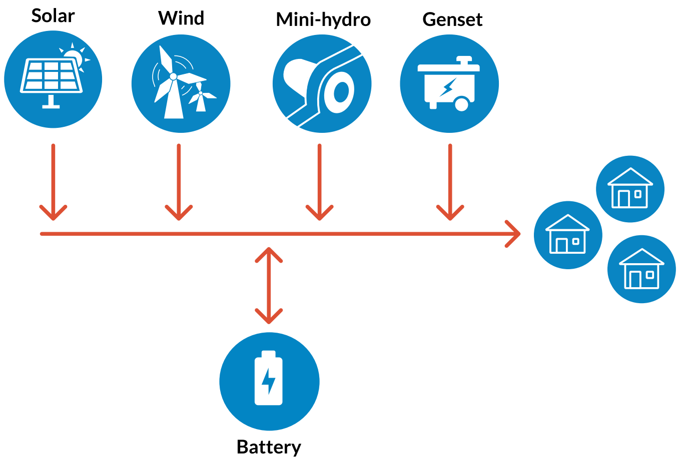
- Provide backup power from an energy storage system located at the site;
- Provide backup power in concert with renewable energy facilities or backup generators located at the site, the usefulness and efficiency of which are increased when paired with energy storage systems;
- Reduce their peak demand and thereby lower their demand charge; and
- In markets in which energy prices vary depending on when the energy is consumed, engage in a form of arbitrage by purchasing energy from the grid when energy prices are lower and storing that energy for use when energy prices are higher.

For each of the uses described above, the grid is viewed as the primary supplier of energy, and the on-site facilities are viewed as a backup or as a source of energy that can be used to reduce the amount of energy consumed from the grid. If a consumer installs on-site generation and storage capabilities that can provide a high percentage of the consumer's needs, the grid may be viewed as a backup to the on-site generation and storage systems. Energy storage systems located on a consumer's site may be owned and operated by the consumer or by an energy services company.

Off-Grid Segment

The Off-Grid Segment used to be dominated by high-speed diesel generators. These generators can often run at low load factors, which decreases their efficiency and increases their maintenance requirements.

Today, energy storage systems are primarily used in the Off-Grid Segment for time-shifting. By storing energy generated by variable renewables, these energy storage systems can enable off-grid systems such as mini-grids and home solar systems to achieve close to 100% availability. Combining renewable energy with high-speed diesel generators and energy storage can enable these systems to achieve 100% availability with smaller renewable energy facilities, and a smaller generator that may run very infrequently. Most new modern micro-grids, for example, pair renewables with storage and require only a few hours per week of support from a diesel generator, if any. By combining renewable energy and energy storage systems, mini-grids can achieve a levelised cost of energy that often makes them the most economical way to deliver reliable electricity to many remote and underserved locations.



Micro-grid illustration with numerous generation sources and an ESS providing a small distribution network

From Use Cases to Value Streams

As we have seen, energy storage projects can serve a variety of purposes for utilities and consumers of electricity. In some electricity markets, these varying uses of storage can stack value streams from multiple use cases. Owners of energy storage projects may seek financing based on anticipated cash flows or savings from all or a portion of the components of this value stack. The following chapter will detail how several services may be combined to make the various ESS business models more viable.

Illustrating Value Streams

Introduction

In developing markets, the early deployment of grid-scale ESS started with the pairing of storage with renewable generation assets. In some cases, the ESS is added to existing assets, but it is increasingly included in the design of new generation projects to optimise the dispatch profile and increase the electricity benefits to the ultimate customers. When looking at the economic viability of such a co-located facility, utilities and developers have often focused on one use case to justify the additional investment needed for the project's additional capital expenditure.

As the applications of the various ESS technologies are gradually becoming more familiar to system operators and asset owners, it has become a widespread practice to derive more value from the ESS by using it to perform multiple energy or capacity services. For example, private ESS initially designed and optimised for pricing arbitrage may also be used to enable more renewable energy penetration by giving local transmission and distribution infrastructure the ability to integrate higher levels of variable renewable generation. In turn, the private owner may also be contracted to operate under a certain daily profile that assists in reducing system peak capacity. These additional services add value to both the ESS and the system as a whole, and the private owners may be better compensated by adding several revenue streams, such as a fixed charge or variable fee based on capacity or generation levels.

The storage industry is also starting to pair or 'stack' ancillary services with multiple energy and capacity services to derive more value from these same storage assets. Grid operators, large load customers, and utilities are looking at new modelling and mechanisms which accurately compensate storage asset owners for these ancillary services. For example, it is operationally feasible for the same plant described in the preceding paragraph to be designed and operated to also provide frequency regulation services to a regional grid, provide direct backup power to a local customer, or aid the national utility in the event of a black start.

With proper initial analysis and design, supported by the use of a robust operational software package, energy storage assets can better optimise the value of generation assets, decrease customer energy or system costs, and defer or cancel the need for new infrastructure investments.

Below we explore several practical real-world examples where ESS can be used to solve some problems through the stacking of use cases, as well as the financial benefit that such storage systems can deliver.

Case Studies

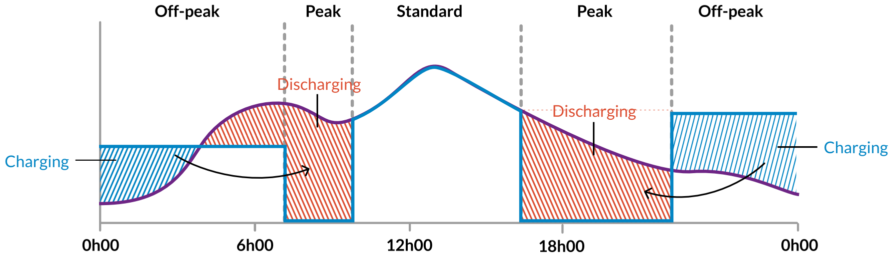
Case 1: Behind the Meter Time-of-Use Tariff Customer

Industrial tariffs often include several charges related to capacity and energy. Consider, for example, a static tariff that includes the following cost components:

- Time-of-use energy charges – These are charges for energy (kWh) that vary depending on the time of day or day of the week. Such a tariff could have, for example, a high peak energy charge for peak hours (Mon-Fri, 0700 to 0900 hours and 1700 to 2000 hours), a low off-peak energy charge for low usage hours (Mon-Fri 2000 to 0700, and all of Sat and Sun), and a mid-level standard energy charge for all other hours.
- Capacity charges – A charge for the maximum capacity typically used during a month, with an associated charge per unit of capacity used.
- Notified maximum demand charges – A fixed monthly charge to enable a particular maximum capacity that can be reserved (but does not have to be used).

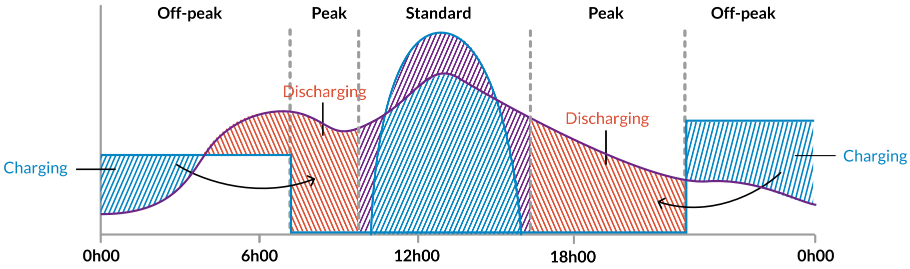
A customer on such a tariff has the option to reduce all of these charges through the use of an ESS, perhaps co-located with a renewable power plant. The installation of a behind-the-meter, self-consumption (non-exporting) solar Spelling out photovoltaic (PV) plant could reduce the amount of daytime electricity consumed, producing electricity cheaper than if purchased from the utility. However, the benefit of such a plant would be limited to the mid-day consumption peak while the sun is out. The inclusion of an ESS system could further enable the following use cases:

- Generation shifting – The ESS can lower energy costs by charging off low-cost off-peak electricity and then discharging it into peak hours. Thus more off-peak and less peak energy would be purchased, leading to a net saving. There needs to be a sufficient difference between the tariffs to justify the ESS CAPEX and OPEX costs, as well as the round-trip efficiency losses and expected life of the system.



ESS time-shifts energy to reduce peak costs

- Peak reduction – If the customer has, for example, a short but high peak that happens at least once a month (in reality it would happen almost daily), the ESS could also act to reduce this peak demand charge, by discharging during these hours. Furthermore, if this also led to a new peak demand well below the maximum notified demand, the maximum notified demand charge could also be reduced leading to further saving.
- Increased renewables penetration – If the customer installs a larger solar PV system, this additional energy could be stored into the ESS and discharged at other non-sunny hours, either in the evening/night/morning or if a cloud went over. As with the generation shifting, there would need to be a sufficient cost differential between the cost of the solar electricity and the cost of electricity for the time to which the solar is shifted, along with the battery CAPEX, OPEX, and performance characteristics.



Solar energy time-shifting

- Power factor correction – If the customer had a poor power factor that the utility was penalising the customer for, the ESS could assist in correcting this issue.

Case 2: Utility with a Peak Constrained Substation

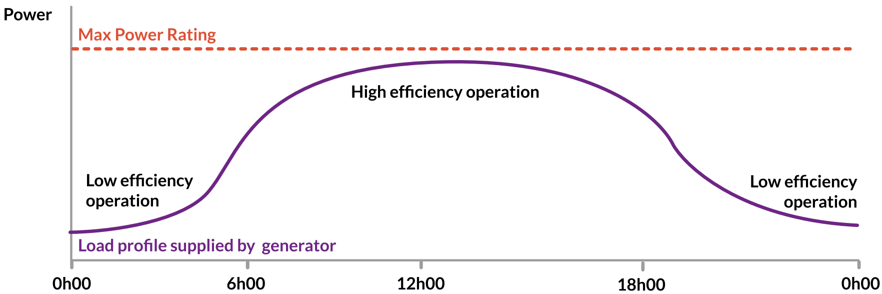
In this example, consider a utility with a transmission substation supplying into a distribution network where peak demand is increasingly reaching the limits of the substation, and the transmission lines that feed it. The conventional option would be to plan to upgrade the substation and the lines, which could come at a significant cost.

An alternative could be to deploy an ESS at the substation. This could allow the substation to provide power to a new distribution line without upgrading the current infrastructure. The ESS can charge during periods of low demand and supply during periods of high demand. At a simple level, the cost of the ESS could be compared to the cost of the substation/line upgrade (considering the life of both).

The ESS could stack additional services that optimise the grid, such as voltage regulation, power factor correction, step load change voltage-transient support, and could also allow the integration of variable renewable generation at the substation.

Case 3: Off-Grid Consumer

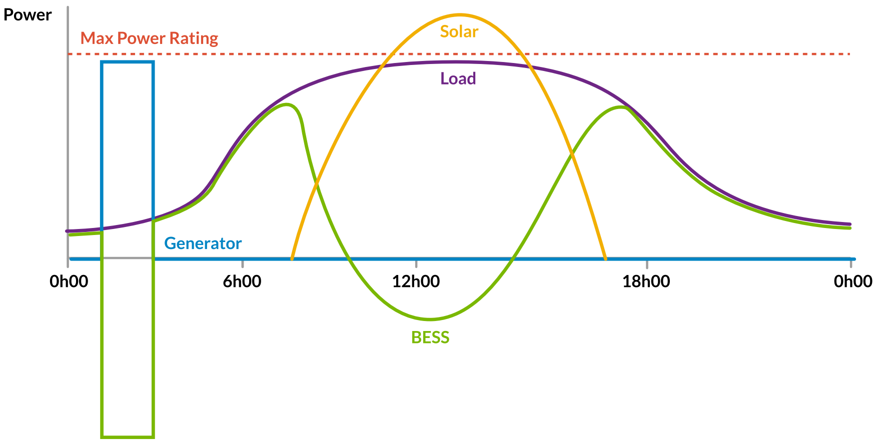
Many off-grid consumers do not have the option to connect to utility infrastructure and often run solely on diesel or other thermal generators. The generators are typically sized to meet the maximum load demand, and as a result, may run at low load factors at various times of the day due to fluctuating loads. This can lead to poor efficiency and other technical issues with the generator.



Off-grid load solely provided by a generator

A customer wanting to add renewable generation, such as solar PV, to reduce reliance on the thermal generators may exacerbate the issues related to the generator running at low factor for substantial portions of the day. Should an ESS be added to the system, numerous benefits could be added to the existing off-grid power system, including:

- The solar PV can be sized larger than the load, allowing the full load to be supplied during the day and the ESS charged with any extra energy. During night periods, the ESS will supply the load.
- When the generator is required to run, the ESS will ensure that the generator runs at an efficient load factor.



Off-grid load is now mostly supplied by a PV + BESS

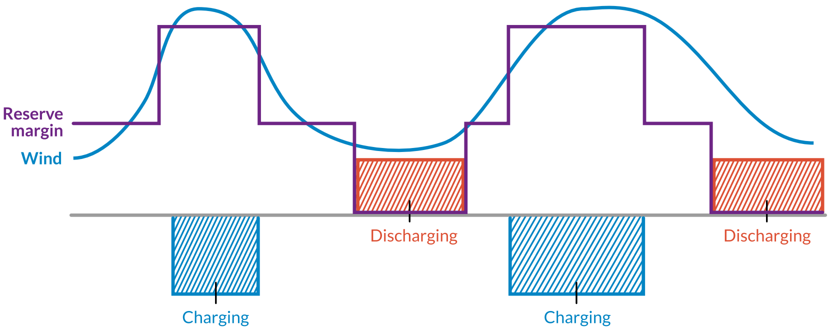
Case 4: IPP On-Grid

Utilities and investors are increasingly looking to procure power generation through an IPP business model (described in more detail in the *Public and Private Business Models* chapter). Traditional generation assets have been developed under this model, with the IPP often owning and operating the asset and selling the generation to the offtaker. When building variable renewable energy assets, pairing with ESS for optimisation of the generation captured and the timing of its use can maximise the financial outlook for the asset by enabling several revenue streams.

In the case of a new wind site being added to a small national grid by an IPP, consider that another large wind project has already been commissioned and wind's share of total generation in the national energy mix is close to matching that of the existing technologies. As variable wind capacity increases, the ageing grid is ill-suited to manage substantial amounts of electricity that varies over each day and month. This causes network frequency and voltage issues that traditionally could be mitigated by new investment in costly grid infrastructure assets.

With the addition of ESS from the inception of the new wind site, the facility's wind and storage capacity can be designed and optimised to serve many functions.

- Arbitrage – After meeting its Power Purchase Agreement (PPA) obligations, the IPP can store excess electricity produced at off-peak hours and dispatch that from the ESS during peak hours to maximise the profitability of the facility.
- Reserve margin – Given that ESS can operate as a dispatchable asset, the facility can contribute to the national utility's reserve margin. This allows the utility to rely on this as available capacity in periods of near peak demand to function as a buffer for unexpected drops in supply or spikes in demand.

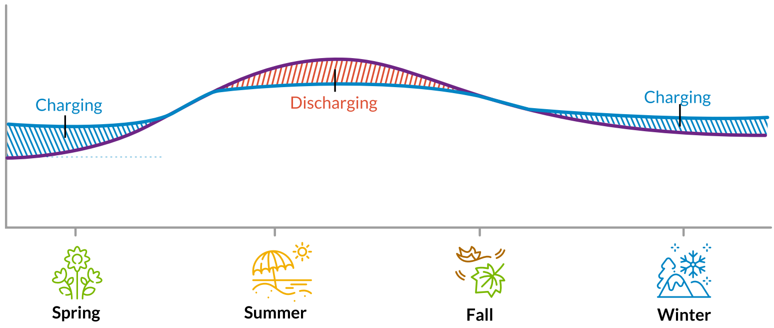


Storage enabling wind to provide reserve margin

- Renewable penetration – Without ESS, the grid operator may not permit more variable renewable energy without corresponding network infrastructure upgrades. Adding storage at the wind site allows the IPP to develop the project and help the country achieve a higher percentage share of renewables on their national grid and reduce dependence on traditional fuels and technologies.
- Frequency and voltage regulation – This site can perform many grid-firming services with its paired ESS. It can likely market services such as frequency regulation and voltage control support to the utility.

Case 5: Seasonal Energy Storage

A consideration in many countries that have strong differences in seasonal electricity supply and demand profiles is whether energy can be shifted on a scale of weeks or months. When the need for this energy shift is significant, some long-duration energy storage technologies can fill this role.



Seasonal energy storage

Consider a market where energy imports for some baseload power are not contracted at fixed volumes but purchased primarily on the spot market. Furthermore, this same market experiences seasonal reductions in generation from hydroelectric assets, the other primary source of baseload power, during the summer months when regional energy demand is also the highest. When considering how to best ensure system reliability and cost-effectiveness during these months the utility may consider building an additional conventional power generation asset to provide a buffer for expected and unexpected dips in power supply. As an alternative, pumped hydro long-duration energy storage could be procured, allowing the utility to also accomplish another set of objectives:

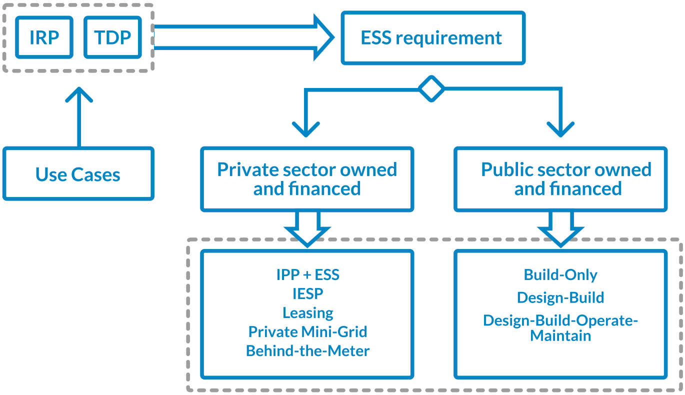
- Generation shifting – The long-duration ESS can store the energy for days, weeks, or months to fit the demand patterns that the existing supply may struggle to meet.
- Reserve margin – This same asset can act as reserve capacity for the utility during periods where it would typically only be storing energy while waiting for its seasonal discharge. Should an unexpected period of high demand occur where planned supply levels may become inadequate, the utility may call on the long-duration ESS.
- Increased renewables penetration – A long-duration ESS can be paired with the predictable load profile of a renewable energy facility to create a baseload generation profile.

Public and Private Business Models

Introduction

Energy storage systems can be deployed both as a general system with a variety of roles or as a dedicated component of an individual power project. Whether the ESS is used on a flexible or dedicated basis is a matter of discretion that rests in the hands of the system owner. As a result, the business model of an ESS deployment is of great significance and can be defined both in terms of ownership and operation. The choices made in structuring the project can be as important as the system's technical design.

This chapter lays out the primary business models for ESS and differentiates between the models deployed by public and private actors in the power market. The key difference between a public and a private model is that the public model typically focuses on the acquisition of a specific energy storage asset, whereas the private model typically focuses on the economic viability of the energy storage asset in an integrated or standalone system. The last section of this chapter also lays out the various sources of financial capital that can be leveraged to fund the acquisition of energy storage.



Overview of public and private business models

Public Business Models

For this chapter, we treat any ESS acquired by a government or parastatal entity as a "public" business model. In most developing economies, this public actor will be a state-owned electricity utility (in part) or subject to considerable influence by the host government (either through policy or regulation). Other public actors include sub-national governments (state, regional, municipal, etc.) or citizen/community groups (development councils, school districts, agricultural co-operatives, etc.). Public business models for ESS share several common characteristics; however, there are meaningful differences that result from the particular public actor involved in the acquisition of the ESS.

Utility-Owned ESS

A government may elect to integrate ESS into the power system through direct ownership and/or operation via the utility. Utilities typically acquire energy storage assets through their existing procurement processes, which may require a competitive procurement for a portfolio of assets or direct negotiation for a specialised system or pilot project. In either case, as noted in the chapter *Planning*, the utility will be required to detail the location, design, performance, and other relevant aspects of the ESS to attract qualified bidders. Following the procurement, the utility will integrate the energy storage asset into its existing operations, although the degree of ownership and control may vary.

Under the utility-owned business model, the utility will directly acquire and own the ESS and deploy that asset to support a broad array of generation, transmission, and distribution requirements. In addition, utilities that engage in retail sales of electricity to customers may also use an ESS as part of a load management system, capacity firming requirements, or to make use of other ESS services as detailed in the *Use Cases* chapter.

It is important to note that even though the ESS will be owned by the utility, the financing of the asset purchased may be funded from several sources, including DFIs, export credit agencies, and commercial lenders. Since the utility will need to satisfy the lending requirements of these funders, the development and ownership structure of the ESS can have a significant impact on the ability to secure financing. A summary of the structuring options a utility may employ when procuring an ESS for its use is provided below.

Build-Only

In the most simplified model, the utility will prepare its design specifications for the ESS and then procure the construction and installation of the system from the private market. As part of this procurement, the utility often requires the manufacturer of the ESS to provide a warranty for the performance of the system over a defined period. Aside from the warranty, the manufacturer will have no direct involvement in the ESS, with the utility managing all operations and maintenance. In this simplified model, the utility will also have the responsibility to budget for the cost of the system or raise financing for the acquisition.

Case Study: Utility Procuring on a Build-Only Model

Eskom's Ingula Pump Storage Scheme

Ingula is a 1,332 MW pump storage power project completed in 2017. It has four 333 MW reversible pump turbines and provides Eskom with much-needed flexible generation at a time when VRE penetration is increasing in South Africa. The scheme construction encompasses two dams – the upper and lower reservoirs, a powerhouse, two tunnels that carry water from the reservoirs to the powerhouse, access roads, and transmission lines. To generate electricity during high energy consumption, water flows from the upper dam to the lower dam. The process is reversed during low energy consumption periods to replenish the lower reservoir.

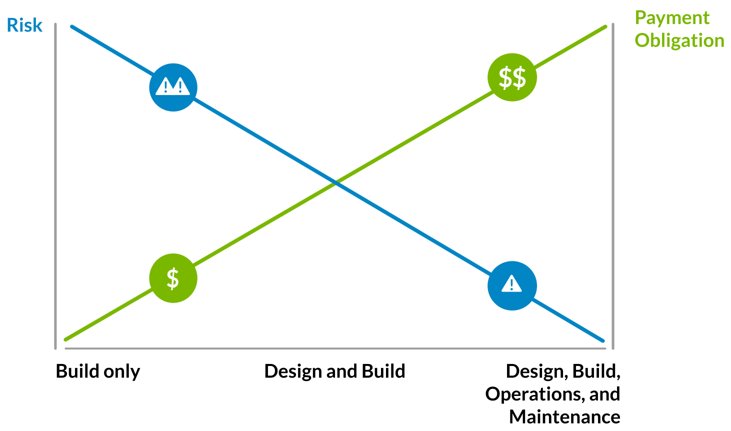
The project highlights the requirement to start implementing large hydro schemes at an early stage to cater to long lead times. The project involved a large number of construction companies and consultants. The complexity of the project led to significant delays in implementation. The extended development period of this project also highlights the risk a utility takes by implementing a project on a build-only basis since it must complete all design, permitting, and funding before construction, then manage the interface risks between contractors if the project is not constructed under an Engineering, Procurement, and Construction (EPC) Contract. Despite these challenges, the completed project represents a major technical and project management accomplishment with significant economic benefits in the long run.

Design-Build

In this model, a private party is responsible for the construction, installation, and detailed design of the ESS based on the needs expressed by the utility. The utility is still required to provide detailed specifications for the ancillary services and/or generation requirements. As with the Build-Only model, the utility remains responsible for the operation and maintenance as well as the budgeting and financing.

Design-Build-Operate-Maintain (DBOM)

In this DBOM model, a majority of the activity around the ESS is within the responsibility of a private party, including design, construction, and operations. This relationship between the private party and the utility is typically governed by a long-term service contract that includes payment obligations on the part of the utility and performance obligations on the part of the private party. Penalties and bonus incentives may also be incorporated to encourage optimal performance over the life of the contract. The primary responsibility for the utility under this model is financial, both in raising the funding for the development of the system and the ongoing obligation to make payments to the private party under the long-term contract.



Public sector exposure

PRACTICE NOTE The participation of private partners in the DBOM model may be further extended to allocate the responsibility of securing financing for an ESS project. Participation in the financing by private parties is often referred to as a "Design-Build-Operate-*Transfer*" (DBOT) model. The key characteristic is that the private project developer in a DBOT will both operate and own the project for some time and use the revenue generated by the project to repay the debt raised for financing and to earn a reasonable return. However, the DBOT model may still involve a degree of public ownership since the ESS will eventually be transferred to a public entity (typically a utility). The timing of the transfer may be early in the life cycle of the project (i.e., after the utility acquires enough experience to manage the asset directly) or near the end of the life cycle (i.e., after the value has been fully recovered by the private developer). The timing of the transfer will also impact the economics of the project. For example, an earlier project transfer will often require the utility to make a significant payment to the project developer to retire the project's debt and provide the developer with their expected return on investment.

Additional Considerations for Utility-Owned ESS

In vertically integrated utility applications where the ESS is owned by the utility, the utility's direct control over the asset allows for flexible utilisation in areas such as generation, T&D, grid management, etc., or targeted solutions such as deployment behind-the-meter for demand-side management. The asset-based nature of utility-owned ESS acquisitions also allows for the leveraging of a utility's broader capital budget to implement ESS solutions on an as-needed basis. By owning the ESS, the utility can evolve its use over time as grid utilisation shifts during the energy transition, and implement changes on a discretionary basis (as opposed to the need to renegotiate a contract under a private business model). The utility is, however, exposed to additional costs as the use of an ESS system evolves, such as modifications, upgrades, and additional maintenance.

The deployment of ESS by utilities through direct ownership may have the added benefit of satisfying policy requirements in addition to producing cost savings. Public utilities are often incentivised by their host governments to support obligations under international agreements to contribute to climate change mitigation through the transition to lower-carbon power sources. As further discussed below in the *Sources of Capital* section, this may allow government and utilities to access funding for the development costs of pilot ESS projects (pre-feasibility and feasibility studies) as well as grants and concessionary funding for project development.

Municipality-Owned ESS

In some countries, sub-national entities are responsible for the distribution of electricity, including network and retail billing and service, particularly in rural areas where the economics of a privately-financed utility are not viable. For these local actors, there is an opportunity to increase revenues through the deployment of energy storage assets much in the same as utilities. For this section, we will focus on smaller, more localised municipalities, although they may also be larger entities such as states within a republic/federation or aggregations of local jurisdictions under a Regional Electricity Distributor.

Municipal and other rural energy providers often face the burden of higher energy costs relative to more dense, urban markets. The business model for ESS deployments in these contexts often focused on mitigating these high energy costs through peak reduction where the municipality purchases electricity at off-peak wholesale tariffs to charge the ESS system and then discharges that power at peak times. Aside from the peak reduction effect at the wholesale level that can assist in the general grid capacity, the municipality can increase revenue via the arbitrage between peak and off-peak tariffs. Municipalities may also leverage ESS to increase the adoption of renewable energy sources by purchasing excess PV or wind energy when available.

It is also worth noting that energy storage has become increasingly common in municipal mini-grids that serve electric customers in areas where grid-connected power is not available. In the case of mini-grids, the ESS can be paired with an intermittent renewable energy source, such as solar PV, and extend the availability of electricity by charging during high generation periods (daylight) and discharging during periods of no generation (night).

Rural electric markets are also more prone to load shedding (due to a more limited number of energy sources), which can be mitigated through the use of ESS as a source of backup power. The balance of cost, load shedding duration, and sizing of the ESS system will need to have an economic benefit to both the municipality and the consumer.

Co-Operative Owned ESS

Co-operative (co-op) utilities serve their owner-members, all of whom live in the co-op service area. They are similar to a municipal-owned utility except that they exist to only serve their owner-members' energy needs.

These can be found in localities that do not have access to electricity or in communities far from the grid, which makes grid access expensive or uneconomical for utilities. Co-ops may also be developed to serve concentrated demand from local industry, such as processing by an agricultural co-op or manufacturing by cottage industries (textiles, shoes, etc.). The structure of co-op-owned ESS is almost identical to the municipally-owned structure described above. The primary difference is that, as both owners and customers, co-op members may enjoy the benefit of sharing in the surplus revenues of the co-op utility or, in the case of ESS value, the cost savings of peak-shaving.

Private Business Models

In many developing countries, utilities are financially constrained. These financial constraints limit the ability of utilities to secure the up-front capital needed to acquire ESS directly. Even without financial constraints, utilities may also lack the expertise or experience to develop and manage an ESS deployment directly. In either case, host governments and utilities seek private investors to take on the entire burden of ESS deployment, including technical design, legal structuring/permitting, and financing of the project. The simple fact that any rational investment must produce a net profit means that private business models in the ESS space share technical characteristics with publicly-owned models detailed above but differ significantly in terms of ownership and operation.

IPP Project Including Energy Storage

As discussed in the *Understanding Power Purchase Agreements* handbook, there has been a significant shift in power markets away from vertically integrated utilities that own and operate generation assets toward IPPs. The IPP model is to develop a generation project on a private basis and contract with the utility (or any other offtaker) for the long-term sale of the electricity generated by the project.

From the perspective of financial structuring and availability of capital, deploying energy storage through IPPs is a natural extension of the ownership and operation structure that has enabled this power project structure to earn the trust of utilities, developers, and lenders. As described in the *Understanding Power Project Financing* handbook, the key characteristic of an IPP project is the inclusion of *all* project assets and liabilities within a dedicated company (project company). As a result, when an IPP collects revenue from the sale of energy, it uses those funds to cover operating costs directly, service debt, and pay dividends to investors.

Within the IPP project structure, the incorporation of energy storage assets has the effect of increasing the development costs at the outset and (ideally) generating additional returns over the long term. The increased capital cost of an IPP including an energy storage project (as opposed to the same project without energy storage) will require the project developer to secure additional debt during the development phase, which will, in turn, require the developer to convince a potential lender that this additional debt is sustainable under the economics of the project. This assurance to lenders will typically be derived from the additional revenue that the IPP will be able to generate with the ESS. As a result, IPP including energy storage projects are highly sensitive to regulatory and market conditions since it must be clear that the energy storage assets of the project will be permitted to participate in the power market in a manner that allows for the realisation of the expected return on that investment.

Case Study: Prevailing ESS Business Models in Namibia

Namibia amended its power market regulations in 2019 to allow increased participation of market players in the generation sector. This market reform saw significant investment, which produced 75 MW of new capacity (solar PV). To manage the intermittency of this new generation (through peak reduction), Namibia Power Corporation (NamPower) is currently procuring 60 MWh of energy storage capacity under a design-build model. Namibia's Central Northern Regional Electricity Distributor (CENORED) has also procured energy storage capacity for peak reduction. Unlike NamPower, CENORED is structuring its acquisition as IPP including the ESS model in which an existing 5 MW solar PV plant, in operation since 2015, will be upgraded to 10 MW and co-located with an ESS. The new project will supply power at a lower tariff and reduce the fixed capacity charges paid to the bulk electricity provider.

Independent Energy Storage Provider Model

An Independent Energy Storage Provider (IESP) is distinguished from the IPP model in that the energy storage assets are the sole source of project revenue. Similar to an IPP project, a private developer is responsible for developing, constructing, and operating the project. As a 'pure' energy storage business, the revenue generated by the project may be based on a long-term contract with an offtaker, or in more developed markets with multiple offtakers, the project may offer its services to the highest bidder. An IESP model often requires service 'stacking' to maximise the return on the energy storage investment and may adapt its operations over time to capitalise on new opportunities in an evolving power market. The inability of IESPs to secure regular, predictable returns without access to an open energy market has limited the viability of this business model in emerging markets. However, the economics are sustainable when there is a credit-worthy offtaker who is willing to enter into a long-term agreement with a fixed tariff.

In emerging markets with limited access to commercial lending, an IESP project is likely to be funded through a project finance structure (see the *Understanding Power Project Financing* handbook) that clearly defines the pricing and purchase obligation for the services provided by the project. The simplest and most predictable pricing structure is an availability payment which the offtaker is required to pay regardless of whether the outputs of the projects are utilised. In turn, the offtaker will require that the IESP maintain the ESS so that it can be used at any moment (sometimes in a manner of milliseconds).

PRACTICE NOTE Although the IESP model is expected to play a critical role in the deployment of energy storage at scale, this model remains largely untested in emerging markets. Deployments under this model are currently constrained by the lack of a regulatory framework that allows energy storage services to be offered, and priced, directly in a power market. This provides policymakers and regulators with a unique opportunity to unleash a significant new source of investment through targeted amendments to their existing market framework.

Lease Model

Both the IPP including energy storage and IESP models detailed above rely primarily on a long-term contract that provides sufficient revenue for the project developer to repay the debt of the project's development and earn a return. Private ESS projects may, however, be based on shorter-term commitments from offtakers. Under a lease model, the private owner of the energy storage asset enters into a limited-term agreement with the offtaker to deploy the system (typically at the offtaker's chosen location). This allows the offtaker to secure the benefits of a dedicated ESS without the full cost of ownership and the private party to monetise the value of an ESS without a fixed installation. The lease model may also address a shorter-term need of a utility, such as T&D deferral or supplement grid capacity during major grid upgrades.

Despite the shorter-term nature of leased ESS, there is still a requirement for the legal structuring of the project. The offtaker typically agrees to make periodic availability payments to the private leasing company for several years (with some leases extending to a decade or more). The lease structure will also define the obligations, such as whether the leasing company will maintain the asset and/or whether the utility will operate the system directly. In terms of scope, leasing arrangements may be limited to only an energy storage asset or part of a larger lease that also includes generation assets. For example, mining operations in remote regions may seek a term lease of an integrated system that includes solar PV generation, battery storage, and thermal backup generators where grid connections are not available.

Currently, the use of the lease model is somewhat limited for ESS deployed in emerging markets. It is, however, a proven funding structure for many other types of equipment in the energy sector and beyond. It is therefore an option that may be considered when the asset is unlikely to be needed for the full length of its lifespan. This could apply, for example, when the ESS is used for T&D deferral or to supplement grid capacity during major upgrades.

As noted in the following case study, leasing may also be used for components of an ESS.

Case Study: Component Leasing within Battery Storage Systems

A flow battery is a type of electrochemical cell where chemical energy is provided by two chemical components dissolved in liquids that are pumped through the system on separate sides of a membrane. The liquids, also called electrolytes, are typically not subject to the same degradation rate as other parts of the system and may retain significant value at the end of the life cycle of the battery. In such cases, the buyer of the battery can purchase the 'dry' components of the system but lease the electrolytes. This allows the buyer to lower the overall initial cost of the asset while avoiding the inconvenience of selling the electrolytes at the end of the life of the battery to recoup a part of the initial cost of the asset. Moreover, since the electrolytes represent the biggest part of the battery, this structure also reduces the disposal cost of the battery for the buyer.

Private Mini-Grid

Mini-grids are increasingly deployed to serve electricity customers where grid-connected power is not available. Mini-grids may also be deployed at the 'grid edge' where grid-connected power is available but unreliable. While the first generation of mini-grids was primarily developed by public entities to serve policy goals, falling costs for solar PV and ESS have created opportunities for private developers to develop these projects on a commercial basis.

From the perspective of energy storage, project economics may be significantly impacted by the integration of ESS into the project. ESS benefits the project by extending the generation capacity of the mini-grid and contributes to the stability and optimisation of an isolated system. However, the integration of ESS into mini-grids does present a challenge since they can significantly increase the capital cost of a mini-grid relative to the modest size of these investments. This is similar to the challenge faced by private developers of IPP including energy storage projects but can be more severe given that private mini-grids may be highly sensitive to cost increases and revenue disruption.

Behind-the-Meter

Commercial, industrial, and residential consumers can benefit from the deployment of ESS at the location of energy consumption. The use cases that are most relevant to electricity consumers include:

- Peak reduction – Reducing demand charges by reducing a consumer's peak demand;
- Energy arbitrage – Buying and storing electricity during the times of day when electricity is least expensive, and consuming it when electricity is otherwise expensive; and
- Backup power – Storing electricity for use during an interruption to the supply of electricity from the grid.

These use cases are often performed by ESS that are located between the consumer's electricity meters and loads. If the ESS is not primarily used to sell energy back to the grid, then the ESS is referred to as being 'behind-the-meter'. To the utility, a behind-the-meter ESS is invisible. As a result, the utility serves the consumer's load as it would any other consumer in the same rates category.

Sources of Finance

The sources of financing for ESS deployments are as diverse as the array of business models. For a more detailed explanation of financing structures for power projects, we recommend a reading of the *Understanding Power Project Financing* handbook. This section builds on the guidance in that handbook to provide insight into the particular considerations around financing energy storage projects.

Public Financing

Well-resourced utilities may fund ESS deployment via regular capital expenditure programmes. However, in many emerging markets this type of significant capital investment will often require the support of the host government either through direct allocations from a central budget or through on-lending (where the government is borrowing and passing the funds on to the utility). Some governments have been successful in raising infrastructure bonds including 'green bonds' directed toward renewable energy adoption, including energy storage deployment. With ESS allowing for greater deployment of renewable energy, there are also some climate-focused multilateral and private funds dedicated to supporting public investment in energy storage capacity through grants or co-development with host governments.

In addition to general project funding, public financing may also be targeted at different stages of ESS deployment, such as funding pre-feasibility studies and/or technical assistance grants for utilities to develop the capacity to manage these complex systems. Some funding sources are also focused on components of ESS, such as loans from export credit agencies for components sourced from foreign manufacturers.

Green Funding

Host governments and utilities can now access international climate change funding for the deployment of ESS, as it may be demonstrated that the project will limit or reduce greenhouse gas emissions. Hence, if capital availability is a constraint for a host government or a utility, ensuring that the ESS qualifies for Environmental, Social, and Governance (ESG) funding or climate finance might help unlock funds from development finance institutions that have set specific climate or ESG objectives.

Furthermore, several DFIs administer climate funds to promote the rapid deployment of these low-carbon technologies which help the sustainable integration of renewable energy generation into the grid. These include the Climate Investment Funds (the Clean Technology Fund and the Strategic Climate Fund (SCF)) which can provide loans at below-market price interest rates (concessional financing) or as loans subordinated to the lenders' senior loans. This improves the capital structure of the investment and the cost of financing. Other funds include the Green Climate Fund, the Global Environment Facility, and the Scaling Up Renewable Energy Programme (funded by the SCF and supporting smaller-scale renewable projects in certain countries), among others. Commercial lenders and private equity firms have also set ESG objectives in recent years that have promoted the financing of ESS.

Project Finance

Most of the bankability requirements applicable to power projects explained in the *Understanding Power Project Financing* handbook apply to the private financing of ESS. However, to the extent that traditional project finance requires that every risk be mitigated or passed along to the best-placed party, ESS may require intervention from a larger cast of private participants when it comes to areas such as O&M, insuring projects involving emerging technologies, manufacturer warranties, and others.

Innovative ways to mitigate the particular risks stemming from the ESS technologies can help address the concerns of lenders who do not have prior experience with energy storage projects.

Policy

Introduction

Energy storage development can revolutionise power systems in Africa and enable faster, greener expansion into underserved areas. However, it is essential to understand existing policy environments to unlock this potential.

Understanding the Existing Policy Environment

Consideration of the broader enabling environment is key to decision-making about strategies for proposing or adopting energy storage systems. For example, a country that focuses on growing its domestic minerals sector, or another that focuses on developing its technology sector, would always have these considerations in mind when contemplating decisions about energy storage system deployment. These considerations could lead to prioritising the technologies that align with their objectives. Similarly, approaches to trade and trade protection, job growth, and decisions about the allocation and use of land for a variety of mutually exclusive activities could lead to some technologies being more favourable in specific markets. This consideration of an assessment of the enabling environment and its importance has been covered in greater detail in other handbooks in the series, as detailed throughout this chapter.

Understanding Power Projects Procurement

In the *Understanding Power Projects Procurement* handbook, a policy is described as a critical element within the enabling environment that needs to be considered for successful power project development. That handbook notes that “Policy objectives may include the quest to increase and improve energy access, economic development, reduce carbon emissions, attract foreign direct investment, advance job creation, ensure energy security, stabilise the grid, and position the country for industrialisation (*Understanding Power Projects Procurement*, page 32).

Understanding Power Purchase Agreements

Many countries in Africa are undergoing industry restructuring that is being driven by domestic policy. Regard needs to be given to the applicable type of market or industry. For instance, procurement decisions for markets with vertically integrated electricity supply industries may be different from those for markets with separate generation, transmission, distribution, and retail segments. The single buyer in the latter market type may be more of an enabler for private sector involvement in certain countries. This market structure topic is covered in more detail in the *Understanding Power Purchase Agreements* handbook.

Links Between Policy, Regulations, and Planning

Understanding the links between policy, regulations, and planning in a particular country will be essential to advocate for the further deployment of energy storage systems and determine at which point advocacy should be applied. Therefore, understanding the particular context in the relevant country is crucial. Questions to ask to determine the links in a particular country include:

From Policy to Regulations

- Consistency – Does policy translate into regulations or are these mismatched?
- Predictability – Is there an established process for developing regulations and are the regulations adhered to? Alternatively, what is the process for regulation within a country – who makes the authoritative decisions? What informs the decision-making? Is it predictable or arbitrary?
- Institutional capacity – Are regulator mandates clear and is there adequate capacity to execute the mandates?
- Pricing – How are prices established? Is this the role of the regulator or someone else? Will energy storage systems be compensated together or separately for each of the services that can be provided? Will the regulator establish the prices, or will they be established via contract?

From Policy to Regulations to Planning

- Transparency – Is the planning process transparent and documented? Is it consistently applied? If not, what process is adopted in each country for planning?

- Central planning – Is there a centrally planned integrated resource plan (IRP) or do planning and procurement occur in an ad hoc manner?
- Stakeholders – Who are the decision-makers and what is their resistance to change? What assumptions are made in the planning process, and will they provide benefits or disadvantages to a particular technology?
- Pricing – Will the pricing be fair?

Taking Advantage of Existing Policies

Given the enabling power of energy storage, those working to increase ESS penetration in Africa may have a place to start. In addition to encouraging the development of new policies for energy storage technology, the following are common policy positions that could be cited in conversations with regulators and planners to encourage the deployment of energy storage.

Localisation

Many battery energy storage system technologies require minerals that can be sourced or beneficiated domestically. By pointing to the use of these local minerals, ESS deployment could be prioritised over other technologies to meet existing localisation policies. It is important to note that with initial ESS pilots and deployments there can be an organic or required level of technology transfer. The ability to manufacture, assemble, recycle, and operate ESS systems may align closely with the goals of localisation policies as storage sectors further develop.

Jobs, Industrialisation, and Economic Growth

Energy storage deployment has the potential to create local industries and associated jobs. The deployment of energy storage systems will also allow for further job creation during the development, construction, and operations phase. These jobs would include, amongst others, developer, construction personnel, maintenance personnel and asset management personnel.

ESS can also enable the fast expansion of electricity generation capacity; thus, ESS deployment can enable economic growth in countries in which electricity demand is suppressed by the lack of availability or unreliability of supply.

Renewable Energy Penetration and Climate Change Mitigation

ESS integration can support existing policies toward the integration of higher proportions of variable renewable energy. One can easily argue that energy storage deployment is synergistic and a prerequisite to a country reaching its existing renewable energy deployment policies.

Energy Security and Diversity of Resources

Countries typically have long-term policies aimed at energy independence to ensure that their energy market is not beholden to that of an energy exporter. The addition of energy storage (along with other technologies) enables a country to achieve energy independence decoupled from the rise and fall of commodity prices and the associated currency exchange rate risk. The addition of energy storage also provides an opportunity to diversify the electricity generation mix and thereby improve the electricity system's reliability and ability to resiliently recover from disasters and other large-scale shocks.

Fiscal Responsibility

Storage technologies can help defer the major capital costs of new electricity transmission grid investments, especially in contexts where the electricity grid is funded through a state-owned entity

Universal Electrification

Energy storage deployment can provide reliable access to electricity for the most unfortunate, encouraging several existing, related policies. This electrification could occur by way of mini-grids created for islands or other communities where the full electrical grid does not reliably reach. This electrification could also occur by providing continuous, reliable electricity for those that rely on it for their health and wellbeing.

Disaster Recovery Planning

ESS can support black-start or distributed services, enabling a country to be resilient and self-reliant following natural or other disasters.

Case Study: Turning Disaster into Opportunity

Before 2017, the Puerto Rico Electric Power Authority was saddled with large debt and an ageing infrastructure. In 2017, Hurricanes Irma and Maria caused most of the transmission and distribution systems in Puerto Rico to collapse leaving 95% of residents without electricity in the immediate aftermath of the storms and leaving residents in some parts of the territory without electricity for almost a year.

In 2019, local lawmakers amended renewable energy standards, with the new aim of reaching 40% renewable energy by 2025 and 100% renewable energy by 2050. Many people viewed this requirement as the best way to strengthen the island's infrastructure so that it would not be as susceptible to future devastation while also meeting pressure to align with widespread green energy goals. They likewise saw this as a way to help save vulnerable citizens from the impact of future deadly disasters and a way to reduce their dependence upon high importation fuel costs.

Although each of these policies would be fulfilled by renewable energy, local authorities were aware that these policies could not come to fruition without the enabling power of energy storage. Puerto Rico's IRP called for 1,500 MW of energy storage sought, and RFPs launched since that time have included the procurement of both renewables and energy storage from IPPs. Such policies have also procured utility-owned storage.

Risks and Challenges

Deployment, or the lack thereof, of renewable energy generation technologies in Sub-Saharan Africa in the last decade (in 2021, only 6% of the world's wind and solar power generation capacity was in Sub-Saharan Africa) can be directly attributed to the late preparation of enabling policy and rules to incentivise the development of this clean energy, even though renewable resources are abundantly present throughout the continent. This lack of development is in part due to the warnings in the literature of observed impacts of renewable energy generation in developed countries, namely, the impact of variability on power system reliability. In Africa, the support provided to countries to create policies and planning for renewable energy generation resources development in the last two decades reflected this conservative thinking. Policymakers believed that fragile power systems would suffer even more from renewable energy generation's intermittency. As an illustration, master plan designs in Sub-Saharan Africa widely referenced these potential impacts and recommended conservative approaches and targets for wind and solar technology development. However, it has been proven, in country after country, that power systems were robust enough to incorporate renewable energy generation assets in a manner that was cost-effective, environmentally friendly, and met other national policy goals.

The same empirical thinking that led to the slow development of renewable energy generation in Africa could be repeated in the conversations around the implementation of ESS in Africa. Policymakers could easily ask themselves why they should develop storage of electricity in power systems that do not yet have enough energy to supply the customers 24 hours a day and avoid talking about the many other benefits that energy storage can still provide.

It is paramount to draw lessons from past renewable energy development on the continent, from energy storage deployments worldwide, and proposed use cases and business cases for ESS in Sub-Saharan Africa, to provide an adequate enabling environment for further energy storage systems deployment. Energy storage systems can play not only a catalytic role in scaling up renewable energy in African countries but can also help bring much-needed flexibility to system operators who often have no other choices than to run their generation assets beyond their prescribed limits or offset the total electricity demand.

In addition, as markets unbundle, system operators are increasingly being restricted in terms of owning and deploying generation assets. In cases where the ESS is classified as a generation asset for licensing and regulatory purposes, this can create uncertainty. The uncertainty on rules that govern ESS creates a challenge where deployment is particularly beneficial in terms of system operations only.

Since system operators are important stakeholders in the adoption and deployment of ESS, they should be allowed to participate in ESS development and ownership. Regulatory safeguards will need to be developed to ensure that market distortions favour participants.

Regulatory Framework

Introduction

Global experience shows that providing a regulatory framework to a nascent infrastructure sector/sub-sector independently of the market model and specific use cases can provide stability to the overall sector and transparency to investors. In light of the potentially revolutionary nature of widespread adoption of energy storage technology, it is imperative that regulators expediently provide such a regulatory framework.

Many developing economies are already starting to respond to the growing need to enable the inclusion of energy storage systems in their electricity technology mix. This is driven by various considerations including the need to meet domestic imperatives as well as international commitments.

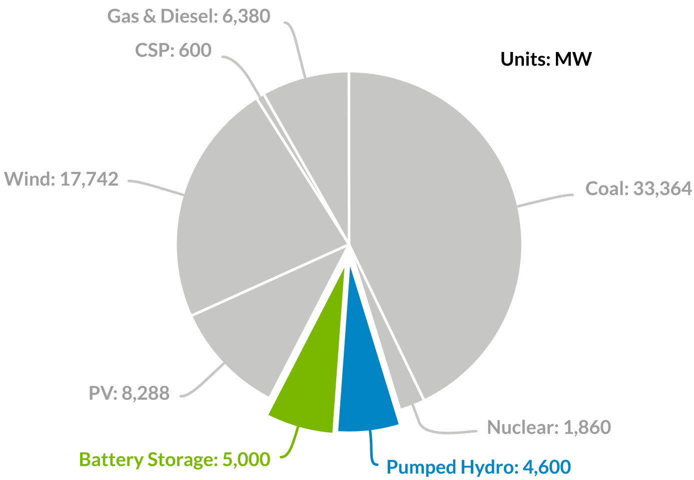
Emerging Approaches to Regulating Energy Storage Systems

The special regulations or modifications of regulations being considered include:

- Definitions of the types of ESS that are subject to regulation;
- Recommendations for special licensing for storage (considering storage's dual character as both a consumer and a source of electricity);
    - In some markets, customers or loads, and sources incur different charges
    - Due to the nature of storage, there is concern about an additional burden on regulators due to the integration of ESS
- Amendments to tariff structures to factor in revenue from new value streams;
- Amendments to grid and distribution codes to ensure that the inclusion of novel energy technologies is both possible and not disruptive to the grid; and
- Subsidiary regulations (that are also reflected in licensing processes) related to the environment, health, and safety.

Namibia and South Africa are two countries that have taken the steps to create regulations related specifically to storage systems. In Namibia's case, one of the primary drivers of the development of their energy storage regulations is the need to enable their adoption. Emphasis is placed on technology agnosticism and some consideration is given to the need for some categories of storage applications to be exempted from regulation. In

South Africa's case, the regulator has taken steps to develop technical and design specifications for ESS being connected to the grid. Developers and suppliers that are looking to establish energy storage facilities on the continent need to take account of the different regulations that are being established.



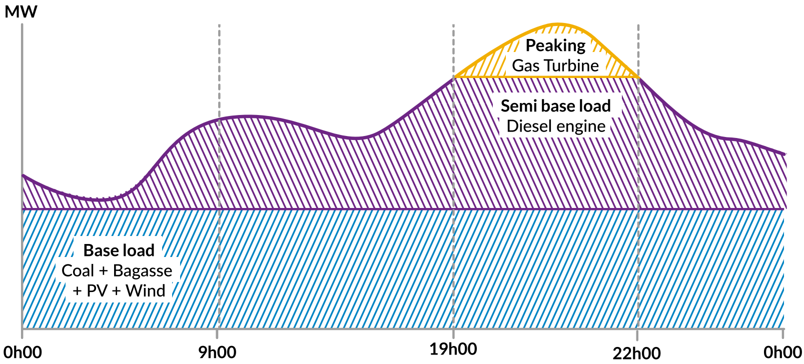
ESS as part of South Africa's 2030 goals

In countries where regulations that are specifically related to battery storage have not been developed, energy storage system developers, suppliers, and financiers need to consider the country's history in dealing with the introduction of new technologies. Some countries have a delayed response to new technologies but when they catch on to their potential proliferation, they enact a raft of regulations that can become barriers or enhancers to adoption.

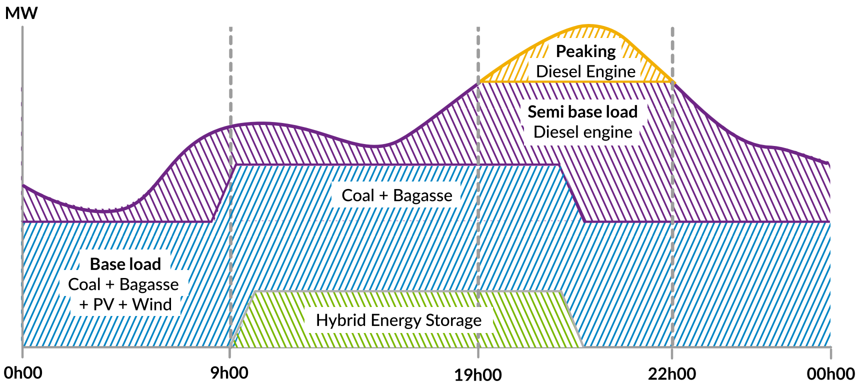
Other countries tend to take an experimental approach by allowing the integration of new technologies and observing whether there are adverse impacts. In some cases, the first energy storage projects in a given country may have the ground rules embedded into an offtake contract (i.e., regulation by contract). Given the lengthy regulatory process in many countries, this option may be favoured for pilot/demonstration projects that require speedy implementation. However, these offtake contracts often create a precedent from which the overall sector will have difficulty deviating.

Case Study: Mauritius

In Mauritius, the utility forecasted that peak demand would soon be higher than the installed peak generation capacity. The utility studied the potential solutions and recognised that a hybrid solar-plus-storage project might provide the required peaking needs at a lower cost than a combined cycle gas turbine. The utility published an international bidding process to seek offers for the construction of such a project. The offerors were required to guarantee a daily power profile to encourage the expansion of renewable energy and displace a potentially high-cost generator. Certainly, the solar component alone would create times of excess generation and curtailment. However, in combination with a battery, the combined system could meet the utility's requirements. Although Mauritius had no regulatory framework in place for the use of energy storage systems, the utility was able, through its contracting process, to regulate the usage of the battery component by providing price incentives and contractual requirements that mandated the combined system to achieve the daily profile which was not compelled through regulation. Additionally, although there was no regulatory framework in place for the provision of ancillary services by an energy storage system, the utility included provisions in the contract requiring the combined system to provide frequency response, voltage support, and power factor correction, with associated penalties for the failure of the combined system to provide these ancillary services when the battery had sufficient charge.



Supply Duration Curve – Business as Usual (Mauritius case study)



Supply Duration Curve – Hybrid ESS (Mauritius case study)

Key Considerations When Evaluating and Developing ESS Regulations

We acknowledge that the variety of power sector structures, potential energy storage use cases, and level of incentives/constraints to be provided via regulation makes it difficult to present case-by-case recommendations per country, but the general principles listed below can be used as an aid to regulators and other stakeholders in developing and assessing a regulatory framework for ESS.

Licensing

Some developing economies have mature licensing frameworks because of the provision of traditional services by the electricity supply industry. The licensing of ESS can use the existing licensing framework as a starting point. An approach can be taken of issuing an existing generation facility that is integrating ESS with a modified licence that reflects the changes to the technology type and any capacity changes. As regards standalone electricity storage systems, two types of licences can be envisaged. In a single buyer market model, a transmission licence already issued to the transmission owner can be modified to include the development and operation of an ESS. In a partly liberalised wholesale market where there are multiple buyers, an energy storage licence can be issued to the project company. African countries can consider developing a regulatory framework to exclude behind-the-meter/off-grid electricity storage systems from licensing provisions below a threshold capacity to incentivise customers to install such types of systems. A generation licence may be issued to the remaining behind-the-meter/off-grid ESS.

Technical Regulations

Codes are technical regulations to define the requirements for an ESS to connect to a power system to preserve the integrity, safety, security, and economic operations of the network. The codes will specify the connections of the ESS to the transmission network or the distribution network. These are typically written and enforced by the regulator.

An ESS will be required to withstand frequency and voltage deviations under normal and abnormal conditions. Disconnection and connection to the network will be at the discretion of the system operator. The codes will also specify the number of tests to be performed by the project owner to demonstrate compliance with the code requirements before being allowed connection by the system operator.

Environmental and Safety Regulations

Government and regulators can put in place regulations to ensure that ESS on the continent use materials extracted and beneficiated per ecological standards and with full respect for human rights. The components of the system will have to be long-lasting and safe. The installation and the operation of the ESS must minimise the impact on the environment. At end-of-life, regulations will have to be provided for repurposing, remanufacturing, or recycling the ESS to be fed as valuable materials back into the economy. The regulations will also comprise the safe use of the system and minimise the injury of persons and property in the vicinity of the ESS. Developers and suppliers alike must be mindful of methods to meet these requirements in applications for new ESS licences.

Alignment with the Existing Framework

Regulatory change will likely have to be reflected in primary legislation such as the electricity law, whereby the operations of an ESS will be recognised as a regulated activity. This change will enable the regulator to issue a licence to a project company or amend existing licences issued to regulate the activities of ESS. Specific electricity storage regulations, codes, and standards may then be developed by the regulator. Moreover, associated environmental and safety regulations will have to be amended to include ESS.

Case Study: Namibia's Interim Measure for ESS Licensing

In Namibia, the Electricity Control Board (ECB), the regulator of electricity, developed energy storage rules to be provided under a new Electricity Bill. It is to be noted that the existing Electricity Act (Act 7 of 2007) is being amended to include ESS of power capacities exceeding 500 kW. As the new Electricity Bill is not yet promulgated, the ECB approved, as an interim measure, the deployment of ESS technologies under the existing regulatory framework, with current operational energy storage rules.

Under the existing regulatory framework, current ESS licensing applications are being considered as generation licence applications, with specific ESS conditions such as whether the ESS will be used for capacity, ancillary, or energy services as specifically mentioned and stated in each approved ESS licence application.

Generation licensees wishing to apply for ESS licences will apply for an amendment of their licence. The process will allow the generation licence to be amended to include ESS with accompanying new conditions for storage including ESS application, dispatching conditions, system integration as well as applicable tariffs to be charged.

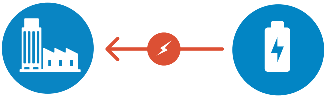
For any new ESS project, the existing regulation will be applicable (using the generation licence application). Applications began being processed in 2022. As of June 2022, one (1) successful ESS project has been approved by the regulator with several applications under consideration.

Evaluating Requirements for ESS Regulations

To enable the fast adoption of ESS, industry participants may need to be proactive in evaluating the existing regulatory framework and recommending or developing new draft regulations. Some rules can be adapted to determine under which circumstances an ESS would qualify for exemption from regulations or trigger a licensing requirement or other regulatory requirements. For example, exemptions may apply to small capacity ESS or behind-the-meter systems and licensing requirements and other additional requirements may only kick in for very large ESS relative to the size of the power system, or when the ESS plays a critical role in stability, reliability, or resilience.

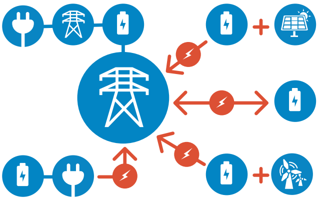
The following table is a guide for industry participants to evaluate and think through the development of new regulations to enable the integration of ESS.

Baseline ***Pre-existing regulations***	**Actions to be taken w/ ESS** ***Potential new regulations***
All configurations	Environment and safety regulations Requirements for ESS registration (e.g., above certain thresholds)



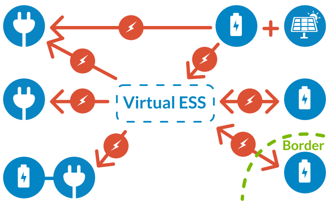
Business-to-Business (mini-grid, self-generation, behind-the-meter backup ESS)

Baseline ***Pre-existing regulations***	**Actions to be taken w/ ESS** ***Potential new regulations***
Regulations for rooftop PV, embedded generation	Amendments to requirements for registration of ESS assets with the regulator and the capacity thresholds that trigger additional regulations – especially for grid-tied assets
Mini-grid regulations	Technical standards for maintaining the quality of supply for grid-tied systems (*)
Any storage regulations (i.e., pump hydro)	Technical standards and regulations for monitoring and dispatching behind-the-meter assets for grid services



Single Buyer (vertically integrated utility)

Baseline ***Pre-existing regulations***	**Actions to be taken w/ ESS** ***Potential new regulations***
Independent Power Producer (IPP) regulations Feed-in-Tariff regulations Distribution system operator, Transmission system operator, state-owned entity regulations Any storage regulations	Rules for PPA amendments to incorporate energy storage including the development of a tariff regime to accommodate multiple services from ESS Amendment of the economic regulatory framework to facilitate cost-recovery through the tariff for utility-owned assets Technical standards and regulations for monitoring and dispatching behind-the-meter assets for grid services (*)



Full Market or Power Pool

Baseline ***Pre-existing regulations***	**Actions to be taken w/ ESS** ***Potential new regulations***
Power pool regulations Ancillary services regulations Market operator Cross-border regulations	Amendment of existing regulations to create new markets for trading the entire suite of ESS services

(*) It is complex to set rules if RE+ESS is behind the meter; it depends on the type of regulation in place (net metering, net billing) and the customers' tariff structure.

Risks and Challenges

It should be noted that existing regulatory frameworks, as well as the development of new energy storage regulations, may have outsized impacts on the development of ESS as well as the energy sector as a whole. For example, with the increased deployment of ESS in behind-the-meter applications, utilities and system operators face the challenge of reduced revenue from these customers. Should the utility be permitted to raise tariffs to compensate for these losses, rather than to devise mechanisms to maintain or grow their customer base, this may further incentivise consumers, industrial, and corporates to further deploy self-generation and storage to reduce costs. The cycle can continue until the utility becomes unsustainable, affecting the entire power sector. A balance must be reached that will allow both grid operations to continue and customers the flexibility to manage their consumption patterns. There will be a need for regulatory intervention to ensure a healthy power sector with sustainable grid operations and the deployment of ESS. This requires consistent regulatory oversight and compliance concerning ESS deployed behind the meter.

Planning

Introduction

A well-designed policy may not necessarily lead to the realisation of the policy goals of the government without a clear plan for implementing the policy. "Even when plans are useless, planning is indispensable," former United States President General Dwight Eisenhower said. This maxim could apply to the integration of energy storage into long-term planning in developing markets.

As planning is at the junction between the vision (policy) and the rules/guidelines (regulatory framework), it is incumbent upon the planner to understand as many of the tools as possible that might be available at its disposal to meet propounded policy and the grid's needs. Proper integration of energy storage into planning tools and documents is an essential step in harnessing the flexibility of energy storage technology to meet the requirements of the grid and implement national policy.

An ESS will not be a solution for every problem that the planner sees in the power system nor will it meet all policy goals, but the planner should be cognisant of the potential benefits of ESS including the declining cost of energy storage systems, as a new, increasingly viable tool to be considered in all planning decisions.

Planning Context

By its very nature, planning is context specific. A planner needs to understand the generation and load profile, transmission and distribution capacity, defining characteristics, and future growth to effectively perform this function. The introduction or potential introduction of ESS into the power system does not fundamentally change any of these requirements. However, ESS are a flexible tool that the planner has available to fulfil its role. To effectively perform the planner's role, it is incumbent that the planner:

- Understands the use cases of ESS (see *Use Cases* chapter), including the flexibility to provide multiple use cases at different times or simultaneously;
- Understands that ESS technologies are varied and that each has unique characteristics that might be considered;
- Understands that ESS have dramatically dropped in cost;
- Understands the effects that energy storage will have on existing or future generation resources, such as optimising the use of existing power generation assets and contributing to the extension of their economic life or enabling the integration of additional renewable generation assets to fully capture the renewable resources available to a region;
- Understands the effects that energy storage will have on existing or future transmission and distribution resources; and
- Understands that end of life of the energy storage asset must be accounted for from initial planning. This includes disposal, repurposing, and recycling, for potential financial gain or to comply with relevant codes.

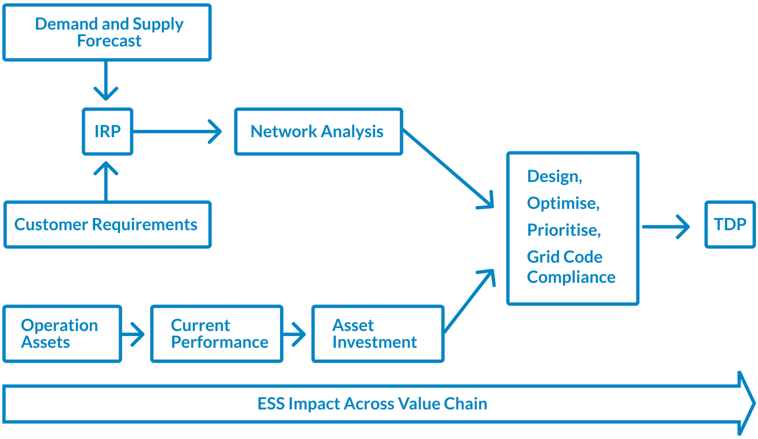
Types of Plans

In some countries, electricity capacity is planned centrally and published in an Integrated Resource Plan (IRP). These plans are updated periodically (typically every two years) and indicate the electricity generation capacity that will be integrated into the grid over a 10 to 30-year planning window.

In some other countries, electricity generation is not planned on a long-term basis and is often based on unsolicited project proposals that are made to governments or projects sponsored by donor agencies or development finance institutions. Even in this case, as in the case of the planned and predictable generation plans, the typical process for procuring or developing electricity generation projects needs to be understood so that developers and investors are aware of what technologies, prices, and risk allocation would be appropriate for each country of interest.

The risks associated with the outcomes that each planning approach adopted also need to be considered. In countries where the planning is less holistic and predictable, there is a risk that the assumptions based on which technology is deemed viable, can change. For instance, if grid reliability is not assured, then there might be a risk to business models or contracts that rely on assumptions about the availability of infrastructure to deliver the service. The integration of new technologies into these environments may attract higher tariffs and take or pay contracts to consider the risk of grid unavailability, however, these solutions may not be sustainable for the public utility if the underlying problems are not addressed. The asset performance and life can also be affected by changes in the quality of supply of the grid to which it is connected.

High-level Planning Process



ESS impact planning flow chart

The planning process starts with a policy addressing the host government's goals, this could be done through the development of the Integrated Resource Plan (IRP). This becomes a required assumption for the development of a Transmission Development Plan (TDP), and distribution plans are developed with input from the IRP and TDP. The process of planning is iterative and customer demand data is fed back into the policy environment resulting in IRP and TDP optimisation and further developments.

Because of the flexibility in the deployments of ESS, plans across the value chain (generation, T&D, and behind the meter) in a power system will be impacted as demonstrated by the use cases. In most integrated resource plans, peak demand projections drive supply-side options as a starting assumption. With ESS deployment, this assumption needs to be carefully evaluated as peak demand can now change as a result of deploying an ESS system (either by the utility, an IPP, or a customer).

Optimisation and reliability studies have hence become an important aspect of utility planning. Instead of 10 to 20 years plans for TDPs, what is classified as operational transmission and distribution plans (less than 1 year) now gains more prominence as some ESS deployment can be done in days rather than years (like containerised BESS).

As some ESS like pump storage and Concentrated Solar Power (CSP) plus storage, have longer construction timelines, long-term IRPs (20 to 30 years) as well as long-term TDPs (usually 10 to 20 years) will need to be developed traditionally. However, demand projections will need to be carefully considered for utilities to not over-invest and to prevent the stranding of assets.

Case Study: New Technology Development

Pilsworth Grid-Scale Demonstrator Plant: Grid-Scale Liquid Air

The 5 MW/15 MWh grid-scale Liquid Air Energy Storage (LAES) plant was commissioned in 2018 and is reported as a world first. The project developers, Highview Power, partnered with GE and Viridor. The cost was reported as £8 million and took 3 years to construct.

LAES converts air, which is stored as a liquid, into gas using an expansion process that releases stored energy to drive a turbine and generate clean electricity. Unlike battery storage, the process does not use any potentially harmful metals or chemical elements, as the LAES plant comprises mostly of steel.

The plant has a lifespan of 30 to 40 years and can be decommissioned easily without the need to dispose of any dangerous materials. The long-duration nature of the facility allows it to provide high levels of energy storage capacity to several reserves, grid balancing and regulation services. In addition to providing energy storage, the LAES plant also converts waste heat to power using heat from the on-site landfill gas engines. Aggregator Kiwi Power was selected to take the facility into the ancillary services market. The project was funded by the UK government. Now that the plant has been proven, a full-scale 50 MW/250 MWh LAES facility is under construction at Trafford Energy Park in Carrington with UK government support.

The rapid evolution of this type of project from conception to demonstration, now in its full-scale construction, demonstrates the speed at which technology is evolving. With this type of technology, it will be desirable for a utility to collaborate with the developer as specifications and designs will still be developer specific. With UK policy firmly promoting new industries through the Modern Industrial Strategy, the support from the government to facilitate the development and implementation of the LAES plant was critical for the demonstration facility to get to full scale. Planning engineers can now include this option into their integrated resource plans as a technology option and since it is still driven by the UK government, the planning for the deployment can be managed.

Case Study:

South Africa was the first Sub-Saharan African country to integrate quantitative ESS targets in its long-term national electricity plan: the Integrated Resource Plan (IRP) approved in 2019 aims to have 2,000 MW of BESS connected to the grid by 2030. The Botswana IRP, approved in 2021, also included quantitative BESS targets, and several master plans under preparation also included the targets, with the main objective of scaling up wind and solar development thanks to the storage capacity.

Risks and Challenges

Stranded Assets and Inefficient Cost Allocation

ESS deployment without coordinated planning with utilities can lead to network assets becoming redundant or being over-designed. A typical example is in a case where peak shaving is occurring and utilities are planning networks to accommodate peak demand requirements. Customers may as a result pay higher connection fees and the utility may earn lower revenues if the balance between fixed cost and variable cost in the tariff is not attained. Therefore, planners require ongoing and consistent data in terms of monitoring ESS deployment and customers need to consult with utilities as they deploy ESS systems.

Stick to the Plan

As a special note, because of the critical enabling role that energy storage will play in power systems, it is important to implement energy storage projects and programmes as planned. A failure to implement such projects and programmes could bring uncertainty to a nascent market, creating risks for other users of these technologies and reducing the demand for external investments in energy storage in the region. Additionally, a failure to stick to the plan might also impact the development of other assets that depend on the storage capacity to perform optimally.

This is notably the case for wind and solar projects that may see their output and profitability affected due to the non-materialisation of planned storage infrastructure. Conventional generation resources, without energy storage, might need to be run irregularly reducing the lifecycle of the investment. It is also the case for grid development that is usually dimensioned by the incoming power supply, demand, and storage capacity. In each case, if alternative investments were planned or made based upon the presumed availability of energy storage, the non-realisation of such energy storage would diminish the other investments, which could delay the development of a power system.

Procurement

Introduction

While the deployment of energy storage assets is becoming more common in both developed and developing markets, procurement design remains a complex undertaking that requires the adaptation of core procurement principles in a new context. The *Understanding Power Project Procurement* handbook describes the following general approach to procurement:

An effective procurement policy provides a framework which allows policymakers to achieve certain objectives. For instance, for a procurement policy to develop power projects, a menu of options can be considered which will impact the design and implementation of the procurement process. To achieve a coherent and consistent procurement policy, it is important that all stakeholders involved in the decision-making and oversight of the procurement process share aligned objectives. Such objectives must be balanced and prioritised in order to meet governmental strategic goals, such as adding installed capacity or growing the economy.

These same principles apply to the procurement of energy storage. In many ways, a focus on clear objectives and stakeholder engagement as ESS procurement involves additional value considerations (generation vs. services, greater revenue vs. cost savings) and a larger group of actors (manufacturers, programmers, etc). This chapter will briefly revisit the general procurement guidance from the *Understanding Power Project Procurement* handbook and highlight unique considerations that should be applied to energy storage (illustrated by case studies).

Case Study: Malawi's Experimental Approach to Grid-Scale BESS Integration

An IPP in Malawi became one of the first-generation asset owners or operators to integrate grid-scale BESS in Southern Africa. The IPP paired a 5 MW/10 MWh BESS with their 20 MW solar PV asset. This pairing was not part of the initial plant design, but the IPP decided to integrate the asset to partially address the utility's concern about the impact of the intermittency of solar PV plants. The BESS asset was enabled by the availability of donor funding and the CAPEX was not a significant part of the project costs. The integration of the storage asset will now be used in various operating configurations and for a variety of use cases to determine the best usage of such an asset in Malawi. This creates an opportunity for the lessons from the operation of the asset to be used to inform the procurement of other energy storage assets in Malawi and the rest of the region. This is a case of an environment where the regulations and plans for integrating a specific asset type do not exist but the regulator, the offtaker, and other decision-makers are open to taking an experimental approach, creating an opportunity for learning and developing regulations and plans. This type of approach is often enabled by grids that have significant constraints and decision-makers are open to the fast deployment of assets within a flexible planning paradigm.

General Procurement Principles

Choosing a procurement process and developing the associated documentation requires careful consideration of many factors. There is no one-size-fits-all approach to procuring a power project. A procuring entity should keep overall procurement objectives in mind while also accounting for the specifics of the target project.

Procurement Structure

One of the threshold questions in infrastructure procurement is whether to conduct a competitive tender or invite direct negotiations. The comparative advantage of each of these procurement strategies is too complex to cover here (please see the *Understanding Power Project Procurement* handbook). In general, competitive tenders are viewed as having the benefit of maximising competition to reduce costs but require more time to prepare and conduct the tender. Direct negotiations are viewed as having the benefit of faster implementation and the flexibility to evolve the procurement requirements as negotiations progress but may suffer from reduced transparency and less competition. The decision to adopt either of these procurement structures may be influenced by the target outcome (pilot projects vs large-scale deployment) and the capacity of the procuring entity to manage complex processes.

Allocation of Risks

How the procuring entity allocates risks under the terms of the procurement will also have a significant impact on project economics. The general philosophy of risk allocation is that developers are attracted to projects with favourable risk-reward ratios: the lower the risk, the more interest the procurement can attract. At the same time, the procuring entity may wish to allocate greater risk to developers for first-time projects or emerging technologies. This balancing of risks is also influenced by policy priorities, financial constraints, and market conditions. Procuring entities that wish to attract risk-conscious investors can employ several strategies, such as investing in project preparation before the procurement, allocation of risk away from the investor to the procuring entity in the project contracts, and increasing the tariff to reward investors who assume a greater share of risk.

Sources of Finance

In developing markets where access to financial capital is constrained, possibly by a limited domestic banking sector and/or currency volatility, DFIs and Export Credit Agencies (ECAs) play a major role in the financing of power infrastructure. If a procuring entity anticipates the need to attract DFI or ECA funding, it would be wise to pay particular attention to the aspects of the procurement process that most concern these institutions. DFIs often seek both positive policy and financial outcomes as part of their lending by placing a heavy emphasis on transparency, environmental, social equality, and fiscal responsibility. For ECAs, the requirement that goods or services be procured from the ECA's home country may require the procuring entity to ensure that the technical and commercial specifications of procurement do not limit (or exclude) the ability to import equipment and financial capital from foreign sources.

Complaint Mechanisms

Although a majority of planning for procurement should focus on the factors that lead to success, a procuring entity should also consider the potential for negative outcomes. The resolution process for any potential complaints related to the procurement process should be established in advance since it is often difficult to negotiate a dispute resolution process between parties that are already at odds with each other. The processes a procuring entity may use to address complaints are very likely to be constrained by whatever law governs public procurement generally, the procurement of Public-Private Partnership (PPP), or administrative procedure generally. In general, however, the process will rely on the use of a neutral process, possibly through an independent tribunal. Where the law governing the procurement process does not provide for the referral of complaints to an independent tribunal, the procuring entity may establish a procedure in the procurement terms to govern how aggrieved parties may file complaints.

Case Study: Concentrated Solar Power with Storage

Starting in 2011, South Africa has conducted 5 rounds of competitive tenders under the Renewable Independent Power Producer Programme (REIPPP), resulting in more than 6,300 MW of renewable energy capacity across 92 projects. 600 MW of that new capacity is in the form of concentrated solar power (CSP) capacity which includes energy storage capacity. The REIPPP procurement started with an integrated resource plan that included a target for renewable energy with storage. Then, in every round except bid window four, CSP was allocated a capacity of 50 MW to 200 MW including a special bid window dedicated to CSP only. This consistent allocation throughout the bid windows allowed for power developers to continue to refine their project proposals. This progressive approach also resulted in tariffs falling in later rounds. In this way, a well-planned and phased procurement process for developing technologies can facilitate both adoption and cost savings.

Project Name:	*KaXu Solar One*	*Khi Solar One*	*Bokpoort**	*Xina Solar One*	*Ilanga I*	*Kathu Solar Park*	*Redstone*
Location:	*Pofadder*	*Upington*	*Groblershoop*	*Pofadder*	*Upington*	*Kathu*	*Postmasburg*
Technology:	*Parabolic trough*	*Tower*	*Parabolic trough*	*Parabolic trough*	*Parabolic trough*	*Parabolic trough*	*Tower*
Thermal Energy Storage	*Molten salts*	*Saturated steam*	*Molten salts*	*Molten salts*	*Molten salts*	*Molten salts*	*Molten salts*
Turbine Net Capacity (MW):	*100*	*50*	*50*	*100*	*100*	*100*	*100*
Start Year:	*2015*	*2016*	*2016*	*2017*	*2019*	*2019*	*2024*
Storage Capacity:	*2.5 hours*	*2.5 hours*	*9.3 hours*	*5 hours*	*4.5 hours*	*4.5 hours*	*12 hours*
Status:	*Operational*	*Operational*	*Operational*	*Operational*	*Operational*	*Operational*	*Under Construction*

*In October 2020 (summer months with high irradiation) this project broke records by operating continuously for 310 hours (24/7) of load following at an 83% capacity factor.

Approaches to ESS Procurement

The procurement approach for ESS must be aligned with the technology, design, scale, and structure of the intended energy storage deployment to ensure cost-efficacy. The tailoring of an ESS procurement will be influenced by special characteristics of available ESS technology, such as maturity, the prevalence of the ESS technologies, pricing dynamics, and risks. In addition to the technology, the procurement must also account for the cost of complexity of integrating the procured ESS into the existing grid.

Case Study: ESS Pilots

The very concept of scaled electricity storage – the fact that one can store a significant amount of power and discharge it in a given power system – is still unfamiliar territory for many utilities worldwide. Based upon experience in the deployment of existing networked power systems (e.g., smart meters, control-command, or other grid infrastructure), many utilities choose to evaluate the viability of ESS through a pilot program before large-scale deployment.

Piloting an ESS system should not be viewed with any less rigour than large-scale procurement. The pilot should be well thought out, with a market awareness campaign, preparation of detailed technical specifications, structuring of the legal and financial arrangements for the project, operation and maintenance, and a monitoring and evaluation phase. As with all pilots, the main objective is to draw lessons before scaling up the technology, hence the emphasis on a careful implementation process. Developing regulations for future ESS deployments can be conducted simultaneously with the ESS pilot as the utility and government increase their knowledge and ability to generate value through an ESS deployment.

The following is a brief and non-exhaustive summary of the special considerations that should be factored into ESS procurement design.

Special Considerations Related to ESS Procurement

Some main factors affecting the type of procurement to be undertaken include:

- Flexibility in specifications – Energy storage is envisioned in almost all countries, for grid-scale, mini-grids, off-grid, and electric vehicle applications. But reaching from a vision to a policy, and then from a policy to a regulatory framework can be a lengthy process during which technologies and grid needs may evolve. Therefore, procurement plans and processes should be created in such a way that contemplates not only existing needs but also future needs. In this regard, a consideration in the procurement design of the intended business model for the procured resource is necessary.
- Flexibility in procurement approach – When energy storage technology integration is not yet envisioned or planned for, it may be that a stand-alone project emerges, either to reinforce a VRE project or to respond to a specific storage need; ad hoc procurement can be envisioned in that case, on a pilot basis and using regulation by contract.
- Consideration of existing procurement rules and regulations – Independently from the energy storage policy and regulatory framework, it may well be that other rules and guidelines – including on procurement – do not allow procurement for large-scale ESS assets. Other rules (Customs, Environment and Safety) may also be an obstacle. Contrarily, some countries have fast-tracked procurement rules for pilot projects that may be well suited for ESS. In this case, the procuring entity and potential bidders should ensure that the procurements are not at risk of collapsing because they do not reference domestic laws and regulations.

- Lack of experience with technology – Lack of knowledge of the degradation or wear and tear of certain ESS technologies can put the forecasted performance/revenue streams at risk. Entities running procurement processes as well as bidders should ensure that there is sufficient risk coverage for technology risk under warranties and performance guarantees. For niche technologies, procurers should anticipate the risk of allocating too much capacity to a single technology and provider. This raises the consideration of splitting procurements between some technology providers with proprietary technology or specifying in procurement terms a technology with many potential service providers or one that uses open technology platforms or protocols. The risk of new technology not integrating well with existing infrastructure is also worth considering in the structuring of procurements. The procurer and the bidder must negotiate the sharing of this risk where sufficient data does not exist.

Risks and Challenges

Specification and Detailed Design for the ESS System

When procuring an ESS, the entity procuring has the responsibility to specify the requirements to meet identified needs. This can be a high-level specification or a detailed specification. The risk of poorly defining the system being procured is that the contractors participating in the tender will not meet the expectations resulting in a failed procurement or the procurer will acquire a system that does not adequately meet identified needs.

In some instances, the burden of preparing a detailed design may be allocated to the contractor under the procurement terms. This may lead to an increase in costs of the system but does help to ensure that the risk of the system underperformance rests with the contractor (who will likely have more experience with managing this risk). When the procurer has the capacity for in-house systems design, there is still a technical risk of underperformance but there is also the potential for cost savings. In either case, the procurer must have a good understanding of available technologies to specify the outputs and requirements that guide the design process.

Case Study: ESS Procurement in South Africa

Since 2018, South Africa has embarked on an ambitious ESS market development journey, intending to address several key objectives including (i) helping to scale up the development of renewable energy, (ii) enabling the country's Just Energy Transition (JET), (iii) creating more flexibility and reliability in its grid and (iv) developing a critical market size for all segments of the ESS value chain creation.

The state power utility, Eskom, designed its BESS demonstration programme in 2018, building on successful experimentation of various technologies in its research centre which had been conducted since 2016. Eskom was convinced that a substantial energy storage capacity would be needed to cope with increasing power systems challenges, i.e., the increasing slope of evening peak load ramp-up coinciding with the shutdown of solar photovoltaic power generation at sunset. From the utility's perspective, adding BESS in various grid locations – colocated with Eskom substations – would tremendously help the power system cope with the variability of an ever-increasing wind and solar photovoltaic power generation fleet.

The electricity sector IRP approved by the South Africa Cabinet in October 2019 has been a key pillar supporting the Government's ambition and was innovative in many ways: it was the first masterplan in Africa to put wind and solar as the least cost technologies and to have explicit targets for BESS. It was acknowledged in the IRP preparation that the Eskom BESS programme would serve as a demonstration programme, before potentially scaling up the use of BESS technology in the country.

In effect, the Eskom BESS programme paved the way for BESS development in South Africa, including the programme managers contributing to the BESS grid code preparation, getting the first environmental impact assessments (EIA) approved for BESS infrastructure, and conducting several roadshows to attract BESS suppliers and integrators in the South Africa market. As a result, Eskom awarded six BESS sites in March 2022, for an aggregated capacity of 860 MWh, to be built and commissioned before June 2023.

The Eskom BESS programme has attracted tremendous interest from the international BESS supply market which sees the South African energy storage market as a platform from which the BESS market could develop across Africa. The successful response from the market so far has encouraged the South Africa government to scale up the deployment of BESS technology: a tender for 513 MW of capacity is under preparation for IESP to prepare their bids by the end of 2022. It also contributed to the RMIPPPP which is currently under procurement.

The South Africa IRP targets to have at least 2,000 MW of BESS in its power system by 2030. Given the market growth discussed already, the pressing need for power reliability in the country, the incoming large volumes of intermittent renewable energy and the overall sector's energy transition, it is expected that this target will be easily reached. Moreover, the Eskom repurposing and repowering programme plans to have BESS as part of the repurposing options, in replacement of the decommissioned coal plants; BESS technology is hence fully part of the South Africa energy transition agenda. The growth of BESS manufacturing in-country is poised to be a green growth vector creating sustainable local jobs that also play a substantial role in the creation of socio-economic benefits tied to the JET.

In just four years South African public entities went through multiple types of BESS procurement: experimentation and technology testing, piloting and demonstration, emergency generation procurement and – soon – IESP auctions. The large scale of the potential market assuredly played a role in the successful procurement processes to date, with crowded road shows when the Eskom BESS programme was presented to potential suppliers and with offers within or below estimated budgets (which, in comparison with historical results, was surprisingly competitive for the first tender of a pilot programme). The chain of events also played a significant role in the success by (i) having the BESS grid codes approved before the first privately financed bids were provided and (ii) having the environmental and safety concerns of licensing authorities addressed before the first large public tender.

The South Africa case has been scrutinised by neighbouring countries and utilities, which are now following similar steps in the development of their energy storage infrastructures, e.g., an RFP and RFI for BESS in Namibia and Lesotho, respectively, and BESS deployment targets in Botswana's IRP.

Contracting

Introduction

The innovative technology and flexible utility of energy storage systems are often the primary focus of anyone considering deploying such systems. However, the structuring of such projects may be just as unique. Building on the overview of business models in the previous chapter, this chapter provides an overview of the considerations at the contract level for the acquisition and deployment of ESS, including a table summarising the alignment of contracts and business models. As with the business models, the structure of a project's design, ownership, and operation may vary widely, with each permutation requiring a contract that appropriately identifies and allocates risks amongst the parties.

This chapter maps out the type and general character of the contracts required for an ESS project. For a more detailed explanation of the content of these agreements and the allocation of risks, please refer to the *Understanding Power Purchase Agreements* and *Understanding Power Project Financing* handbooks.

Contracts for a Utility-Owned ESS

The simplest contract structure is when a vertically integrated utility intends to develop, own, and operate an ESS. Depending on which utility-owned model is used (see the *Public and Private Business Models* chapter for more details), the utility will need to enter into a series of design, construction and/or operation contracts. Such a utility could enter into a turnkey, lump-sum EPC contract with a single contractor or a consortium of contractors. It could also enter into multiple supply and construction contracts under which several contractors would supply and construct various components of the project. ESS may be managed over the long term under an operations and maintenance (O&M) agreement, which is often signed with companies with significant experience in managing the complexity of energy storage. In addition, some specialist services and spare parts may be required from the original equipment manufacturer. The actual equipment manufacturer would typically provide these services and spare parts under a long-term service agreement (LTSA) between the owner and the original equipment manufacturer.

IPP, Including ESS and IESP Projects

The prominent role of private developers in both the IPP, including ESS and IESPs business models, results in a contract framework that involves multiple parties and many overlapping obligations. This contract framework would typically include:

- Constituting Documents – Documentation to establish a project company (also known as a specialised purpose vehicle) to own the ESS assets and operate the project, including the articles of organisation and bylaws.
- Shareholder Documents – Agreements to govern the relationship between the shareholders in the project company. The agreement often defines the rights of the shareholders (i.e., the right to share in the profits of the project) and their obligations (i.e., to provide equity for the project's development).
- Offtake Agreement – A bilateral agreement whereby the project company commits to sell, and a utility saves on purchasing the energy and storage services produced by the project.
- Government Support Documents – A commitment by the host government to the project company (and its lenders) to mitigate risks that are beyond the control of the project developers, including credit support that may take the form of (i) a direct guarantee of the utility's general obligations under the offtake agreement, (ii) a put-and-call option agreement that defines payments to be made if the project is terminated, and (iii) liquidity support, often in the form of a standing letter of credit, for the offtaker's regular payment obligations. These

credit support arrangements can each be complex in their own contract design and are covered in detail in the *Understanding Power Project Financing* handbook

- Finance Documents – The lending documents (the agreements under which the senior lenders will make debt financing available to the project company), which may include a common terms agreement, one or more facility agreements, an intercreditor agreement, and the documents which create security over the shares in the project company and all of the assets of the project company, including a collateral assignment of the project agreements.
- Construction Contracts – A series of often inter-linked agreements between the project developer and construction companies to design, engineer, supply, construct, and install the generation and energy storage facilities and connect them to the grid.
    - Long-Term Service Agreement (LTSA) – A long-term service agreement under which the original equipment manufacturer may provide (i) specialised services that are periodically necessary to maintain the project and (ii) spare parts and replacement parts; and
    - Operations & Maintenance Agreement (O&M) – A long-term contract that parallels the offtake agreement under which a contractor – often an affiliate of the project developers with significant experience – will manage the day-to-day operation and maintenance of the project.

Contracts for Private Mini-Grids

As noted in the chapter on *Public and Private Business Models*, developing markets are experiencing increased investment in private mini-grids. The structuring of these projects often mirrors that of an IPP, including ESS but also includes the need to allocate the risks of building and operating the distribution network to deliver power to customers. As a result, virtually all mini-grids, as described above, will involve construction contracts, an O&M agreement, and an LTSA.

The ownership structure of the mini-grid, as defined in the constituting documents, may also parallel an IPP including ESS but may be more complex. Especially in the case of smaller mini-grids, the mini-grid is likely to be owned by a company that owns multiple mini-grids (possibly through a dedicated project company). As opposed to a project company that focuses on a single project under a project finance model, these holding companies may leverage the more extensive portfolio of assets as security to borrow funds under a corporate or securitisation financial structure (see *Understanding Power Project Financing* handbook) to raise funds and may use those funds to develop multiple projects concurrently.

Lease Arrangements

The time-bound nature of lease arrangements may be the primary contractual structure for an ESS deployment (as noted in the *Public and Private Business Model* chapter) or the basis for acquiring an ESS asset within a more permanent IPP, including ESS or IESP projects. In either case, this contract will include a commitment by the owner to deploy the ESS at a particular site and the obligation of the lessee (the party contracting for the ESS services) to make regular payments throughout the lease period. The contractual structure may be a finance lease (where the lease term covers most of the expected useful life of the ESS) or an operating lease (a lease with a term much shorter than the expected useful life of the ESS).

Summary Table

The below table summarises the various contracts and their corresponding business models:

Contract	Utility-Owned ESS	IPP including ESS	IESP	Mini-grid
Constituting Documents		✓	✓	○
Shareholder Documents		✓	✓	○
Offtake Agreement		✓	○	○
Government Support Documents		✓	✓	○
Financing Documents		✓	✓	○
Construction Contracts	✓	✓	✓	✓
Long-Term Service Agreement	✓	✓	✓	✓
O&M Agreement	○	✓	✓	

Legend

✓ Contract typically required
○ Contract may be required

Constituting documents, shareholder documents, government support documents, and financing documents are discussed in the *Understanding* series of books. This chapter will highlight some key issues that should be addressed in the remainder of the agreements described above.

Offtake Agreements

For projects structured using the IPP model, including an ESS, the offtaker and the project company will enter into an offtake agreement to sell and purchase the project's output. This also applies to projects structured using the IESP model, where the work may be a service rather than a supply of electricity. When a utility procures storage functions under either of these models, the offtake agreement will set out the principal rights and obligations of the utility and the project company. It forms the core of what the utility is paying for and is the commercial foundation of the project.

Although the terms of the offtake agreement may vary depending on the technologies and use cases, they will generally cover a core set of rights, obligations, and remedies. As the foundational agreement, both the parties to the offtake agreement and other project stakeholders will be interested in its structure. This group of interested parties may be quite large. It may include the project company, the lenders, the offtaker, the regulator, and, depending on the market structure, more general entities such as the transmission system operator and the system operator.

The following is a general overview of the principal types of offtake agreements, a selection of key provisions, and a summary of other project agreements. This overview assumes that the reader is already familiar with the general contractual structure of power generation projects, which share significant similarities, and focuses primarily on the unique aspects of energy storage that may require variation from generation project agreements. For an explanation of the general structure of power generation projects, it is highly recommended to first review other volumes of the *Understanding* series, especially the *Understanding Power Purchase Agreements* handbook.

IPP, Including ESS Offtake Agreements

For projects that colocate an ESS with a generation facility, the offtake agreement structure will align with the output that the customer/utility seeks to procure. As previously noted, in most developing markets, the cost of the energy storage asset is incorporated into the general tariff defined by the PPA (please see the *Understanding Power Purchase Agreements* handbook). This type of contract generally has no separate pricing for utilising the ESS. Instead, the combination of a capacity and energy charge common to most PPAs would be adjusted to account for the additional expected cost of the ESS over the contract's life.

When the customer/utility seeks the ability to dispatch the generation supply and ESS capabilities of an IPP, including ESS separately, the offtake agreement must be adjusted to provide pricing for both generation (tariff) and energy storage services (availability and other payments). The project's performance obligation would similarly be split, with separate definitions for the capacity of the generation system and availability of the ESS. In addition to distinct pricing/performance terms under the contract, adjustments to the monitoring and accounting system for the project must also be made.

IESP Offtake Agreements

The dedicated nature of the ESS in an IESP project requires a contracting arrangement that reflects the flexible nature of these resources. At the same time, as an investment, there must be confidence in generating predictable revenue from the project. The most common arrangement is an energy services agreement where the project company builds the project and grants the offtaker, typically a utility, the right to dispatch the ESS. Under this contract, the offtaker will have the right to elect when to charge and discharge the ESS for generation or service purposes. Although the utility retains significant discretion over the use of the ESS, the agreement will still define a pricing formula for the expected use of the system. The deal will also impose obligations on the project developer to meet and maintain detailed performance requirements of the system to ensure that it delivers the expected benefit to the utility.

As power markets evolve away from bilateral agreements toward open markets where buyers and sellers bid for generation and services, the energy services agreement for an IESP may become more open-ended. For example, the IESP could retain control of dispatch, which would result in a situation where the system is available to the utility (i.e., responsive to their dispatch signal). Still, the IESP would otherwise be free to operate the ESS to respond to market signals to generate additional revenue.

Behind-the-Meter Agreement

An additional broad category of offtake agreements is the behind-the-meter agreement, where the ESS is being installed at the site of and utilised by the customer (residential, commercial, industrial, etc.) to augment their current energy usage. Where the customer owns the ESS, no offtake agreement is required since the owner is free to use the system as they see fit. However, where the ESS is owned and operated by a private investor, an offtake agreement will be required to define the relationship between the customer and the storage provider. Such offtake agreements could take one of two primary forms:

- An agreement to sell all energy discharged from the offtake agreement to a customer (either as a means to shift the timing of the availability of energy from an intermittent resource or to provide the customer with improved reliability); or
- An agreement to grant some control of the energy storage system, individually or in the aggregate with other energy storage systems, to a utility (to allow for reducing peak energy usage or meet another required grid service). Each type of offtake agreement will have special provisions that will cause the arrangements to be negotiated differently.

Key Considerations

Defining the Services

To successfully enter into an offtake agreement concerning a particular ESS, the offtaker and the project company must agree on the specific use cases contemplated under the contract. The agreement will be based upon the individual market and regulatory framework at the time of contracting and may consider that certain use cases met by the energy storage system will be provided to the offtaker and that others will belong to the project company (including for sale to a different offtaker). For example, a project company might provide reliability services to an industrial customer, but at peak demand, it also provides demand response services to the grid. Suppose the offtaker and the project company are entitled to use the energy storage system to meet their use cases. In that case, the offtake agreement must provide priority rules to determine which use cases will prevail when there is a conflict. Many of the remaining key provisions in an energy storage offtake agreement will be tailored based on this preliminary agreement between the parties to ensure that each party is receiving the services necessary to satisfy its intended use case, including tailored compensation and penalty mechanisms.

Tariff Structures

Tariff structures for energy storage agreements vary depending upon the technology and the use case. The tariff for an IPP including an ESS system is likely to include both an availability payment and an energy payment, particularly if the offtaker holds the right to dispatch the plant. The availability payment component of such a tariff will be payable regarding the capacity to store energy, regardless of whether or how often that storage capacity is used or cycled. The energy payment will generally have the following characteristics:

- Enable the project company to recover the value of energy lost during charging, storage, and discharging; and
- Enable the project company to recover any variable operations and maintenance costs incurred with the charging, storage, and discharging of energy.

Note that the availability payment described above relates solely to the capacity to store energy, not the ability to generate power. Additionally, suppose the offtaker elects not to dispatch the plant when the energy storage system is already complete. In that case, curtailment payments or deemed generation payments will be payable to the same extent that they would be expected to a renewable energy project that does not include an energy storage system.

If the project company holds the right to dispatch the plant, the tariff may be structured so that only an energy payment is paid. This structure would require that the energy payment be sized to enable the project company to recover its costs.

Another potential pricing structure would provide a payment to the project company each time it successfully responds to a signal from the system operator to meet an intended use case. This last pricing structure would require the project company to have different revenue sources to ensure sufficient revenues are available to make the project viable and financeable. This diversity of revenue sources is often referred to as a revenue stack.

Regardless of how a tariff is structured, the revenues earned by the project company must be sufficient to enable it to:

- Pay for the operations and maintenance expenses it incurs as it incurs them;
- Service its debts by paying both principal and interest when they become due and payable over the term of the project loans;

- Provide for the return *of* the equity invested in the project by the investors over the life of the project;
- Provide for a reasonable return *on* the equity invested in the project by the investors over the life of the project; and
- Pay corporate income taxes on the net income of the project company and other tariffs as those taxes are incurred.

Curtailment

As in any energy generation project, integrating an energy storage system may constrain the electricity network. Hence, the curtailment concept may apply in emergencies arising from high generation, low generation, or other situations. Curtailment occurs when the offtaker or the system operator, despite the project's continued ability to produce energy, elects to cease purchasing power or reduce the output of the energy storage system for some time. The project company needs to protect itself from these situations in which it loses its ability to earn revenue despite the project's continued operability so that it will seek compensation from the offtaker. The scope of allowable curtailments, deemed generation payments, and the cost-shifting associated may be a highly negotiated provision. In most cases, curtailment payments would not be payable under an offtake agreement for a stand-alone energy storage system.

Charging Requirements

The offtake agreement should include provisions for charging the energy storage system, both the times over which charging is allowed and whether the offtaker, the project company or the customer will pay for the energy required to charge the energy storage system. A hybrid energy storage system may need energy from the network to charge during periods over which the primary energy source is not available or is available only in reduced quantities (during periods of low solar irradiation or low wind speeds, for example). The system operator may allow the import of energy for charging under specific conditions and coordinate with the offtaker to offset the cost of importing against the revenue under the offtake agreements. The time of charging the facility will have to be agreed upon with the system operator to ensure that no additional load is created during periods of peak demand. In the case of a stand-alone energy storage system, the project company can charge from the network at a time to be agreed upon with the system operator. Behind-the-meter energy storage systems will generally be treated like any other electricity consumer.

Performance Guarantees, Penalties, and Defaults

An energy storage offtake agreement will contain certain performance guarantees tied to the use cases contemplated and the performance of the ESS technical attributes. These performance guarantees include the level of performance promised by the project company to the offtaker. Typically, there are two different means by which the project company will be incentivised to achieve the performance guarantee. The performance guarantees and thresholds are highly negotiated provisions.

The first level is liquidated damages. Suppose the failure to meet a performance guarantee is slight. In that case, the project company will be required to pay liquidated damages to the offtaker that depend on the amount or duration of the shortfall. The second level is a default. If the performance is worse and further from the performance guarantee, an event of default may occur, and the offtaker may terminate the offtake agreement. As an example, only the project company may provide a performance guarantee that the availability will equal or exceed 95%. In this example, if the availability is 95% or greater, there are no effects on the offtake agreement. If the availability is less than 95% but greater than 70%, the project company will pay liquidated damages to the offtaker. Finally, if the actual availability is 70% or less, then the offtaker may be able to elect to terminate the offtake agreement.

Performance guarantees should be tailored to the particular use cases and technical performance attributes of the ESS technology contemplated under the offtake agreement and might be limited to one performance guarantee or multiple performance warranties. Some typical performance warranties include the following:

- Capacity – The project company warrants that the energy storage system will maintain an agreed-upon ability to store energy each time it is tested;
- Availability – The project company warrants that the energy storage system will be available for use by the offtaker for a certain percentage of hours in a month or year;
- Efficiency – The project company warrants that the energy storage system will maintain particular efficiencies while charging, while the system is at rest, and while discharging (for example, a round-trip energy efficiency);
- Charging/Discharging – The project company warrants that the energy storage system will be able to charge or discharge energy at a specific rate over time; and
- Response Time – The project company warrants that the energy storage system will respond to a dispatch or charging signal from the offtaker within a certain length of time from receiving such signal.

Testing

Testing of the performance warrants and functions of the ESS will be required as a condition of commercial operation and then periodically (perhaps annually) after commercial operation commences to ensure compliance with the contracted performance warranties. One highly negotiated point will be for optional retests. If the project is not performing to the standards demonstrated in the previous annual test or if the project company has repaired a fault that was demonstrated in the most recent annual test, then either the offtaker or the project company, as applicable, will seek the right to conduct a new test before the next annual test. Still, the other party may resist the ability to retest. The allocation of any costs associated with the testing or re-testing should also be included in the offtake agreement. However, mandatory tests are typically conducted at the expense of the offtaker, and optional tests are conducted at the cost of the requesting party. The outcome of the tests will also determine the performance liquidated damages payable by the project company. The tests called for by the offtake agreement should be tailored to the use case and the technology and should be aligned with the performance warranties provided under the construction contracts and the LTSA.

Metering

A key consideration when designing an ESS project (especially an IPP including an ESS) is the number and location of the meters about the generation resource and the energy storage resource so that all performance aspects and losses are well captured for reporting. For example, an energy storage technology with a high resting discharge rate (the amount of energy that will be lost from the system when it remains idle) might be best served by adding two meters close to the generation project to measure each of the energy discharged to the grid and the energy used to charge the energy storage system. Without these meters, the energy discharged when the system is at rest could lead the offtaker to believe that the generation resource is performing sub-optimally.

System Control

The controllability of an energy storage system is an issue for all types of energy storage systems but takes on special significance for hybrid projects. If the project company controls dispatch, it may be able to maximise revenues. Still, if the offtaker controls dispatch, then it may have more flexibility to use the ESS to meet the specific demands of the grid at any moment in time. The speed at which control instructions can be issued and acted upon is also important.

Conditions Precedent to COD

The typical energy storage offtake agreement will contain several conditions precedent that must be satisfied for the project to achieve commercial operation. Some of these conditions will be similar to those found in any PPA (such as the receipt of necessary licensing or certification from responsible persons that the conditions precedent have been met and that the project is not in default). Still, others will be technology-specific and may focus on the required testing results. Because revenues will be dependent upon the project successfully reaching commercial operation, it is essential to understand what these conditions precedent are and confirm that they will be achievable at the expected time of commercial operation.

Flexibility

One of the main values of an energy storage system is its flexibility to meet many different use cases and provide various services, which may be provided simultaneously. Negotiating an offtake agreement for the energy storage system should consider this flexibility. In most cases in developing markets, the selection of use cases and the flexibility to modify the services used will be owned by the offtaker. They will be limited only by the terms of the offtake agreement, including the operating parameters. In other markets, the project company may own this flexibility subject to the requirement to provide the applicable services outlined in the offtake agreement. In these other locations, the project company will sell a limited set of services to the offtaker. So long as there is no conflict with the traded services, the project company will be free to monetise any other services it sees fit. In each case, the offtake agreement must be negotiated to understand the particular technology, the market rules, and proposed use cases so there is sufficient flexibility to change the use of the energy storage system in the future as market rules and grid conditions change.

Change in Law

In any long-term offtake agreement, the change in law risk must be allocated between the offtaker and the project company. This allocation is highly negotiated, and typically risks are borne by the party best able to take them. In the case of changes in the law that affect the revenues earned by the project company or the expenses incurred by it, the risk is likely to be allocated to the utility offtaker because the project company will have limited (or non-existent) ability to earn the foregone revenues or recover the increased costs under another revenue-generating agreement.

The importance of change in law provisions is magnified in the case of energy storage, where the markets, laws, and regulatory regimes are developing and more likely to change the contract's life. Inadequately addressing a future change in the law might leave a project uneconomic and failing.

Operating Parameters

Because each technology and manufacturer has its technical specifications and warranty requirements, negotiating the operating parameters in the offtake agreement is essential to any negotiation. The operational parameters are the list of conditions that the offtaker must meet to dispatch the energy storage system. Such operating parameters might include the number of allowable cycles in a day or a year, the minimum and maximum charging capacity, any required rest periods, or the temperatures at which the energy storage system may be operated. However, each of these operating parameters limits the offtaker from fully accessing the benefits and full range of services that might be available. On the other hand, as outlined in greater detail below, the failure of the offtake agreement to contain acceptable operating parameters might enable the offtaker to utilise the energy storage system in a way that nullifies the project company's warranty from the original equipment manufacturer (OEM) or a service provider.

Intellectual Property

In some instances, the offtaker will want to receive intellectual property rights to operate the system after the termination of the offtake agreement. In these cases, the offtaker will seek to acquire intellectual property rights to utilise the energy storage system via the project company or directly from the OEM. This may even include the requirement to provide source code for the operation of the system to an escrow agent so that the offtaker can ensure that it will be able to run the energy storage system following the termination of the offtake agreement because the offtaker would otherwise have no privity of contract with the OEM. Because these intellectual property rights require an agreement of the OEM, the proposed provisions in the offtake agreement must be discussed with the planned OEM before executing the offtake agreement.

End of Contract Requirements

Often a utility will enter into an offtake agreement with a project company to cause a developer to build an energy generation or energy storage project because the developer has the experience necessary to do this cost-effectively and because the utility wants the flexibility of owning the underlying asset. If the offtake agreement is terminated before the expiration of its term, the utility may desire to purchase the project from the project company or to purchase all of the shares in the project company from its shareholders. To ensure that the utility has the right to purchase the project following the termination of the offtake agreement, the project company may grant an option to purchase the plant to the offtaker. To ensure that the utility has the right to purchase the shares in the project company following the termination of the offtake agreement, the shareholders may grant a right to purchase the shares in the project company to the offtaker.

Such a purchase option might accrue to the utility at either specific negotiated points during the term or might only accrue at the end of the time. In some cases, the developer may resist this utility purchase option because it removes the flexibility entailed in long-term ownership of the energy storage project. In all cases, a purchase option must be carefully negotiated to ensure that the price paid will be sufficient to ensure that lenders have protection from a purchase price that is less than the loan principal, accrued interest, termination fees under other project agreements, and any fees and expenses the lenders may incur in connection with the termination and the exercise of the purchase option.

A second option occasionally added to an energy storage offtake agreement is the option to relocate the energy storage system either during or at the end of the term. This option is much more prevalent than in other power generation assets because of the batteries' flexibility and small size. This option may not be an issue to the extent that all costs of relocation and loss the offtaker pays revenue and that the contract is a fixed price contract such that the new project location and underlying use cases are unchanged. If the project company has to bear any of these previously enumerated costs or if the removal of the energy storage system might cause a reduction in use (and associated revenues), then such a relocation right is likely to be resisted by the project company.

Addition of Energy Storage to Existing Projects

An additional consideration in energy generation offtake agreements is pre-negotiated rights to add energy storage to the project. In many locations, adding an energy storage project to a renewable or thermal generation project might unlock additional revenues for the project company while providing added benefits to the offtaker (to the extent that the same offtaker will be agreeing to the energy storage component of the project). The offtaker has typically negotiated an offtake agreement that is technology-specific and would prevent the project company from adding in an energy storage project later to avoid the risk that the energy generation project will not operate as it was expected to operate during the procurement phase. Prudent developers recognise that although storage might not be economical for a particular project at execution of the offtake agreement, that may change. Often they will request the right to add storage, and the offtaker will typically receive an option to enter into an offtake agreement concerning such added storage.

EPC Contracts

The next major contract needed to successfully develop an energy storage project is an engineering, procurement, and construction (EPC) contract. Typically, when a new energy storage technology becomes commercially available, the EPC Contract is fully wrapped; in other words, the project company will enter into a single contract with the original equipment manufacturer (OEM) or an EPC contractor, which will collectively include all engineering, procurement, and construction services required for the construction, testing, and commissioning of a project. However, these different workstreams may be separated as technologies become more widely utilised. The OEM will provide and install the Energy Storage System on-site, but separate contractors will give any required engineering and balance of plant construction services. Regardless of the EPC contract structure, it is essential that the project company endeavour to ensure that the various construction contracts work together so that there are no gaps in the supply and construction of the project and no conflicts between the terms that could lead to disputes.

Generally, an EPC contract for an ESS will be relatively similar to an EPC contract in the renewable or other generating energy space. It will include similar terms, conditions, and pain points. However, it is important to remember some differences between construction contracts for energy storage systems and generation projects.

Testing

The most important difference relates to the testing required to achieve commercial operation. It is important to ensure that the testing required by the EPC contract will meet the commercial operation testing requirements under the offtake agreement and, if applicable, to understand who between the construction contractor and the OEM will be responsible for the various aspects of testing. The testing procedures in the construction contracts should align with those in the offtake agreement.

Performance Warranties

The testing requirements should be created in such a way to align with the performance warranties under the offtake agreement, as well as tests of any other energy storage parameters that are required by the use cases or the business model for the project. Ensuring alignment between the offtake agreement and the EPC contract is important, especially for limitations of liability which may be higher in the offtake agreement than in the EPC contract, leaving the developer with some risks. Each performance warranty will be technology and project specific.

Intellectual Property

In the case of an energy storage system, the electronic components running the energy storage system may be just as critical as the physical components storing electrons. As such, in an energy storage EPC contract with an OEM, it will be essential to ensure that the project company receives a royalty-free, perpetual, and irrevocable licence to use both the physical and electronic components of the energy storage system. The contract should also contemplate what rights the project company will receive concerning any updates to the electronic components.

Credit Support

Additionally, ensuring adequate credit support from the EPC contractors is essential. When technology or an OEM is less experienced or less capitalised, they must be able to satisfy any warranty requirements in the EPC contracts for the length of the warranty period in the EPC contract. The credit support may take the form of a guarantee from an investment-grade entity, a letter of credit from a creditworthy bank available to be drawn in an accessible jurisdiction, or an insurance product available for recovery to the extent of any warranty claims made.

Service Agreements

Types of Contracts

Following the commercial operation date, the project will require many service agreements to be entered into with reputable service providers. These agreements are project specific and may follow several different approaches, but the following broad categories may be required.

Long-Term Service and Warranty Agreement

For many energy storage projects, the project company will enter into a long-term service agreement or a long-term service and warranty agreement (LTSA) with the OEM to ensure that the energy storage project will continue to perform over the expected life of the LTSA (which will ideally match the length of the offtake agreement). Although the EPC contracts will contain some warranties, performance guarantees, and testing requirements, these are typically limited to a brief period after the project achieves commercial operation and may not ensure that the project remains at peak performance over its entire life. The LTSA may also include a performance warranty from the OEM. In the case of some battery technologies, the performance warranty may require the OEM to replace batteries that fail to meet the operating parameters described in the warranty. These warranties from the service providers should ideally match what is being provided by the project company under the offtake agreement.

O&M Contract

To the extent that the LTSA does not fully wrap the maintenance of the project, for example, if the LTSA only provides maintenance of the energy storage system and not the balance of the plant, then the developer will be required to enter into an operations and maintenance agreement (the O&M Contract). The O&M contract should cover those gaps in operations and maintenance in the LTSA. It should also ensure that gaps in the offtake agreement's long-term performance warranties are filled. For example, an O&M contractor will need to sufficiently maintain the balance of the plant to allow the energy storage system to operate and meet the performance warranties that the LTSA service provider is otherwise committed to performing. In other ways, the O&M contract for an energy storage system is likely similar to any other renewable or other energy generation O&M contract.

Energy Management Agreement

An energy management agreement may be required to ensure dispatch rights remain with the project company. The energy management agreement may be entered with a service provider that has developed specific dispatch and charging algorithms to maximise project profit. In reviewing and negotiating an energy management agreement, it is essential to understand what the service provider is promising to provide in the energy management agreement, the penalties for the service provider's failure, and the limitations of liability that might prevent the project owner from fully capturing damages for the service provider's loss to live up to its promises.

Management Services Agreement

A management services agreement may also be required to operate and finance the project. The management services agreement typically covers administrative and other minor services required following a commercial operation that is not included in any other service agreements. This agreement is not typically highly negotiated or a high-dollar contract. It may occasionally be entered into between the project company and the developer or an affiliate of the developer to the extent that the developer will continue to manage the project following a commercial operation. There is no specific reason a management services agreement for an energy storage project would be different than for energy generation projects. Still, there is a project-specific need to ensure that the management services agreement fills any gaps left after executing the other service agreements.

Important Provisions

Within the service agreements required for an energy storage system, many vital provisions may be distinct from those needed in power generation projects.

Scope of Services

The most important thing in service agreements is to understand the scope, identify the gaps between the various service contracts, and ensure that the correct service provider will fill those gaps. For example, some components may be shared between the energy storage system and the balance of the plant or even details provided by the OEM that are not energy storage components (for example, battery containers) that might be excluded from the LTSA and would need to be added to the O&M contract to ensure that proper maintenance occurs.

Performance Warranties

A similar need exists in service agreements to ensure that the LTSA or O&M contract service provider will bear some risk associated with failing to meet offtake agreement performance warranties. Ensuring alignment of testing provisions, performance warranty thresholds for liquidated damages and defaults, and limitations of liability will best protect the project from incurring liquidated damages or risking an event of default. However, given the typical dollar size of LTSAs and O&M contracts, there is often a mismatch in the overall limitations of liability or a separate limit of liability for the payment of damages related to the performance warranties compared to the rules of liability under an offtake agreement. This could lead to a scenario where, with poor performance, the project company is required to fund the gap in the form of liquidated damages to the offtaker.

Warranty Exclusions

An additional important consideration is exclusions from the warranty. Some of these exclusions, such as vandalism, force majeure, and improper maintenance or use of the energy storage system by the project company, are typical and fairly allocate responsibility to the project company. However, a more significant risk arises concerning dispatch rights and operating parameters associated with the energy storage system. Typically, these operating parameters can be highly negotiated with the offtaker to ensure that the offtaker can use the energy storage system to its maximum potential. However, if these parameters do not match the allowable uses under the LTSA, the warranty may be voided, or the commitment to meet the performance guarantees may be excused. A typical example of this issue would arise if the LTSA allowed for, for example, 365 annual charging and discharging cycles. Still, the LTSA only warranted 200 cycles. The risk of this mismatch would likely be borne by the project company and demonstrates the importance of understanding a technology's limitations when entering into an offtake agreement in advance of an LTSA.

Credit Support

Similar to the situation mentioned above concerning EPC contractors, it is even more important to understand the credit situation of the O&M contract and LTSA service providers. Given the long-term nature of these contracts, it becomes more likely that the service provider may undergo an event that affects its creditworthiness and the ability of the project company to seek damages for breaches of these contracts. As such, the project company should look for an investment-grade parent guarantee, a letter of credit from an accessible, creditworthy bank, or some insurance policy to ensure that the long-term warranty and maintenance obligations will be completed (or that damages will be available to compensate the project company for the failure to complete such duties).

Financing Agreements

As mentioned previously, the *Understanding Power Project Financing* handbook extensively addresses the scope and requirements for project financing a power generation project. Typically, the conditions and the executed agreements for a power generation project financing are in line with those required for financing an energy storage project, except for technology-specific differences. The project's lenders will need to understand the technology sufficiently and then will propose conditions, precedent, representations and warranties, and covenants that are analogous to those found in financing documents for other types of power generation project financings. The project's lenders will also need to understand the project's economics and trust those economics over the near-term and the long-term with sufficient certainty to commit to financing the project.

Sustainability

The United Nations Sustainable Development Goal on Energy (SDG7) aims to provide "*access to affordable, reliable, sustainable and modern energy for all by 2030*". According to the 2022 Tracking SDG7 Energy Progress Report, 733 million people still do not have access to electricity, and the COVID-19 pandemic has impacted the progress towards universal access to electricity. The report acknowledged that BESS is part of the key technologies contributing to bridging the gap from the SDG7 targets.

Introduction

Sustainable Development Goals (SDGs) have gained widespread political support in most countries as beneficial to the public interest. Countries are interested in fulfilling SDGs because national policy drivers point towards these goals. Moreover, countries are affiliated with global organisations and various conferences which call for joint efforts to make the world a better place for today's inhabitants and future generations. For example, by way of the Equator Principles, various financial institutions ensure that power generation developers assess potential adverse human rights impacts and climate change risks as part of the Environmental and Social Impact Assessment (ESIA) for the projects that they are financing. Assessing national progress towards commonly endorsed sustainable development goals also allows allocating resources more efficiently to themes and sectors most in need.

Traditionally, the successful development of any project focused mainly on technical and financial deliverables. Recently, project development has increasingly required environmental, societal, and sustainability deliverables in line with the relevant SDGs. Sustainability is a cross-cutting consideration that must be incorporated into choices about technology and business model selection, policies, and regulations, as well as planning, procurement, and contracting. As elsewhere in this handbook, we assume a basic understanding of the SDGs considerations that must be considered in the power system; accordingly, this chapter addresses some specific considerations for implementing a sustainable ESS.

Environmental Considerations

Resource Extraction Sustainability

Resource extraction is another important environmental consideration (related to other SDGs). As the world becomes more conscious of the practices employed in the extraction of minerals, it becomes essential for the developers and offtakers to ensure that the materials used in developing ESS are not sourced in a way that damages the environment. It is likewise essential to ensure that forced labour and other exploitative practices are not employed when extracting, and beneficiating minerals used to manufacture components of ESS. To confirm compliance, developers and others participating in the electricity system should ensure that adequate policies, protocols, and audit procedures are in place at each level of the mineral value chain. The project company and the offtaker must ensure that the equipment procured for ESS is certified ecological and that goods produced by forced labour are prohibited.

In African countries with proven reserves of minerals for battery manufacturing, creating an ESS market provides the opportunity for creating value in the country with other segments of the battery storage value chain. If these segments are developed sustainably, they can contribute to the country's organic green growth, with a fast-growing sector that could boost the post-pandemic economic recovery.

Clean Technology Financing

Whether an energy storage system qualifies as clean technology can determine whether it can attract concessionary financing, thus lowering its capital costs. The requirement for cleaner technologies can ultimately determine whether an ESS clears bankability hurdles and can be funded.

In the use case of ESS for renewable energy integration, the climate co-benefit is apparent, all the more so if this renewable energy power capacity replaces thermal power generation.

The use of ESS to improve the reliability of a power system predominantly using thermal power plants is a more complex question. However, the flexibility that ESS provides may contribute to a net benefit on carbon emissions for the same volume of electricity generated. The thermal plants would be able to run at their optimal regime and reduce the emission of greenhouse gases to decarbonise the electricity sector. Although fewer sources of concessionary financing might be willing to consider providing funding for such an ESS, the broader market can still view these projects for their long-term potential to unlock benefits associated with the clean energy transition.

Protection of the Local Environment

ESS should be built considering local policies aimed at protecting the environment against adverse effects arising from construction and operation. Even when no local or national regulation explicitly protects the environment from adverse impacts due to ESS, project-financed projects typically need to adopt leading international practices concerning environmental health and safety assessments and impact mitigation. The International Finance Corporation's environmental, health and safety guidelines have been mentioned as a go-to guide for development finance institutions and other financial institutions, including the Equator Principles Financial Institutions (EPFIs).

Economic Development Considerations

Local Skills and Job Creation

Deployment of ESS in an electricity market creates an opportunity for new jobs to be created in the energy value chain in the country. Technology with a high direct and indirect job creation potential will likely align with most developing countries' aspirations to facilitate buy-in from decision-makers. The deployment of ESS will allow for the creation of jobs during the project's development, construction, and operation phases. To the extent that locally sourced or beneficiated minerals are integrated into the manufacture of the ESS, more local labour can be integrated into the value chain.

Local Industry Involvement

Technology with a high potential for local industry development or involvement will similarly gain easy buy-in and align with national policies in developing countries. Involving local industries ensures that the expertise related to energy storage technology is retained in the country. Any future improvements or developments will likely be undertaken locally, boosting the local labour force. This initiative has a high potential for future industries to (i) expand locally, (ii) facilitate industrialisation, and (iii) boost the energy ecosystem in developing countries.

Locally Sourced Minerals

In pursuing ESS deployment, ensuring stable and predictable sourcing of materials along the value chain is important. As part of planning, it is important to consider all materials required and identify sources of the material. Requirements for additional material can be secured through long-term agreements.

Technologies that use local materials need to be considered and promoted to reduce ESS costs based on country-specific requirements. Therefore, ESS suppliers and developers may need to consider research and development investments alongside the marketing and development of more established technologies. This is especially important when a country is concerned about exposure to global supply chains and foreign currency fluctuations. Host governments may consider locally sourced minerals as an element of mitigating this exposure. Using locally sourced materials reduces the carbon footprint associated with shipping such materials from other parts of the world, enhancing the local economy's development.

End-of-Life Considerations

In evaluating the sustainability of a particular ESS, it is essential to factor in all required resources. It considers the entire deployment life cycle, including the phases of the installation, operation, maintenance, and decommissioning. A developer must consider the total costs required to decommission and dispose of all of the components of the ESS and return the installation site to its original condition. End-of-life considerations, such as disposal, site rehabilitation, and re-use, must be built into contracts and financial models to ensure that they accurately account for the actual total cost of operation of an ESS. Alternatives in the decommissioning phase may include:

- Reuse – Implies reusing the system for the same purpose as its initial design. This means that the system components will be used as initially intended to comply with regulations that govern the end-of-life management of the ESS;
- Recycling – Provides a more viable alternative to disposal. Recycling involves the recovery of elements and chemicals for use in applications that may or may not affect the original application of the ESS; and
- Disposal options – These are essential as they are not entirely within the control of the project company. Where adequate solutions for disposal have not been developed, policymakers and procurers may be reluctant to procure proven technologies. To unlock the potential for energy storage, developers and OEMs must develop safe and cost-effective disposal options.

Gender and Inclusivity Considerations

One of the United Nations' SDGs aims is to empower and promote the social, economic, and political inclusion of all, irrespective of age, gender, disability, race, ethnicity, origin, religion, economic, or another such status. In addition, various countries have adopted empowerment policies to address inclusivity and inequality. However, specifically targeted groups could receive more attention to bring about equality, partly due to past injustices or exclusive policies. Many countries have targeted these groups, especially in the technology sector. Therefore, stakeholders must consider how to promote inclusivity in different aspects of the value chain when an ESS market is developed, or ESS is deployed.

Safety Considerations

Safety is paramount for any new energy storage technology being developed. Each energy storage technology will have its safety risks which must be analysed and mitigated. For example, batteries might experience leakage and have experienced negative press about the risk of fire. In some instances, the resistance to new technologies may lead to an overstatement of specific safety concerns. Still, in each case, the energy storage system should be carefully constructed by industry standards, safety norms, and OEM recommendations to mitigate material safety risks.

Case Study: ESS and Sustainable Development

In June 2021, countries in the Economic Community of West African States (ECOWAS), with a primary objective of achieving their SDGs, decided to (a) join forces to expand access to grid electricity to over 1 million people, (b) enhance power system stability for another 3.5 million people, and (c) increase renewable energy integration in the West Africa Power Pool (WAPP). BESS technology is at the centre of this initiative.

Supported by the World Bank, the sub-regional project plans to (a) increase grid connections in fragile areas of the Sahel, (b) build the capacity of the ECOWAS Regional Electricity Regulatory Authority (ERERA), and (c) strengthen the WAPP's network operation with battery energy storage technologies infrastructure.

Up to 325 MWh of BESS will be installed in selected sites in Mali, Côte d'Ivoire, and Niger to enable the installation of up to 200 MW of PV projects, which may produce excess energy, which could be traded into the WAPP due to the storage capacity.

This innovative way to increase VRE usage in cross-border trade is very promising and could prefigure energy trade in Africa at an even larger scale in sub-regions like Southern Africa, where the solar potential is one of the most significant worldwide and required transmission infrastructure is already in place.

Acronyms

A

AC – Alternating Current

B

BESS – Battery Energy Storage System

BES – Battery Energy Storage

BOOT – Build, Own, Operate, Transfer

BMS – Battery Management System

C

CAPEX – Capital Expenditure

CSP – Concentrated Solar Power

D

DBOT – Design, Build, Operate, and Transfer

DC – Direct Current

DFI – Development Finance Institution

DSM – Demand-Side Management

DSO – Distribution System Operator

E

ECA – Export Credit Agencies

EIA – Environmental Impact Assessment

EPC – Engineering, Procurement, and Construction

ESS – Energy Storage System

ESG – Environmental, Social, and Governance

G

GHG – Greenhouse Gas

I

IESP – Independent Energy Storage Provider

IPP – Independent Power Producer

IRP – Integrated Resource Plan

J

JET – Just Energy Transition

O

OEM – Original Equipment Manufacturer

O&M – Operation & Maintenance

OPEX – Operating Expense or Expenditure

P

PHP – Pumped Hydropower Plant

PSP – Pumped-Storage Plant

PPA – Power Purchase Agreement

PPP – Public-Private Partnership

PV – Photovoltaic

R

RE – Renewable Energy

RfI – Request for Information

RfP – Request for Proposal

RMIPPPP or RMIQuadP – Risk Mitigation Independent Power Producers Procurement Programme

S

SCADA – Supervisory Control and Data Acquisition

SCF – Strategic Climate Fund

SDG – Sustainable Development Goals

SoC – State of Charge

SOS – Security of Supply

SOE – State-Owned Enterprise

SSA – Sub-Saharan Africa

T

T&D – Transmission and Distribution

TSO – Transmission System Operator

V

VRE – Variable Renewable Energy

Glossary

A

Augmentation – the technical term used to add additional capacity to an existing ESS over its life, as it loses capacity due to degradation or other reasons, to keep the capacity at nominal levels.

Availability – the percentage of time an ESS or another power generation asset is capable of operating and the percentage of the capacity of such ESS or other power generation asset that is available, as such measurement is calculated under the Offtake Contract, PPA, LTSA, or other contracts.

Availability Payment – a payment based on the Availability of an ESS or a power generation asset.

B

Backup Power – the ability to power operations when there is a disconnection from the network.

Battery Energy Storage System or BESS – a system that can absorb, store, and discharge energy from an electrical grid or other source and uses batteries as the storage medium.

Battery Management System or BMS – the electronic system that manages the charging and discharging of a battery or bank of batteries. Battery management systems may link to a SCADA system.

C

Capacity – the maximum amount of electrical energy the generation asset can generate about generation assets. About an energy storage system, the quantity of energy the system can store. Capacity is measured in Watts.

D

Depth of Discharge or DoD – how deeply a battery is discharged during a cycle, as a percentage of its capacity.

Development Finance Institutions or DFI – financial institutions with a mandate to finance projects that achieve development outcomes. Examples include the World Bank, AfDB, DFC, FMO, DEG, CDC, DBSA, and Proparco.

E

Energy Storage System or ESS – a system that can absorb, store, and discharge energy from an electrical grid or other sources. Examples include battery energy storage systems, pumped hydro facilities, and other forms of kinetic energy to store energy.

Energy – the capacity of a system to do work. For energy storage systems, it is typically measured in units of Wh (Watt-hour).

Environmental and Social Impact Assessment or ESIA – a process of evaluating a proposed project's environmental and social impacts, evaluating alternatives, and designing appropriate mitigation, management, and monitoring measures.

Engineering, Procurement, and Construction (EPC) Contract – a type of construction contract setting out terms and conditions for the design, engineering, procurement of materials and equipment, construction, and commissioning of a facility such as a generation facility or energy storage system.

EPC Contractor(s) – contractor(s) who are party to an EPC contract and are responsible for engineering, procuring, and constructing the works under an EPC Contract.

Equator Principles – a risk management framework adopted by financial institutions for determining, assessing, and managing environmental and social risk in projects. It primarily intends to provide a minimum standard for due diligence to support responsible risk decision-making.

Equator Principles Financial Institutions – a financial institution that will require borrowers to comply with the Equator Principles.

Export Credit Agencies or ECA – public agencies that provide loans, guarantees, and insurance to facilitate the export of goods or services from their home country.

F

Force Majeure Event – an event beyond the control of a party to a contract that prevents it from performing one or more of its obligations under that contract. Force majeure events are generally further classified into political force majeure events and non-political force majeure events, which result in different financial and contractual consequences to the contracting parties. Natural force majeure events fall within the latter category.

Frequency – the number of cycles in an AC system that occurs in one second, measured in Hertz (Hz).

G

Grid – a system of electrical conductors and associated facilities such as substations that transmit electrical power throughout a region.

I

Independent Power Producer or IPP – a unique purpose company established to develop, finance, construct, own, operate, and maintain a power plant or ESS.

Independent Energy Storage Provider or IESP – an IPP, except that the energy storage assets are the sole source of project revenue as further defined in the chapter *Illustrating Value Streams.*

Interconnection – a connection between a transmission or distribution system and a power plant, an ESS, a load, or another transmission or distribution system.

Integrated Resource Plan – an electricity infrastructure development plan based on the least-cost electricity supply and demand balance. Integrated resource plans take several considerations into account, including the security of supply, the ability to reduce or shift the power demand, and the impact of the planned resources on the environment.

Inverter – a device used to convert DC electricity into AC electricity.

K

Kilowatt Hour (kWh) – a measurement of energy equal to 1,000 watts of electricity being generated or consumed continuously for one hour.

L

Load Centre – an extensive, distributed transmission network that typically refers to the network area where most of the load is located.

Long Term Service Agreement or LTSA – an agreement under which the equipment supplier will provide certain maintenance services on a power plant or ESS at regular intervals during the term of a PPA or Offtake Contract and will provide certain spare parts that are necessary to operate and maintain the power plant or energy storage system.

M

Megawatt (MW) – a measurement of power, meaning 1,000,000 watts.

Megawatt Hour (MWh) – a measurement of energy equal to 1,000,000 watts of electricity being generated or consumed continuously for one hour.

Mini-grid – an isolated grid system disconnected from a broader transmission system.

O

Offtaker – the party to a PPA whose obligation is to purchase the capacity or services made available and the electricity generated by the power plant or ESS, subject to the terms and conditions of the PPA.

Operations and Maintenance Agreement or O&M Agreement – the agreement between a project company and an operator under which the operator operates and maintains a power plant or energy storage system.

P

Paris Climate Accords or Paris Agreement – a legally binding international treaty on climate change. It was adopted by 196 Parties at COP 21 in Paris on 12 December 2015 and entered into force on 4 November 2016.

Peak Shaving or Peak Reduction – the reduction of overall maximum system demand.

Power – the amount of capacity to do work that is done. Power is measured in units of Watts.

Power Purchase Agreement or PPA – a medium-to-long-term contract that governs the production, sale, and purchase of electrical capacity, energy, or other services. Also referred to as an Offtake Contract.

Public-Private Partnerships or PPP – arrangements between the public and private sectors whereby a service or piece of infrastructure that is ordinarily provided by the public sector is provided by the private sector, with explicit agreement on the allocation of associated risks and responsibilities.

R

Ramp Rate – how fast a power station or energy storage system can increase or decrease its output.

Regulation by contract – regulation by contract is a form of governing private contracts with utilities that uses no separate regulatory agency, where the public sector owner of the asset monitors the performance of the (private) operator and sets the relevant tariff and revenue arrangements by a tariff methodology described in a contract.

S

Special-Purpose Vehicle – a corporate entity explicitly established to pursue a specific project prohibited from undertaking any activity beyond the project in question. Often called the project company in this book.

Stacking – aggregating value streams through the provision of multiple services.

State of Charge or SoC – refers to how charged an ESS is, compared to the maximum energy the ESS can hold, as a percentage.

Supervisory Control and Data Acquisition or SCADA – shorthand for all electrical infrastructure monitoring and control systems.

T

T&D Deferral – the ability for utilities to defer large-scale transmission and distribution investments.

Transmission Development Plan – a grid infrastructure development plan developed by a transmission system operator or owner.

U

Use Case – a practical technical application or service that an ESS can provide to a grid operator, power plant owner or end-user.

V

Variable Renewable Energy or VRE – renewable energy sources that are non-dispatchable due to their intermittent nature.

Voltage Regulation – the ability of a system to regulate the voltage to keep it constant when it might otherwise change.

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