

Energy Programme, GIZ Indonesia & ASEAN

BESS Regulatory Framework and Business Model

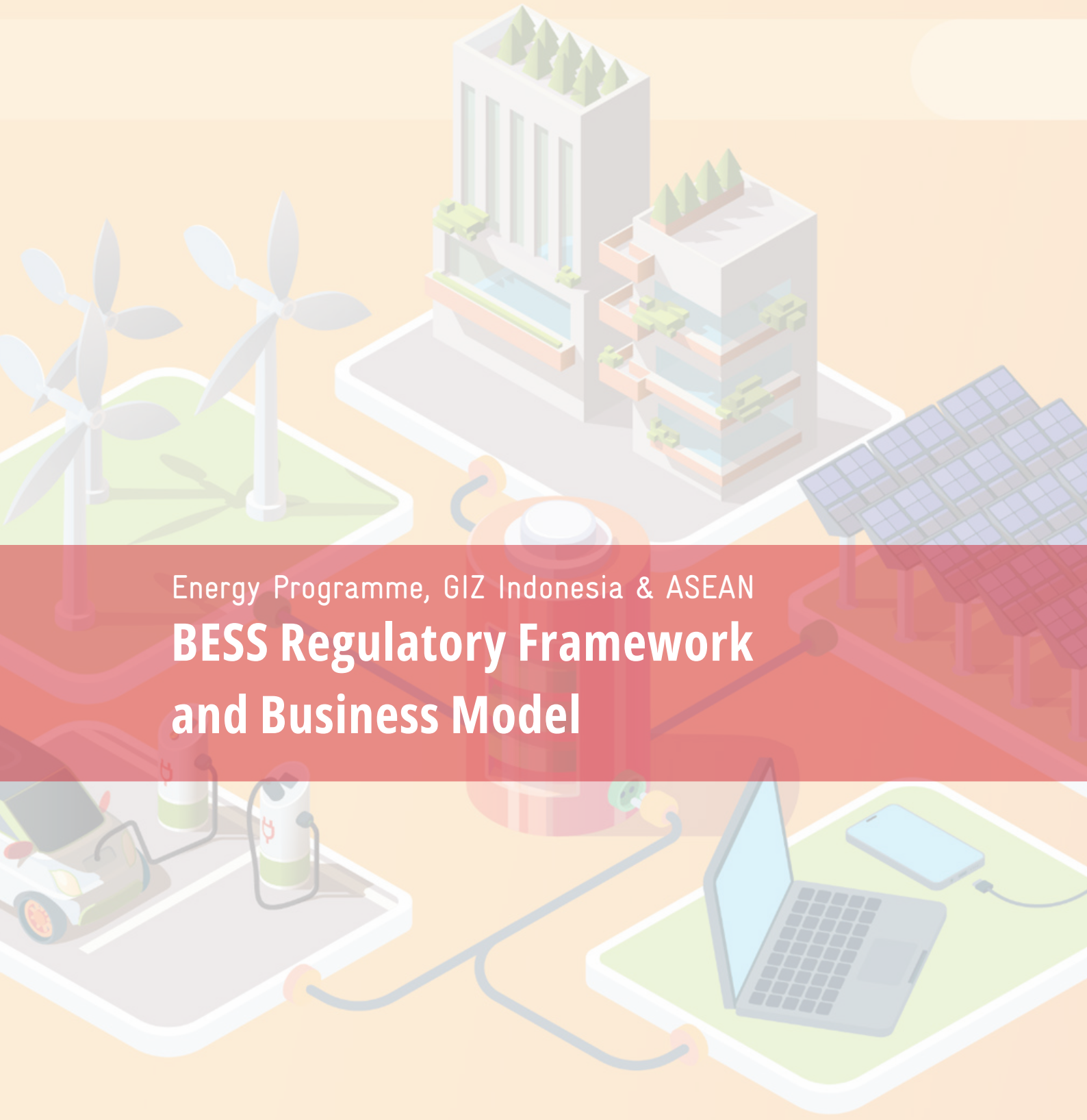
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IMPRINT

Title:
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Main Author:
- Energynautics GmbH
- Oktoviano Gandhi
- UMBRA – Strategic Legal Solutions

Reviewed by:
- I Made Ro Sakya, Power System Planning Senior Expert
- Maritje Hutapea, Policy and Renewable Energy Regulatory Framework Senior Expert
- Vegaswarasti Kumala, GIZ Advisor
- Dini Kemala, GIZ Advisor

Disclaimer:
This report, titled "BESS Regulatory Framework and Business Model" is prepared with the primary objective of offering insights and recommendations for renewable energy and BESS regulatory framework in Indonesia. The contents of this report are intended for informational purposes and are based on the research and analysis conducted by the authors. The findings, interpretations, and recommendations contained within this report represent the views of the authors and do not necessarily reflect the official stance or endorsement of any governmental, regulatory, or institutional entities. The authors and publishers disclaim any liability for errors or omissions in the report or for any actions taken based on the information provided. This report is protected under applicable copyright laws and may not be reproduced, distributed, or utilized in any manner without the explicit permission of the authors. The use of this report is limited to its intended purpose of contributing to the legislative review process and fostering informed discussions on the future direction of electricity regulation. For further inquiries or discussions regarding the content of this report, readers are welcome to contact the authors or the associated experts directly.

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LIST OF ABBREVIATIONS

ADB	Asian Development Bank
AC	Alternating Current
AS	Ancillary Services
ASPA	Ancillary Services Provision Agreement
BESS	Battery Energy Storage System
BMS	Battery Management System
BTMS	Battery Thermal Management System
CAES	Compressed Air Energy Storage
CapEx	Capital Expenditure
COD	Commercial Operation Date
DC	Direct Current
DPR	House of Representatives (Dewan Perwakilan Rakyat)
EMS	Energy Management System
ESS	Energy Storage System
GOI	Government of Indonesia
GR	Government Regulation
h	hour
IE	Incidental Energy
IUPTLU	Electricity Supply Business License for Public Purposes *(Izin Usaha Penyediaan Tenaga Listrik untuk Kepentingan Umum)*
IUPTLS	Electricity Supply Business License for Own Use *(Izin Usaha Penyediaan Tenaga Listrik untuk Kepentingan Sendiri)*
KBLI	Indonesian Business Sector Classification *(Klasifikasi Baku Lapangan Usaha Indonesia)*
kW	kilowatt
kWh	kilowatt-hour
LCOE	Levelized Cost of Electricity
LCOS	Levelized Cost of Storage
Li-ion	Lithium-ion
MEMR	Ministry of Energy and Mineral Resources (Indonesia)
MVA	megavolt-ampere
MW	megawatt
MWp	megawatt-peak
MWh	megawatt-hour

LIST OF ABBREVIATIONS

NGCP	National Grid Corporation of the Philippines
NMC	Nickel Manganese Cobalt (battery chemistry)
O&M	Operation and Maintenance
PCS	Power Conversion System
Perpres	Presidential Regulation (Peraturan Presiden)
PhP	Philippine Peso
PLN	PT PLN (Persero) (Indonesia's state-owned electricity utility)
PLTA	Hydroelectric Power Plant (Pembangkit Listrik Tenaga Air)
PLTBm	Biomass Power Plant (Pembangkit Listrik Tenaga Biomassa)
PLTBg	Biogas Power Plant (Pembangkit Listrik Tenaga Biogas)
PLTP	Geothermal Power Plant (Pembangkit Listrik Tenaga Panas Bumi)
PLTS	Solar PV Power Plant (Pembangkit Listrik Tenaga Surya)
PV	Photovoltaic
RFP	Request for Proposal
RTE	Round-trip Efficiency
RUPTL	Electricity Supply Business Plan (Rencana Usaha Penyediaan Tenaga Listrik)
SOC	State of Charge
SOE	State-Owned Enterprise
SOH	State of Health
UJPTL	Electricity Supporting Service Business (Usaha Jasa Penunjang Tenaga Listrik)
USD	United States Dollar
var_O&M	variable Operation and Maintenance
VRE	Variable Renewable Energy
WESM	Wholesale Electricity Spot Market

Executive Summary

Battery Energy Storage Systems (BESS) are a key enabling technology for modern power systems, particularly in supporting higher penetration of variable renewable energy (VRE). By providing fast-responding flexibility services – including energy shifting, frequency regulation, ramping support, and reserve provision – BESS can enhance power system reliability, stability, and efficiency while mitigating the inherent intermittency and variability of VRE generation.

In Indonesia, increasing VRE deployment is a strategic priority to support energy transition goals and system decarbonization. Recognizing this, the Government of Indonesia (GOI) has issued several regulatory initiatives to facilitate renewable energy integration, including the Presidential Regulation (Perpres) No. 112/2022 on Acceleration of Renewable Energy Utilization for Electricity Supply. This regulation establishes procurement mechanisms and ceiling prices for RE power plants, including VRE paired with BESS (hybrid VRE-BESS). Currently, the GoI is in the process of revising Perpres 112/2022, including a reassessment of applicable ceiling prices.

This study aims to develop recommendations for BESS deployment in Indonesia, regarding BESS business models and regulatory framework for both hybrid VRE-BESS and stand-alone BESS applications. These recommendations are based on the analysis of international case studies and applicable Indonesian regulatory framework, as well as electricity industry structure. In addition, a methodology for determining the levelized cost of electricity (LCOE) of hybrid VRE-BESS power plants is proposed as well as for high level financial calculations that determine the expected PPA prices, aiming to support stakeholders in the process of reassessing ceiling prices. This report includes LCOE and PPA estimates derived from applying these methodologies to assumed parameters in this study.

Key recommendations

Several key recommendations from this study are summarised as follows:

- **BESS sizing:** optimal BESS sizing should be determined on a case-by-case basis, through detailed techno-economic analysis, considering location-specific grid needs, targeted applications (single or stacked services), and power system characteristics such as VRE shares, load profiles, network constraints and flexibility of the existing generation fleet.
- **Ownership and revenue sources:** For Indonesia, third party-owned BESS are generally recommended for PLN, as this model allows PLN to have dispatch flexibility without incurring the upfront capital investment or operational risks. This is the most common model as per international trends. A PLN-owned BESS may be suitable for locations where PLN identifies clear BESS use cases and is prepared to undertake direct investment. Under third-party ownership, BESS revenues are mainly derived from PLN contracts through tolling agreements, capacity agreements, or hybrid VRE–BESS PPAs.
- **BESS contracting strategy and procurement method:** both stand-alone BESS and BESS paired with VRE should be procured through competitive and transparent processes. Procurement frameworks should be as open as possible (e.g. technology agnostic, no BESS capacity specified). Instead, PLN should define minimum technical and performance requirements aligned with its integrated resource planning and desired system services.

- Contract structures may include hybrid PPAs, capacity agreements, or tolling agreements, depending on the degree of dispatch control required and services to be delivered. For third-party-owned BESS paired with VRE providing multiple services, including cases where the utility controls dispatch, installing a separate meter for VRE generation mitigate the issue of having the revenue (when paid based on exported energy from site) impacted by the dispatch decisions of the utility as this incurs roundtrip losses resulting from BESS (dis)charge, as recommended in (World Bank, 2023). For any contract type, a detailed and robust cost-benefit analysis is recommended to better identify the value from the project and avoid being locked into long-term unsuitable payments.

Format	Hybrid PPA contract	Capacity agreement	Tolling Agreement
BESS paired with VRE	Primary option when BESS is used to smooth VRE output, shift energy, and reduce curtailment. Dispatch primarily follows PPA conditions and is controlled by project owner. Limited dispatchability may be required by utility and reflected in PPA price.	Possible in specific cases when capacity adequacy is the main objective and dispatch requirements are clearly defined. Utility has usage rights during contracted period; dispatch is otherwise controlled by BESS owner.	Not common. Considered only when utility wants full dispatch control over the BESS to provide multiple, dynamic services beyond VRE firming.
Stand-alone BESS*	Not applicable	Suitable when services are less dynamic and focused on capacity availability (e.g. peak support). Utility dictates dispatch during contracted period; BESS owner controls dispatch outside those periods.	Preferred when multiple and dynamic services are expected. Offers higher flexibility as utility has direct dispatch control over the full BESS capacity.

** = for stand-alone BESS owned by third parties scheme*

- **Cost/pricing structure:** BESS pricing mechanisms should reflect the full system value provided by storage, including energy, capacity, and ancillary services. Moving beyond simple energy-based tariffs toward service-based or availability-based remuneration is critical to ensuring bankable projects and efficient investment signals. For hybrid VRE-BESS projects, the expected LCOE was calculated for cases of energy shifting and VRE smoothing services and compared to current PPA ceiling prices. Under this study assumptions, the results indicate that the current price ceiling methodology is recommended to be revised and the price ceilings updated.
- **Legal recommendation:** In terms of hybrid VRE + BESS, the recommendation that is worth exploring from the Indonesian law perspective is the possibility of BESS paired with VRE to provide separate ancillary service to PLN. The BESS paired with VRE developers will enter into an Ancillary Service Provision Agreement **(ASPA)** with PLN. The developers of BESS paired with VRE developers providing ancillary services will be holders of Electricity Generation Business License for Public Purposes (IUPTLU) for generation activities. Based on the comparative legal study conducted by GIZ and consultants relating to ancillary services in a separate report, the Generation IUPTLU holders providing ancillary services to PLN using its BESS paired with VRE may register with MEMR to obtain a registration letter or obtain an ancillary service certificate from an accredited agency. Essentially, amendment to GR 14/2012 and a minister regulation specifically on ancillary services will be necessary to accommodate the above arrangements. Amendment to Law 30/2009 may not be necessary because Generation IUPTLU holders providing ancillary services can still be argued as producing electricity, which aligns with the definition of electricity generation activity under Law 30/2009.

In terms of stand-alone BESS, two scheme are proposed which align with the recommendations above:

- **Scheme 1:** PLN-owned BESS, which are divided into two options: (i) **Option A**: PLN owns, installs, and operates the BESS); and (ii) **Option B**: PLN owns the BESS and engages with an installation and O&M contractors
- **Scheme 2:** Third Party-Owned BESS, which are divided into two options: (i) **Option 1**: tolling agreement scheme where the BESS owners lease and provide O&M services to PLN; and (ii) **Option 2**: capacity agreement scheme where the BESS owners provide capacities of the Stand-Alone BESS to multiple parties (e.g.: PLN, other business area holders, generation IUPLTU holders, and holders of electricity generation business license for self-use).

To summarize the abovementioned schemes with respect to Stand-Alone BESS business model (including its pros and cons), please refer to the tables provided below:

	Types of Electricity Business	KBLI and Business License	Cooperation with BESS developers	Cooperation with Contractors for the installation and O&M of BESS
Scheme 1 (PLN-Owned BESS)				

Stand-Alone BESS Development as Transmission Activity	• Part of transmission activity
	• Given that in practice, PLN has been conducting transmission activity for the purpose of grid stabilization, arguments can be made that such grid stabilization activities using Stand-Alone BESS within the current electricity regulatory framework is legally possible.
	• Nevertheless, GR 14/2012 amendment may be conducted to clarify that Stand-Alone BESS development is considered as part of transmission activity.
	• However, due to the issuance of new KBLI 2025, there is a new KBLI 35140 (Electricity Generation in One Business Activity) which indicates that electricity storage is recognized as an additional type of electricity generation business activity. We are confirming this view with BKPM and MEMR. If our view above is correct, then the Stand-Alone BESS does not need to be considered as electricity transmission activity and can instead be considered as a new type of electricity generation business activity. However, the addition of a new type of electricity generation business activity would require an amendment to Law 30/2009 and its implementing regulations as well.
		• KBLI 2025 related to integrated electricity business: KBLI 35140
		• Integrated IUPTLU
		• We are still anticipating the issuance of implementing regulations of BPS Reg 7/2025 to provide further clarity on the scope of KBLI 35140 and the business license required for KBLI 35140.
			N/A because the BESS is owned by PLN	• Contractors engaged by PLN to install and O&M Stand-Alone BESS will be considered as providing UJPTL, namely (i) electricity construction and installation; and (ii) electricity operation. However, GR 25/2021 and MEMR Reg 12/2021 need to be amended to add Stand-Alone BESS as part of electricity transmission field under those two types of UJPTL.
				• The contractors can use KBLI 35151 and KBLI 43211.
				  ◦ If Stand-Alone BESS is considered as transmission activity, KBLI 35151 can arguably be used because it states operation of electricity transmission system. Nevertheless, for legal clarity and prudent purposes, KBLI 35151 can be clarified to expressly include operation of Stand-Alone BESS in the implementing regulations of BPS Reg 7/2025 or amendment of GR 28/2025.
				  ◦ KBLI 43211 may arguably be used for installation of Stand-Alone BESS because it expressly states 'power storage system.'
				  ◦ Procurement: goods and services procurement conducted by PLN.
				  ◦ Pricing: agreed by PLN and the contractors.

	Types of Electricity Business	KBLI and Business License	Cooperation with BESS developers	Cooperation with Contractors for the installation and O&M of BESS
Scheme 2 (Third Party-Owned)				
Option 1 (Tolling Agreement Scheme)	• Does not fall into generation, transmission, distribution, or sale. • Option 1 consists of lease of Stand-Alone BESS and O&M (if agreed contractually)	• (i) KBLI 77395 (Rental and Leasing Activities of Mining and Excavation Machinery and Equipment) or (ii) KBLI 77399 (Rental and Leasing Activities of Machines, Equipment, and Other Tangible Goods YTDL). • Based on our no-name basis consultation with officials from the OSS system, both KBLI may be used for lease of Stand-Alone BESS. Nevertheless, for legal clarity and prudent purposes, the scope of both KBLIs may be amended to specifically include the operational lease of Stand-Alone BESS through the implementing regulations of BPS Reg 7/2025 or amendment of GR 28/2025. • License: NIB. • We are still anticipating the issuance of implementing regulations of BPS Reg 7/2025 to provide further clarity on the scope of KBLI 77395 and 77399 and the business license required for those KBLI. • If the Stand-Alone BESS's owners wish to provide O&M services on its own, the analysis on UJPTL for O&M of Stand-Alone BESS will also apply.	• Procurement: goods and services procurement conducted by PLN. • Pricing: agreed by PLN and the contractors.	Similar with Scheme 2, but the contractors will be engaged by the third parties owning Stand-Alone BESS.
Option 2 (Capacity Agreement Scheme)	• New type of business activity, namely electricity storage and grid stabilization business activity • Amendment to Law 30/2009 and its implementing regulations are needed. • If MEMR wishes to only regulate Stand-Alone BESS in the NRE Bill, this may be conducted so long as: (i) the NRE Bill provides provisions specifically for the Stand-Alone BESS development in the context of electricity generation, including its licenses, its connection with other types of electricity generation business, and other requirements; and (ii) the Stand-Alone BESS is used exclusively for new and renewable grid because NRE Bill only applies for new and renewable energy development. If the Stand-Alone BESS will also be used to store electricity from conventional power plants, amendment to Law 30/2009 is required.	• New KBLI and business license • Under the new KBLI 2025, KBLI 35132 (Electricity Storage Activity) may arguably be used for Option 2. • However, we are still waiting for the issuance of the implementing regulations of BPS Reg 7/2025 to provide further clarity on the scope of and business licenses required for KBLI 35132.	• Amendment to GR 14/2012 to regulate: • Procurement process for Stand-Alone BESS developers • Pricing: agreed by PLN and the contractors, subject to MEMR's approval	

Furthermore, below is a pros and cons table of each proposed scheme:

Proposed Schemes	Pros	Cons
Scheme 1 (Utility-Owned BESS)	• The structure is straight forward because the Stand-Alone BESS is controlled by PLN as the utility. • This scheme may arguably be implemented within the existing regulatory framework, although regulatory amendment is advisable for prudent purposes. • No new KBLI and business license are required for PLN as the Stand-Alone BESS owner (subject to the issuance of implementing regulations of BPS Reg 7/2025).	• Limited private participation. • The implementation of Scheme 1 may be slow because it requires heavy upfront capital expenditures borne by PLN.
Scheme 2 – Option 1 (Tolling Agreement)	• More private participation compared to Scheme 1. • Option 1 scheme is similar with power plant leasing, which is a scheme commonly used in the market. This could help create a more seamless implementation of Scheme 2 – Option 1. • This scheme may arguably be implemented within the existing regulatory framework, although regulatory amendment is advisable for prudent purposes. • No new KBLI and business license are required for the Stand-Alone BESS owners (subject to the issuance of implementing regulations of BPS Reg 7/2025).	• If a special tariff is needed for the BESS charging fee, this will require amendment to MEMR Reg 7/2024 which will take time.
Scheme 2 – Option 2 (Capacity Agreement)	• More private participation compared to Scheme 1. • This scheme is more inclusive compared to Scheme 1 and Scheme 2 – Option 1 because it may involve other electricity stakeholders, such as IUPTLS holders, Generation IUPTLU holders, and Wilus holders other than PLN.	• If a special tariff is needed for the BESS charging fee, this will require amendment to MEMR Reg 7/2024 which will take time. • Longer and more complex process than Scheme 1 and Scheme 2 – Option 1 because amendment to Law 30/2009 will be required to introduce this scheme. • Lack of clarity on whether KBLI 35132 (Electricity Storage Activity) may be used for Scheme 2 – Option 2 and the required business license since we are still waiting for the issuance of implementing regulations of BPS Reg 7/2025.



Introduction

The Government of Indonesian (GOI) has issued several regulations to expedite expansion of renewable energy in Indonesia and support the energy transition targets. One of the regulation is Presidential Regulation (Perpres) No. 112/2022. The continuous growth in the use of renewable energy, driven by technological advancements, necessitates the refinement of regulatory frameworks to ensure continued support for renewable energy contribution in the energy portfolio.

Alongside the trend of declining investment costs, wind and solar photovoltaic (PV) are expected to account for an increasing share of electricity generation. Together referred to as variable renewable energy (VRE), these resources have inherently uncertain and fluctuating output, which need to be mitigated to prevent power system disruptions from high VRE penetration.

Battery Energy Storage Systems (BESS) are a key enabling technology for modern power systems, particularly in supporting higher penetration of VRE. By providing fast-responding flexibility services – including energy shifting, frequency regulation, ramping support, and reserve provision – BESS can enhance power system reliability, stability, and efficiency while mitigating the inherent intermittency and variability of VRE generation. However, identifying an appropriate business plan, procurement method, and tariff pricing structure for BESS can be challenging due to cost differences, changing technology, and a variety of functional applications.

To ensure an effective and economically viable BESS deployment, pricing mechanisms must reflect the system's technical capabilities and use cases. A well-defined business scheme as well as procurement mechanism and pricing strategy will not only encourage investment in BESS but also support the broader goals the energy transition.

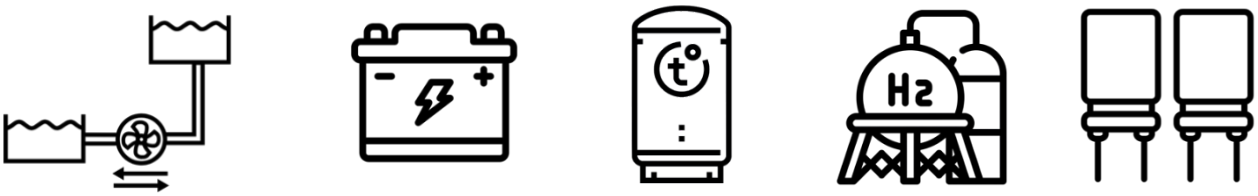
This Report focuses on two applications of BESS:

- BESS paired with VRE; and
- Standalone BESS.

BESS paired with VRE power plant projects have started to be implemented in Indonesia. While standalone BESS is a novel concept in Indonesia, necessitating the development of business schemes and regulations to support this technology. Both applications will be studied. Given the differences between the two, the analysis of the regulation and business scheme of each mode will be conducted separately.

General Overview of Energy Storage System (ESS) and BESS

Energy storage systems (ESS) is different from generators; it does not generate energy, but rather store energy from one period and "move" it to another period. The capacity of ESS is defined in two dimensions. First, power capacity [Watt] is a measure of the amount of instantaneous charging (withdrawing power from the grid) and discharging (injecting power to the grid) that the ESS is capable of. Second, energy capacity [Watt-hour] is a measure of how much energy can be stored in the ESS (Decourt, 2013). Electrical energy is difficult to store, that is why it is often converted to other types of energy for storage (Decourt, 2013), as shown in Figure 1.



Mechanical	Electrochemical	Thermal	Chemical	Electrical
• Pumped hydro storage • Compressed air energy storage • Flywheel • Gravity energy storage	• Lead acid battery • Li-ion battery • Molten salt battery • Flow battery • Fuel cell	• Ice tank • Molten salt energy storage • Phase change material storage	• **Hydrogen** • **Synthetic fuels**	• Super/ ultra capacitors • Superconducting magnetic energy storage

Figure 1. Types and examples of energy storage systems. Adapted from: (EMA, 2020).

Mechanical energy storage, exemplified by pumped hydro storage (PHS), compressed air energy storage (CAES), and flywheels, stores energy in the form of kinetic and/or potential energy. Electrochemical energy storage, such as batteries, relies on chemical reactions to store and release electrical energy efficiently. Thermal energy storage, including molten salt and ice tank, stores energy in the form of heat (or cold), which can be released back in the form of heating or cooling, or converted to electrical energy. Chemical energy storage involves storing energy in the chemical bonds of substances, such as in hydrogen or synthetic fuels, which can then be used in many industrial applications, in transportation sector (including as fuel cell), or to power gas turbine power plant. Pure electrical energy storage also exists, for example in the forms of ultracapacitors and superconducting magnetic energy storage systems but is only able to store the energy for very short duration (less than one hour) (Augustine & Blair, 2021) before discharging it.

PHS has historically been the most installed energy storage technology – 140 GW in power capacity and 9 TWh in energy capacity by the end of 2023 (IRENA, 2024) – due to its long lifespan, mature technology, and ability to provide large-scale, cost-effective energy storage for the grid. However, BESS is rapidly catching up because of significant advancements in battery technologies leading to increased energy density, longer lifespans, and decreasing costs, making them economically viable for a wider range of applications, from consumer electronics to utility-scale energy storage. As of first half of 2024, 89 GW/189 GWh of lithium-ion (Li-ion) BESS has been installed in the forms of distributed and centralised utility-scale storage (IRENA Coalition for Action, 2024). At the end of 2023, in the US alone, there is approximately 1,030 GW of BESS waiting for interconnection permission (U.S. Department of Energy, 2024).

The following characteristics have made BESS particularly relevant for applications in power system:

- Modular: BESS can be deployed in small scale (behind-the-meter at consumer site) as well as utility-scale controlled by system operator. Additional capacity can also be added in phases, reducing capital requirement.
- Location-independent: BESS can be deployed almost anywhere, unlike PHS that relies on availability of water reservoirs at sufficient difference in height (› 100 m).
- Rapidly decreasing cost: BESS cost has gone down 89% from 2511 USD/kWh in 2010 to 273 USD/kWh in 2023 (IRENA Coalition for Action, 2024). Its cost is predicted to continue to decrease as deployment of batteries in electric vehicles (EV) and as BESS rises even further.
- Fast response time: BESS can typically respond to change in frequency and voltage in milliseconds, much faster than traditional generators and other types of ESS (except for electrical energy storage).

Although this report focuses solely on BESS, this does not mean that BESS is always preferred over other types of ESS. Depending on the applications, other types of ESS are still much more suitable than BESS, e.g. PHS and CAES are still more cost effective than BESS for long-duration storage (› 100 hours) (IESR, 2023).

3.1. General Characteristics of BESS: Components and Key Parameters

3.1.1. BESS Components

There are several components that make a BESS: the batteries where the energy is stored, battery management system and thermal management system which monitor and optimise individual battery pack's conditions and operations, power conversion system which interconnects the batteries with the grid, energy management system which optimises the whole BESS, and other supporting equipment.

1. Battery

Battery cells contain cathode, anode, and electrolyte, their materials varying by battery types, e.g. lead-acid battery has lead dioxide as cathode, lead as anode, and sulfuric acid as electrolyte, while lithium iron phosphate (LFP) battery has LFP as cathode, graphite as anode, and lithium salt solution as electrolyte. When discharging, ions move from the anode to the cathode through the electrolyte, releasing electrons that travel through an external circuit, thereby generating electricity. Conversely, during charging, these reactions are reversed to restore the chemical energy within the cell. Multiple battery cells are connected to form battery modules, which are then connected to form battery packs. The connections among the battery modules and cells – whether in series or parallel – are determined based on the desired voltage and capacity.

2. Battery management system (BMS) and battery thermal management system (BTMS)

BMS monitors the batteries' state of charge (SOC), state of health[1] (SOH), temperature, voltage, and other parameters. Moreover, the SOCs of the battery cells are balanced by BMS to prolong the batteries' lifetime. BMS shares battery information with energy management system (EMS) and receives battery operation schedule from EMS. Subsequently, BMS optimises the battery operation among the cells and modules to fulfil the operation.

[1] State of health (SOH) is a measure of the present battery (energy) capacity with respect to its original capacity. SOH is usually presented as a percentage.

Meanwhile, BTMS monitors and regulates the ambient and battery temperature to ensure safe and optimal operation. Depending on specific project configurations, the BMS and BTMS may be housed together with the battery pack in modularised containers, as shown in Figure 2.

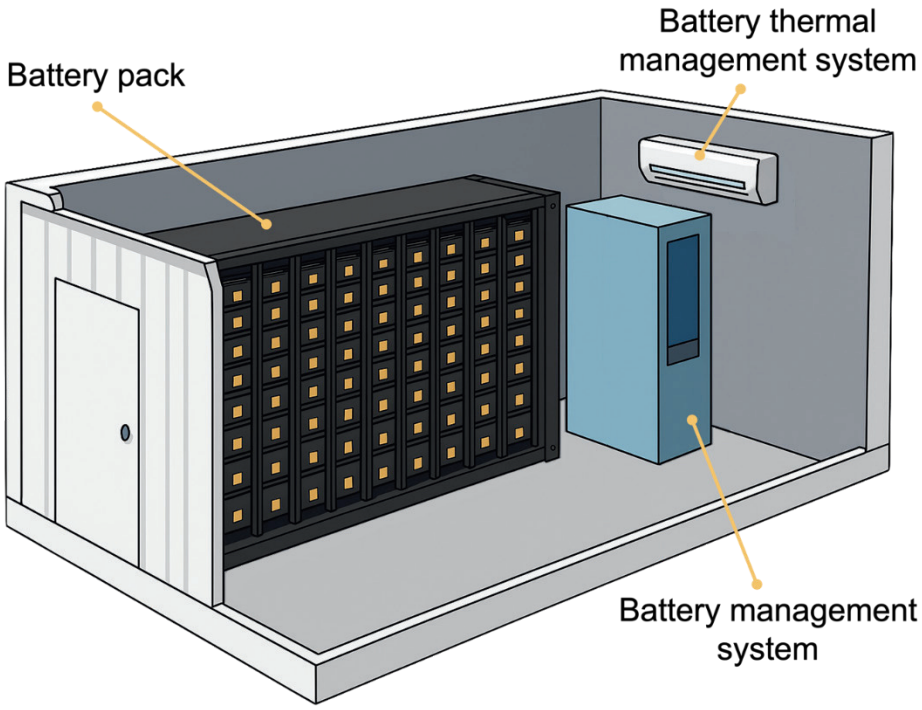


Figure 2. Simplified illustration of a modularised battery container. Adapted from: (EMA, 2020).

3. Power conversion system (PCS)

Inverters are typically the main component in a battery PCS, whose function is to convert direct current from batteries to alternating current for the grid and vice versa. Battery inverters are bidirectional and can be grid-following and/or grid-forming. Grid-following means that the inverters follow the voltage and frequency at the point of BESS interconnection, whereas grid-forming inverters can control their own voltage and frequency. Although grid-forming inverters have been utilised in off-grid setting for decades, utility-scale BESS with grid-forming inverters are still new. Most of the BESS functions can be delivered regardless the types of inverters, the only exceptions being synthetic inertia, black start services, and backup power supply, which require grid-forming inverters.

4. Energy management system (EMS)

EMS monitors the grid voltage and frequency, as well as optimise the BESS overall power flow and operation. While BMS is typically responsible for the safety and optimal operation of a single battery pack/container, EMS is responsible for all the battery packs/containers in the system.

5. Other equipment

BESS may also have other equipment, including but not limited to fire safety equipment, communication infrastructure, human machine interface, lightning protection, and others.

3.1.2. Key Parameters

There are many parameters that can be used to determine and compare BESS' quality, performance, and cost-effectiveness. Some of the key parameters are listed below.

1. Calendar life [years] and Cycle life

Through the charging and discharging cycles, battery energy capacity and efficiency degrade gradually. Battery's end-of-life is usually determined when the available battery energy capacity reaches 80% of its original capacity (SOH reaches 80%) or when the round-trip efficiency (RTE) drops below 80% of the original RTE (Rancilio, 2018). The number of cycles that the battery can withstand before reaching its end of life is the cycle life. Cycle life can vary depending on the depth of discharge, the (dis)charging power (C-rate[2]), and the ambient temperature at the battery location.

Even without the degradation due to usage, a battery will not last forever and will reach its end-of-life after certain amount of time, which is its calendar life. Calendar aging is independent of the charge and discharge cycle, but is affected by storage temperature (EMA, 2020), and storage SOC depending on the battery types (Huvilinna, 2015). The actual lifetime of a battery is either of the cycle life and calendar life that is reached first.

Apart from battery, other components in BESS, such as inverter, may also fail. A typical commercial inverter lifetime currently ranges 10–20 years and also depend on the inverter operations and temperature. It is important to conduct regular inspection and maintenance of the whole system to ensure that they are operating normally and to prevent early failures.

2. Duration [h], Energy capacity [Wh], and Power capacity/rating [W]

Energy capacity represents the total amount of energy that can be stored or delivered by the BESS. A 4 MWh BESS, for example, can store 4 million Watt-hours of energy. Energy capacity is vital for applications requiring sustained energy delivery, such as energy shifting, or providing backup power during outages, as explained further in Section 3.3.

Power rating is the maximum rate at which energy is delivered or absorbed by the BESS, determining how quickly the BESS can discharge or charge, respectively. Power rating is essential for applications such as frequency control.

Duration of a BESS refers to the length of time (typically in hours) the BESS can continuously deliver at its rated power output. It is calculated by dividing the energy capacity [Wh] by the power rating [W]. For instance, a 4 MWh BESS with a 1 MW power rating has a duration of 4 hours, meaning it can theoretically discharge 1 MW of power for 4 hours when fully charged, assuming an RTE of 100%.

[2] The C-rate is a measure of the speed at which a battery is charged or discharged. A 1C rate means that the battery would be fully charged or discharged in one hour, while a 0.5C rate indicates a two-hour process, and a 2C rate would complete the cycle in 30 minutes. A high C-rate means higher current, which leads to higher voltage sag and battery temperature (Huvilinna, 2015), which can lead to higher degradation.

3. Specific energy [Wh/kg]

Specific energy refers to the amount of energy a battery (can be quoted for a cell, module, or pack) per unit of mass. Specific energy varies widely among different battery types; lead acid battery has a fairly low specific energy of 35–40 Wh/kg, whereas Li-ion batteries' range 90–300 Wh/kg (IEA, 2024). While high specific energy is crucial for EV applications, it not very important for stationary BESS, except to transport to very remote places. Specific energy for batteries is still much lower when compared with fossil fuels: around 8,000 Wh/kg for coal and 12,000 Wh/kg for gasoline (European Nuclear Society, 2019). This is one of the reasons why fossil fuels have dominated the energy and transport sectors.

4. Round-trip efficiency [%]

Round-trip efficiency (RTE) is defined as energy delivered by the BESS during discharging divided by the energy required to charge the BESS. Therefore, RTE captures the energy lost during charging and discharging, although not during storing. RTE ranges from 0 to 1 (or 0 to 100%). Among ESS, RTE ranges from 27% for hydrogen systems including combustion turbines to 92% for ultracapacitors (Augustine & Blair, 2021). RTE is also different among BESS types, with lithium-ion batteries generally having the highest RTE.

A low RTE also reduces the economic viability of the BESS, by increasing the energy required to charge the BESS and decreasing the energy available to be discharged, and therefore increasing the levelised cost of storage (LCOS), discussed below.

5. Total investment cost [USD/kWh or USD/kW]

Investment cost is typically the largest cost for BESS as BESS has little operation and maintenance (O&M) cost. The total cost in [USD/kWh] can be converted to [USD/kW] by multiplying the former by the duration, e.g. a 2-hour BESS that has energy capacity cost of 350 USD/kWh has power capacity cost of 700 USD/kW.

Investment cost of BESS can generally be categorised as power-related or energy-related, although the distinction between power and energy-related equipment is not always clear. Energy-related costs mainly comprise the battery packs, while power-related costs mainly consists of PCS and grid connection costs. In general, technologies with low energy-related costs, such as PHS, are suitable as long-duration applications (e.g. seasonal storage) while those with low power-related costs, like most batteries, are suitable for short-duration applications (e.g. frequency regulation).

As BESS is also able to yield benefits for the grid as elaborated in Section 3.4, the total investment cost can be compared with the benefits of BESS, such as deferred infrastructure upgrade, as part of the cost-benefit analysis.

6. Levelised cost of storage [USD/kWh]

Levelised cost of storage (LCOS) is an economic metric that calculates the total lifecycle cost of a BESS. LCOS calculation is similar to that of levelised cost of electricity (LCOE) for generators: total cost during the lifetime of the asset is divided by the total energy delivered. Total lifecycle cost comprises investment cost, O&M cost, as well as end-of-life cost.

Charging cost of BESS is also part of the total cost (analogous to fuel cost in traditional generators' LCOE). The largest contribution to LCOS is typically capital expenditure (CapEx), i.e. the initial investment for BESS and the subsequent battery replacement, if any (Gandhi, et al., 2022).

The lifetime of BESS is a main factor of LCOS; the longer the BESS lifetime, the lower the LCOS. BESS lifetime is affected by the charging and discharging schedule of the BESS. That is why LCOS are different for different applications and for different technologies. It is therefore important to design BESS for the intended use to optimise profitability.

For the system operator, LCOS can be used during capacity planning and scheduling to compare BESS' competitiveness with existing resources for the different applications, e.g. BESS is cost-effective in replacing gas turbine as a peaking plant if BESS' LCOS for peak shaving is lower than the gas turbine's LCOE. For investor, LCOS can be compared against the projected revenue of the BESS over its lifetime to evaluate the profitability of BESS investment.

It is to be noted that LCOS is the cost of providing the service, not the value of the service to the grid or BESS' owner/operator.

3.2. BESS technologies

The battery technologies that have been widely used as BESS are lead acid batteries, lithium-ion (Li-ion) batteries, flow batteries, and molten salt batteries. Lead acid battery is one of the oldest rechargeable battery technologies. On top of its wide usage in off-grid applications (as BESS and portable systems), lead acid batteries are also employed in internal combustion vehicles as a starter battery and as uninterruptible power supply (UPS).

However, thanks to the rapid decrease in costs, higher specific energy, and longer lifetime, Li-ion batteries have increasingly replaced lead acid batteries in solar home systems, solar lighting as well as off-grid BESS in recent years (IEA, 2024). Li-ion batteries' cost has been and is still declining mainly thanks to their adoption in EV (where more than 90% of Li-ion batteries are deployed by the end of 2023 (IEA, 2024)). Even within Li-ion batteries, there are different types (based on the different anodes and cathodes) with varying specific energy, specific power, lifetime, safety, and costs. Some of the common Li-ion battery types are lithium nickel manganese cobalt oxide (NMC), lithium nickel cobalt aluminium oxide (NCA), lithium cobalt oxide (LCO), lithium titanate (LTO), and lithium iron phosphate (LFP). Among these battery types, LFP is arguably the most suitable for BESS applications because of its longer cycle life, higher safety, and lower cost. Although it has lower specific energy compared with other Li-ion battery types, cost is usually a more important factor than specific energy in BESS applications. In 2023, LFP comprises 80% of new stationary BESS, up from 65% in 2022, and is predicted to remain dominant through to 2030 (IEA, 2024).

Flow batteries store energy in liquid electrolytes contained in external tanks, which distinguishes them from conventional batteries where energy is stored within solid electrodes. This design allows for independent scaling of energy capacity (by increasing electrolyte volume) and power output (by adjusting cell size), making them particularly suitable for utility-scale BESS applications. Compared with Li-ion and lead-acid batteries, flow batteries have long cycle life, deep discharge capability, and minimal degradation over time, though they generally have lower energy density and require larger physical space. The technology is relatively mature, with vanadium redox flow batteries (VRFBs) being the most commercially developed and widely deployed, while other variants like zinc-bromine (Zn-Br) and iron flow batteries are emerging as cost-effective alternatives.

Molten salt batteries are high-temperature batteries that use liquid electrolytes and electrodes, enabling high energy density and long lifespan. Unlike standard batteries, which operate at ambient temperatures, molten salt batteries require elevated temperatures (typically above 300°C) – even when not in operation – to prevent decrease in lifetime (Augustine & Blair, 2021). The most mature molten salt battery is sodium-sulfur (NaS), followed by sodium metal halide. Molten salt battery is different from the molten salt energy storage typically used in concentrated solar power (CSP) plants, which is thermal energy storage and is not considered battery.

The deployments of BESS in Indonesia have largely followed the global trend: lead-acid batteries for off-grid applications traditionally, which are increasingly replaced by Li-ion batteries. There does not seem to be any BESS in Indonesia employing flow batteries or molten salt batteries yet.

On top of the aforementioned battery types, there are also others that such as nickel-based batteries, namely nickel cadmium (NiCd) and later replaced by nickel metal hydride (NiMH). NiMH batteries are commonly used in portable electronics and early hybrid vehicles. However, in both applications, NiMH batteries are increasingly replaced by Li-ion batteries.

Although LFP is likely to continue to be dominant in the coming years, especially as the cost is still rapidly decreasing thanks to EV adoption, its dominance is not assured. New developments are constantly occurring that enhance the lifetime, safety, and energy density, while lowering the costs of different battery types. Some of the more promising emerging battery technologies include sodium-ion batteries and solid-state batteries. Sodium-ion batteries offer a low-cost potential as sodium is much more abundant than lithium, greater thermal stability and longer lifetime, although its relative cost advantage depends on the volatile lithium price (IEA, 2024). It currently has up to 40% lower energy density compared with lithium-ion batteries (IEA, 2024). Meanwhile, solid-state batteries offer higher energy density and potential safety improvements through having a solid electrolyte (instead of liquid).

Additionally, as power system keeps evolving, role of energy storage may change. As a result, other technologies may become more suitable and/or competitive compared with Li-ion BESS. Different types of ESS and different BESS technologies may also complement each other. For example, flywheel can be employed for very-short-duration applications, LFP for short- to medium-duration applications, flow BESS for medium- to long-duration, PHS and hydrogen storage for long-duration applications. Table 1 lists the advantages and disadvantages of the different battery technologies discussed above.

Table 1. Overview of different battery technologies that are / can be used in BESS applications. Source: (ADB, 2018) (Huvilinna, 2015) (Decourt, 2013) (IRENA, 2020)

Technology	Advantages	Disadvantages	Main applications	Technology readiness level (TRL)[3]
Lead acid battery	• Mature technology • Good performance at low and high temperatures • Low cost • Efficient recycling • High discharge power • Does not require cell-wise BMS	• Low specific energy • Slow charging • Low DoD. Deep cycling reduces lifetime • Short lifetime (3-5 years) • Adverse environmental impact	• Starter battery in cars, UPS, off-grid BESS	• 9 (Commercially mature)

[3] Technology readiness level (TRL) ranges from 1 to 9, where 1 indicates "Basic principles observed and reported," 5 reports "laboratory-scale, similar system validation in relevant environment," and 9 "actual system operated over the full range of expected mission conditions."

Technology	Advantages	Disadvantages	Main applications	Technology readiness level (TRL)[3]
Molten salt battery	• High specific energy and power • High RTE • Long cycle lifetime • Low-cost potential	• Need high temperature, even when not in use • Combustible • Strict O&M requirements • Not suitable for small-scale applications	• Utility-scale BESS	• 7–9 (demonstration to commercially mature)
Li-ion battery	• High specific energy and power • Long lifetime (10-15 years) • Fast charging • Lifetime not as sensitive to cycling schedule	• Degradation at high temperature and when stored at high voltage • Need protection for fire safety • Some Li-ion battery types use toxic materials	• EV, consumer electronics, BESS of varying sizes	• 9 (commercially mature)
Flow battery	• Long lifetime (20 years), even with deep discharge • Low energy cost • Non-combustible • Independent energy and power sizing	• Low specific energy • More complex than other battery types	• Utility-scale BESS	• 7–9 (demonstration to commercially mature)
Sodium ion battery	• Abundant material • ·Lower-cost potential • Safe	• Lower specific energy than Li-ion battery	• BESS of varying sizes	• 6–8 (demonstration to early commercia-lisation)
Solid state battery	• Higher specific energy potential • Longer cycle life potential • Higher safety potential	• Face many challenges to reach its potential	• EV (potentially including aircraft), consumer electronics, BESS of varying sizes	• 4–7 (development to demonstration)

3.3. BESS Applications and Functions

This report focuses on utility-scale standalone BESS and BESS paired with VRE, but other BESS applications, namely behind-the-meter and off-grid, are also briefly discussed below for completeness. In each application, BESS has many functions, through which it delivers value for the owner and the system operator. Some of the functions elaborated here are not unique to BESS and can also be provided by other types of ESS, sometimes more cost-effectively.

Figure 3 illustrates the functions and services that BESS can provide based on their applications and in terms of the response and discharge duration. Not all functions listed are applicable to all systems; the effectiveness of BESS for each application depends on local power system conditions. The importance of the different functions described depend on many factors such as grid topology, generation composition, VRE penetration, among many other factors. Likewise, economic viability of the different functions depends on many factors, especially regulations, commercial arrangements (including subsidies, financial incentives, payments for the services), and the cost of BESS. Moreover, some functions listed under one application could also be carried out in other applications, e.g. Hybrid BESS, BTM BESS, and off-grid BESS can also provide frequency regulation and voltage support.

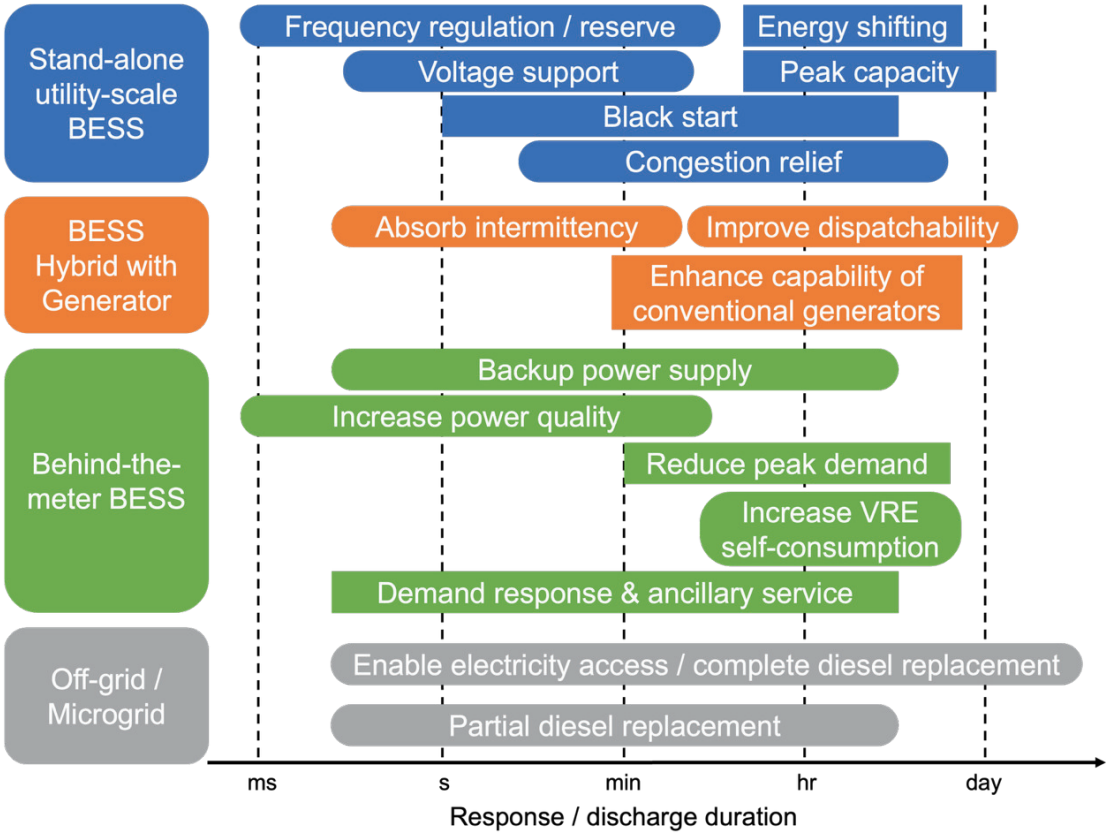


Figure 3. BESS functions and services based on their applications. The functions and services that are already applicable for the case of Indonesia are indicated by stadiums, whereas those that are not yet applicable/needed are indicated with pointed rectangles. Adapted from: (Augustine & Blair, 2021; IEA, 2024).

Considering Indonesian power systems and VRE penetration, the functions that are applicable are indicated in Figure 3 by stadiums (rounded rectangles). For example, frequency and voltage control services from a Standalone BESS are likely already necessary and beneficial for Indonesian power systems, but the energy shifting and peak capacity functions are deemed still unnecessary since VRE penetration in Indonesian power systems are still low and the proportion of synchronous generators high.

Although some of the BESS functions will become more important due to increasing VRE penetration, it is to be noted that BESS does not need to be co-located with VRE to deliver the power system services. As outlined below, Standalone utility-scale BESS is capable in delivering many services and providing value to the grid. The benefits resulting from the services that BESS delivers are discussed in Section 3.4.

A single BESS can carry out multiple functions simultaneously as long as the BESS stays within its operational boundaries (similar to how generators can provide energy and ancillary service simultaneously). Providing multiple functions at the same time allows BESS to earn more revenue (value stacking) and improve its profitability, as further explained in Section 4. However, the combination of the functions may also accelerate the BESS degradation and will require more complex energy management system (IEA, 2024). The terms used to describe the different functions below may vary across jurisdictions, but the concepts remain the same.

3.3.1. Standalone utility-scale BESS

1. Energy shifting / arbitrage

BESS can shift loads by charging at periods of low demand/high supply and then discharging at periods of high demand/low supply. At high enough VRE penetration, there will be periods where VRE generation will be greater than what can be absorbed by the grid, prompting VRE curtailment. BESS can use the excess VRE generation to charge and then discharge said energy when energy supply is not as abundant or when the cost of generation is higher.

Energy shifting can be particularly profitable for the BESS owner/operator if there are time-of-use electricity prices or real time electricity market such that the BESS can earn the difference in electricity prices by charging when electricity prices are low and discharging when electricity prices are high (known as energy arbitrage).

However, even at low VRE penetration and with flat electricity tariffs, energy shifting can be valuable for the system operator when BESS is charged when cost of generation is low and then discharged when the cost of generation is high.

2. Resource adequacy / peak capacity and peaker replacement

BESS is capable of providing peak capacity and act as a peaker plant, whose role is typically fulfilled by gas turbine power plants. BESS has several advantages compared with gas turbine power plants: faster response and ramp up, no minimum uptime and downtime, and no minimum loading. With increasing VRE penetration, BESS may also charge using is zero-marginal-cost VRE energy which otherwise would have been curtailed. As the cost of batteries fall further, BESS is projected to be more cost competitive than gas turbine power plants by 2030 (IEA, 2024).

This function has some overlap with energy shifting discussed above, as the period where a peaker plant is called upon typically coincides with periods when generation cost is high, simply because the cost of generation from peaker plants is generally higher than baseload power plants. The duration needed for peaker replacement depends on the net load profile of the system. If the peak net load profile is very sharp (short duration of peak load), then duration of 1–2 hours may be sufficient. However, when the peak net load profile is wide (long duration of peak load), then the duration required may be 4 hours or longer. In general, increasing PV penetration makes the duration of the peak net load narrower (Frazier, et al., 2021), while increasing ESS penetration widens the peak net load profile (because of energy shifting done by ESS), as shown in Figure 4. Therefore, the importance and value of peaker replacement likely grows with increasing PV penetration. Frazier, et al., (2021) postulated that this function will be the driver of energy storage deployment in the future.

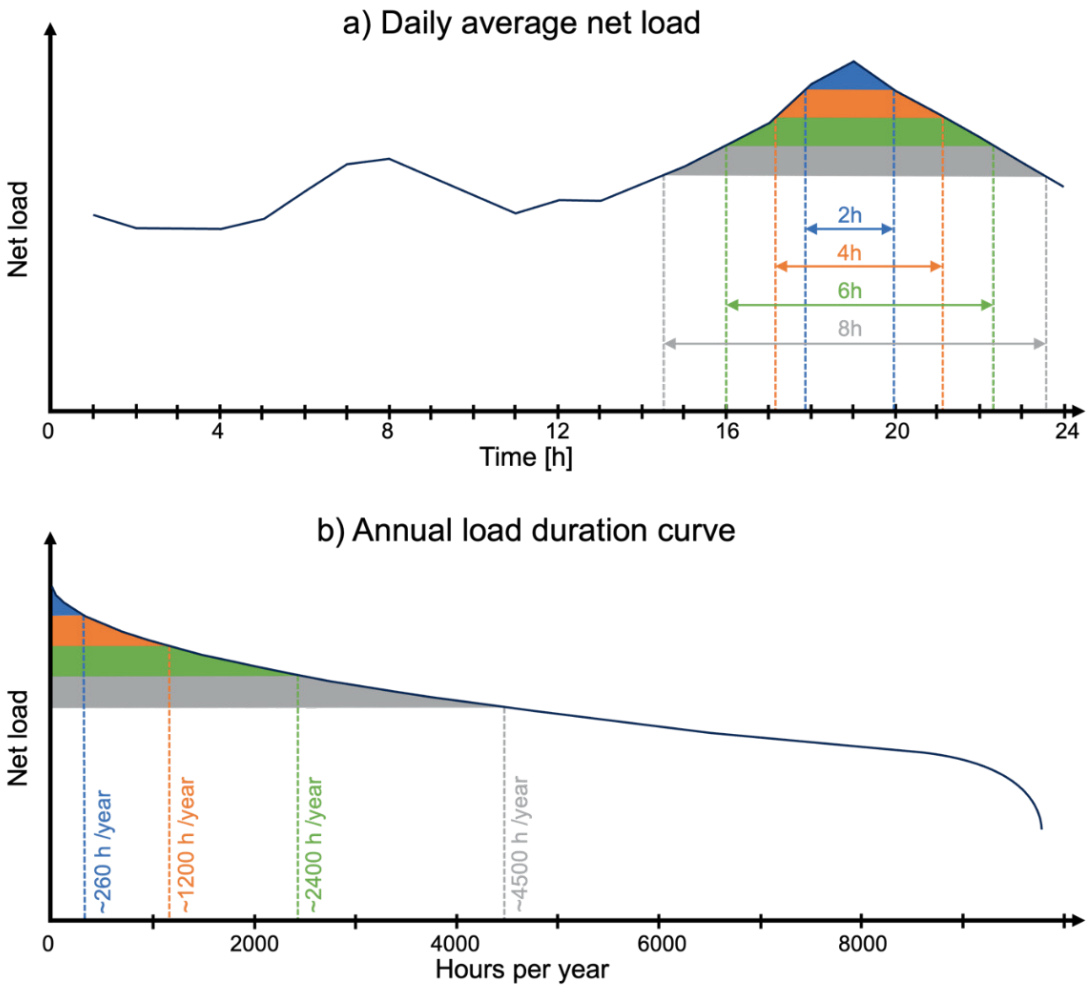


Figure 4. Illustration on how BESS with longer durations are needed to keep incrementally shaving peak load (a) and the BESS' contributions to the annual load duration curve (b). Adapted from: (IRENA, 2020)

3. Ancillary Services

BESS is also capable in providing ancillary services, such as frequency regulation, voltage support, and black start. The different types of ancillary services are discussed more extensively in another report titled **Comparative Study on Ancillary Service Provision.**

a. Frequency regulation and reserves

BESS can quickly respond to changes in grid frequency – by charging to lower the grid frequency and discharging to increase it – without the need for startup time and ramping up, enabling it to provide primary frequency control effectively. BESS is able to provide reserves both for contingency as well as load following during normal operations in the order of milliseconds, faster than traditional generators and typical grid requirements (within seconds for primary control and within minutes for secondary and tertiary control). This is one of the reasons why the majority of frequency control services in California Independent System Operator (CAISO), the US, has been provided by BESS since 2022 (California ISO, 2024).

Frequency control from BESS will likely become more important with increasing VRE penetration, as the proportion of synchronous generator in the grid decreases and the variability of the load increases. It is possible for BESS with storage duration less than 1 hour to perform primary frequency control. To perform tertiary frequency control, duration of a few hours is likely necessary.

BESS that is equipped with grid-forming inverter can also mimic synchronous generators to provide synthetic/virtual inertia (AEMO, 2022) to enhance power system stability during disturbances. Nevertheless, inertia (synthetic or otherwise) is not typically recognised as ancillary service.

b. Voltage support

Voltage control function of BESS is fulfilled by the inverter or PCS that can adjust its reactive power output based on measured voltage, system operator's instruction, and other control methods. As BESS is usually located closer to the load centre than traditional generators, it is especially suitable in providing voltage support services as reactive power does not travel far. The voltage control function is determined by the BESS inverter rating, components, and control setting; it is not affected by the BESS energy capacity. Because of its fast response time, BESS can also help maintain voltage stability during transient events

c. Black start

BESS is able to provide black start services given the right conditions: sufficient energy and power capacity, grid-forming inverter, as well as electrical proximity to critical load and other generators. In providing a black start service, a BESS first powers local loads, and then support other generation (including VRE) sources nearby to power the rest of the grid step by step. As BESS cannot support as much inrush current as traditional synchronous generators of the same capacity, the re-energisation of loads must be done with care and consideration. BESS' capability and suitability in providing black start services highly depend on its location with respect to the overall grid topology.

4. Congestion relief

BESS can provide congestion relief both at the generation/transmission side as well as at the load/distribution side. If the BESS is located closer to load centre than generators (which is usually the case), BESS can be discharged to serve local load and reduce the perceived demand for the transmission system. This reduces stress on the capacity of the transmission system as the BESS helps alleviate the need to transfer power from faraway generators to load centres at peak demand periods. Congestion relief service has been procured from third parties' BESS in the UK, France, and the US (California and New York ISOs) (IEA, 2024).

3.3.2. BESS paired with VRE (and other generation)

1. Absorb VRE intermittency

When coupled with VRE, BESS can reduce intermittency at the point of interconnection – either partially or fully depending on the BESS power and energy capacity – and maintain voltage stability. This has an additional benefit of reducing curtailment and/or penalties when there are constraints in maximum ramp up/down within a short time frame [e.g. MW/s or MW/min].

VRE may also be required to provide generation forecast to the system operator and maybe penalised for providing inaccurate forecast. BESS can make up for the difference in VRE forecasting and the actual VRE generation, i.e. charging BESS when VRE generation is higher than forecast and vice versa, to avoid any penalties associated with inaccurate forecast.

2. Improve VRE dispatchability

BESS can make VRE plant closer to a dispatchable generator by charging when there is excess VRE generation and discharging when VRE generation is low, enhancing its effective load carrying capability (ELCC). BESS is particularly complementary with PV, as PV power is concentrated in the middle of the day, offering predictable charging and discharging time, whereas wind energy generation is distributed throughout the day. This function is similar to energy shifting in a Standalone utility-scale BESS.

With large enough VRE and BESS capacity, VRE can be turned into a fully dispatchable plant which can adjust its output based on system operator's dispatch request (Perez, Perez, Rábago, & Putnam, 2019).

3. Enhance capability and efficiency of conventional generators

BESS can also be paired with any conventional generators to provide more flexibility and allow the generators to operate at more optimal operating points. Adding BESS to conventional generators can reduce the number of cycling, startup, and shutdown of the generators. This can increase fuel efficiency, as well as reduce maintenance costs and emissions (EMA, 2020).

3.3.3. Behind the meter (BTM) BESS

1. Backup power supply

BTM BESS can replace/supplement diesel generators as backup power during grid outage, or act as transitional power supply as diesel generators are ramped up (EMA, 2020). Compared with diesel generators, BESS has faster start-up and response time, requires no fuel, does not produce noise and pollution during operation, and have lower O&M costs. However, BESS requires higher upfront investment costs, especially if longer-duration backup is required. To provide power during a grid outage, BESS must be equipped with a grid-forming inverter. Most commercial hybrid inverters (inverters with PV and batteries' inputs) have grid forming capabilities, although their power capacity is still limited to tens of kW. This function is especially applicable in places with essential/critical loads such as hospitals or data centres.

2. Reduce peak demand

Commercial and industrial consumers may be charged based on peak demand or are exposed to time-of-use electricity tariffs. Should that be the case, by charging at low tariff/demand periods and discharging at high tariff/demand periods, BTM BESS can reduce consumers' electricity bill/charge. This function is essentially the same as energy shifting/ arbitrage in Standalone utility-scale BESS, and can be particularly when there are large difference in electricity prices/tariffs throughout the day. That being said, this is unlikely to be economical in Indonesia for now as electricity prices for industrial customers are very low and the difference in tariffs between peak-demand periods' and non-peak-demand periods' are not sufficiently large.The peak demand reduction by BTM BESS also allows consumers to postpone connection rating upgrade or even downsize their connection rating to save costs.

3. Increase VRE self-consumption

On-site VRE generation (e.g. from rooftop PV) does not always coincide with the consumer loads. When there is excess VRE generation, consumers with BTM BESS can choose to charge the BESS instead of exporting it to the grid to increase the VRE self-consumption. The stored power can be discharged when the VRE generation is lower than the consumer load again. In jurisdictions where there is zero-export policy (either export of electricity from consumer to the grid is prohibited or not rewarded), it may be profitable for consumers to do so. Apart from economic reason, consumers may also want to increase their VRE self-consumption to fulfil environmental goals, such as achieving net zero emission or 100% renewable energy consumption for their facilities.

4. Increase power quality

BTM BESS can also act as voltage regulator and harmonic compensator to maintain power quality at the consumer site (ADB, 2018). Similar to the voltage support in utility-scale BESS, this function is fulfilled by the inverter and not affected by the BESS energy capacity.

5. Demand response and ancillary service

BTM BESS may also be controlled by the system operator or aggregator to provide other functions mentioned under utility-scale BESS, such as energy/load shifting (also known as demand response) and ancillary services. In fact, BTM BESS may even be more effective than utility-scale BESS as they are located directly at the load and are not constrained by the transmission and distribution capacity to perform many of the functions. For the owner of the BTM BESS, being compensated for providing grid services may also enhance the BESS economic viability. This scheme has been implemented in the Netherlands and have provided income to consumers and enhance grid stability at the same time (IRENA, 2020). EV batteries can also serve the same function as stationary BTM BESS when connected directly to consumer loads (whether residential, commercial, or industrial).

3.3.4. Off-grid/microgrid BESS

In many remote areas, PV+BESS microgrid is already the most cost-effective and reliable option in providing electricity, although with high upfront investment. BESS is charged during the day using excess PV generation and discharges the energy at night, where loads are usually concentrated. The BESS typically has 2–3 days of autonomy (energy capacity of 2–3 days of total electricity consumption) to be able to power loads during days with little PV generation (consecutive rainy days).

The BESS power capacity is usually sized according to the peak load. BESS with lower energy capacity can also be employed to save on upfront investment cost and when alternative (diesel) generators are available in case of many consecutive days of low PV generation.

Off-grid BESS enables electricity to be provided fully by renewable energy such as PV, reduce dependence on diesel generators, which rely on costly diesel (transportation), require maintenance, and suffer from downtime. Providing reliable electricity encourages economic development and electricity consumption. As in BTM BESS, BESS in off-grid applications also increase the reliability of electricity supply to critical facilities. Apart from in BESS, batteries have also been used in other off-grid applications as part of solar home systems and solar lighting (both in houses and on the streets).

3.4. Benefit of BESS Deployment

The amount of savings/benefits obtained by deploying BESS is dependent on many factors, such as the load profile, generation composition, VRE penetration, and existing storage deployment, among other factors. As BESS is very versatile in terms of functions, sizes, and locations, quantifying their value is more complicated than quantifying the value of pure generators such as PV or wind energy. The benefits of BESS functions elaborated in Section 3.3 are described in Table 2.

Table 2. Benefits of BESS deployment

Benefit	Description
Defer assets upgrade	When placed near/at the load centres, Utility-scale and BTM BESS can reduce peak demand, delaying the need to upgrade transmission, distribution, and/or consumer-side equipment. Similarly, BESS placed near a generator can store excess generation, reduce transmission congestion (IRENA, 2020), and consequently delay transmission upgrade. In the case of off-grid applications, BESS can defer transmission extension to remote areas until the energy consumption in those areas make transmission extension profitable. Compared with conventional upgrades, BESS is modular, flexible, and helps avoid overbuilding infrastructure, especially in areas with uncertain demand. Additionally, BESS can replace or delay the construction of peaker plants by serving short peak periods more efficiently – an increasingly viable option as higher VRE penetration shortens peak durations and lowers peaker plant utilisation, as seen in Australia (AEMO, 2024; Vorrath, 2024). Lastly, BESS can dynamically provide voltage support, reducing the need for dedicated reactive power devices in distribution networks.
Enable higher penetration of VRE	BESS helps reduce VRE curtailment by storing excess energy, thereby increasing RE mix and displacing generation from fossil fuels. BESS with grid-forming capability enables even further fossil fuel displacement by allowing diesel-off operation during the day. At high VRE penetration, a lack of BESS could slow further VRE deployment as additional VRE generation is curtailed. Utility-scale BESS could reduce generator startups, which are particularly pollutive, and improve fuel efficiency. In off-grid applications, BESS has even higher emission reduction potential through reducing the use of diesel generators, kerosene lamps, and fuel leakage in transport and operation. Hence, BESS is critical in helping Indonesia to be able to achieve net zero emissions by 2050 (IEA, 2024). Where there is carbon pricing and penalty for VRE curtailment, the reduced emission and reduced VRE curtailment will also yield monetary benefits.
Enable higher penetration of VRE	By enabling higher VRE penetration and displacement of fossil fuels, BESS enhances energy security in fossil-fuel-importing countries like Indonesia by lowering reliance on oil and gas and reducing impact of volatile fuel prices on the electricity generation. More locally, consumers with BTM BESS and communities with off-grid BESS could enhance their energy security during power outages and fuel shortages.

Benefit	Description
Reduce energy and ancillary service cost	There are a few ways BESS can reduce energy cost. First, by shaving peak demand, BESS minimises thermal generator startups and cycling, improves fuel efficiency, lowers O&M cost, and ultimately energy cost. Second, BESS can reduce energy cost by charging with low marginal cost VRE when there is abundant supply, and discharging when supply is limited or during high cost of generation. Third, when peaker plants reach their end-of-life, BESS – projected to be cost-competitive by 2030 (IEA, 2024) – can replace them more economically, especially as peaker utilisation declines with increasing VRE penetration. BESS is also more suitable than many traditional generators in providing frequency regulation and voltage support services due to its fast response time, operational flexibility, and location. For example, the Hornsdale Power Reserve in Australia saved an estimate of AUD 40 million in 2018 through more cost-effective frequency control services, while also generating significant revenue and preventing load shedding during frequency drop (IRENA, 2020).
Increase power system stability	BESS can respond faster to frequency and voltage deviations than traditional generators and are able to provide synthetic inertia when equipped with grid-forming inverters. This means that BESS can arrest the deviations before they cascade, enhancing the system stability and security. Many jurisdictions such as the UK and Australia have made new ancillary service products that are primarily fulfilled by BESS, such as the UK's Enhanced Frequency Response (EFR), which requires the provider to respond within 0.25 s for a duration of 15 minutes (IRENA, 2020).



International Review

4.1. Service, Battery Technology, Costs – International Trends

Energy shifting is the primary application in global projects since 2019, with 29 GW added for this service in 2023 and representing 67% of the total installed global Battery Energy Storage System (BESS) capacity in 2023 of 89 GW. China and the United States lead the deployment of new BESS installations, and most new BESS additions are part of a hybrid power plant. Renewable energy production is stored in times of low demand (avoiding VRE curtailment) or times with low market prices (increasing arbitrage revenue), and used later during peak demand or peak prices, increasing system efficiency. (IRENA, 2024)

The local regulatory context and the technical grid characteristics are the main factors defining the viable services. Large-scale BESS has mostly been deployed for frequency regulation or energy shifting. With increasing power generated by VRE and the saturation of ancillary service markets in leading BESS markets, energy shifting is becoming the primary application. (IEA, 2024)

Lithium iron phosphate (LFP) has been the main deployed battery technology in the stationary BESS market since 2019, representing 84% of total capacity additions in 2023, and is projected to remain the dominant technology deployed up to 2030. (IRENA, 2024) (IEA, 2024).

The increased BESS use for energy shifting was motivated by decrease in costs (82% decrease in price of lithium-ion cells between 2013-2023) as well as increase in VRE penetration in certain markets. The global weighted average turnkey BESS cost in 2023 ranged from USD 325/kWh for 1h duration to USD 260 USD/kWh for 4h duration. As shown in Figure 1, costs vary per size and location, and are subject to volatility of raw material costs, which caused the cost rise of 2022. (IRENA, 2024) The global average cost for a 4h duration BESS is projected to reduce to USD 175/kWh by 2030. (IEA, 2024).

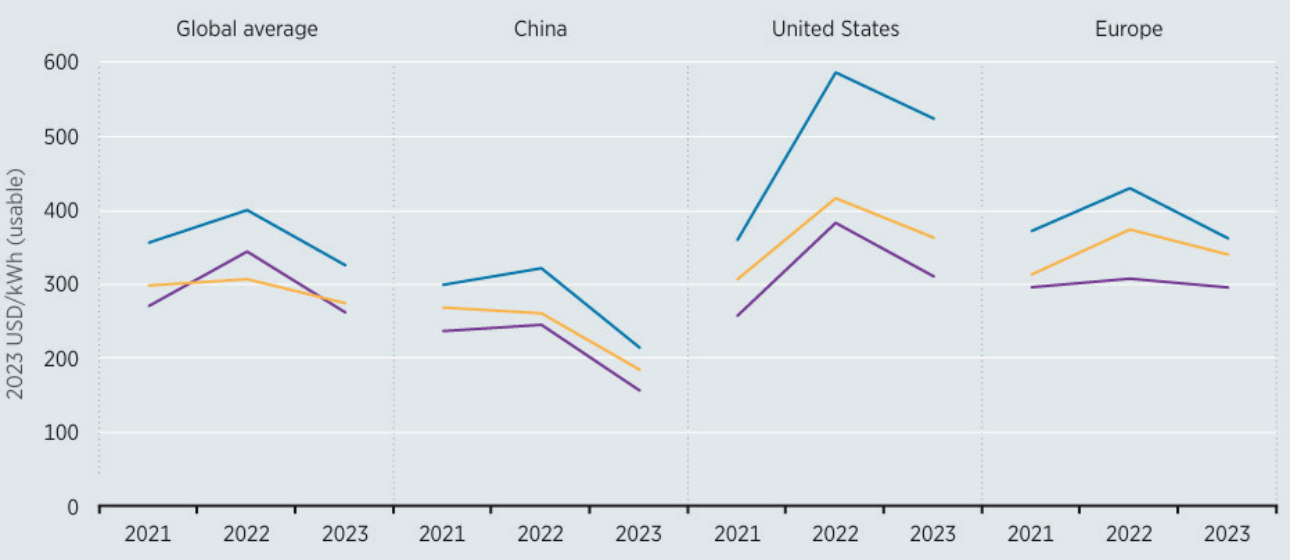


Figure 5: Turnkey BESS costs by market and duration (includes price of battery providers and system integrators, but excludes Engineering, Procurement and Construction (EPC), grid connection and development costs). Source: (IRENA, 2024).

(Chojkiewicz & al., 2024) estimate the 2023 cost of a 4h BESS in Indonesia to be 233 USD/kWh standalone and 157 USD/kWh hybrid, which considers costs for battery pack, balance of system, and engineering, procurement and construction (EPC). As these are estimations based on global values, these should only be treated as a high-level indication.

According to (IEA, 2024), BESS paired with solar PV is one of the most cost competitive sources of electricity today, including when compared to coal and natural gas, whereas standalone BESS is becoming more competitive compared to natural gas peaking options as BESS costs further decrease.

4.2. BESS Ownership and Contract Models

In terms of BESS ownership, the utility can own the BESS and typically have a turnkey contract with a third party, or a third party can own the BESS and have a contract with the utility for usage and cost specification. An overview of utility-owned versus third-party-owned models is given in Table 3.

Table 3: Comparison of ownership options when the utility is the service offtaker. Sources: (World Bank, 2023), (UtilityDive, 2022).

	Utility-owned	Third-party-owned
Model overview	Utility invests, owns and operates BESS Utility has sufficient use cases to optimally use dedicated BESS and is willing to make upfront CapEx payment Regulator typically approves CapEx and tariff	Third party invests, develops, owns, operates BESS Utility is not willing to invest high CapEx and/or has limited set of use cases in the near future Third party provides services as per contract agreement with utility
Contract types	Often a turnkey agreement (EPC builds and delivers a fully operational BESS to utility, which assumes ownership and operation)	Tolling agreement Capacity agreement Hybrid PPA (RE bundled with BESS) (see Table 4)
Advantages	Increased flexibility for utility to use BESS services freely Utility has full control of BESS Long-term cost savings	Lower capital risk for utility, no upfront capital investment Lower operational risk for utility, O&M handled by third party, utility does not worry about performance and degradation
Disadvantages	High upfront investment paid by utility Utility bears full risk Utility handles O&M, requiring dedicated technical resources, or outsources O&M to third party	BESS use limited to contract conditions, utility may have less control especially if the third party is responsible for dispatch Risk of missed/unforeseen revenue opportunities for the utility Higher operational costs (due to lease payments or service fees)

Contract model examples between a third party and the utility for a third-party owned BESS listed in Table 3 are compared in Table 4. These are example formats, specific conditions may vary per case.

Table 4: Contract examples for third-party-owned BESS. Sources: (World Bank, 2023), (Advant, 2025).

	Tolling agreement	Capacity agreement	Hybrid PPA (RE bundled with BESS)
Responsibilities	Third party owns, operates and maintains BESS	Third party owns, operates and maintains BESS Utility contracts BESS for capacity availability during certain hours/seasons, often peak demand periods	Third party owns, operates and maintains RE + BESS. BESS is (dis)charged to moderate RE output to meet PPA requirements Third party is free to use any surplus/deficit for other services
BESS dispatch	Utility controls BESS dis(charge)	Third party controls BESS (dis)charge, but must meet utility's usage rights (and capacity needs) in agreed periods, in which **utility dictates dispatch decisions**	**Third party controls** the BESS dis(charge), respecting PPA conditions Utility may require limited dispatchability during certain periods, and the seller will typically reflect the additional cost in the energy charge (either increasing it directly or having an add-on charge), or may motivate bidders to shift generation to peak times by setting a time of use tariff structure.
Payment by utility	**Fixed charge** for the right to use the battery capacity **and variable operating charge** for actual use (MWh dispatched)	**Fixed** monthly **capacity charge** only. Typically no variable charge.	**Energy charge** (within hybrid PPA - combined RE+BESS output)
BESS usage flexibility	Utility uses BESS as needed	Third party may use BESS outside contracted hours	Third party may optimise around RE obligations (e.g. use surplus for other grid services)

4.3. Application Examples

In this section, international examples of grid connected utility-scale BESS paired with VRE (as a hybrid plant or co-located) and standalone will be described, focusing on business scheme overview (ownership, main value/revenue stream), BESS size and services, contracting strategy and procurement method, cost and pricing structure, to the extent of available information found online. The selection of examples prioritised grid-connected BESS under conditions that might be closer to the Indonesian context (e.g. island power systems, and/or lack of markets to remunerate services, and/or project located in Asia), that had the utility involved (either as owner or as service offtaker when BESS is owned by a third party), and that combined showcase different contract models and ownership, as well as different BESS sizes and provided services. An overview of selected examples is shown in Table 5 and Figure 6.

Table 5: Overview of selected examples.

	BESS Setup	BESS size	Ownership	BESS Contract Model
Mililani - Oahu, Hawaii	BESS+ PV	39 MW/ 4h	Third party	Capacity agreement
Alaminos - Laguna, Philippines	BESS+ PV	40 MW/ 1.5h	Third party	Ancillary service procurement agreement (BESS is co-located with PV)
Sint Eustatius - Kingdom of the Netherlands	BESS+ PV	5.4 MW/ 2.3h	Utility	Turnkey
Kilokari - Delhi, India	Standalone BESS	20 MW/ 2h	Third party	Capacity agreement
Nantucket Island - U.S.	Standalone BESS	6 MW/ 8h	Utility	Turnkey
Scatter Wash - Arizona, U.S.	Standalone BESS	255 MW/ 4h	Third party	Tolling

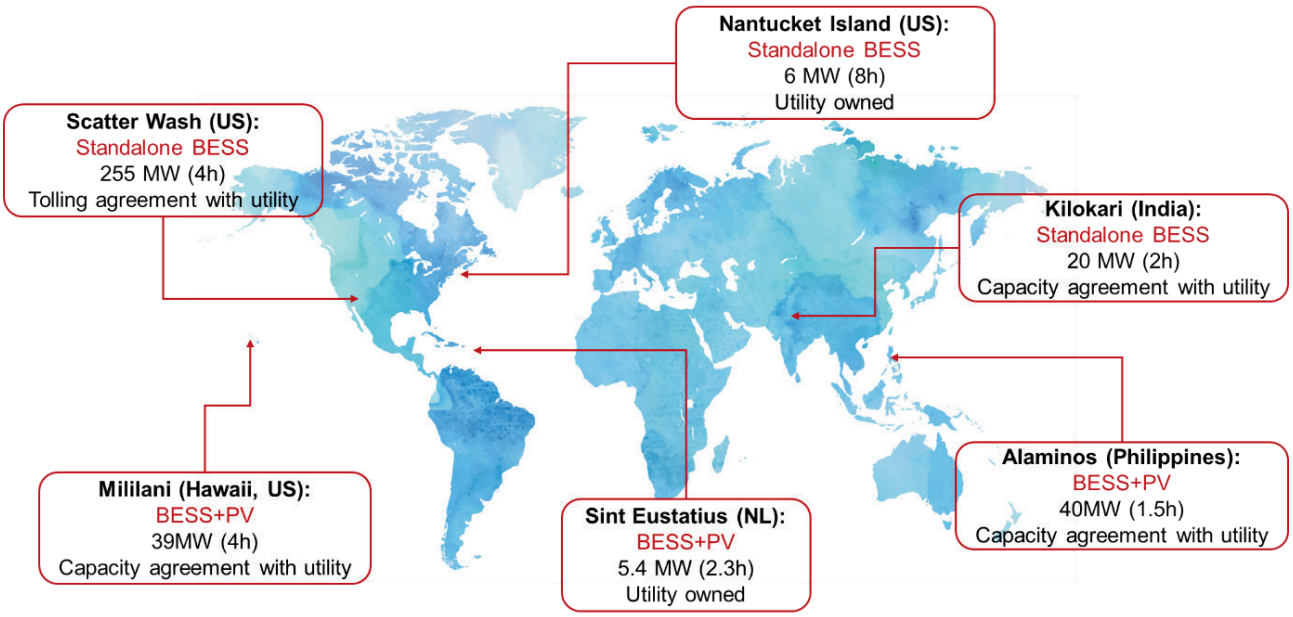


Figure 6: Overview of selected examples' locations.

4.3.1. BESS Paired with VRE

4.3.1.1. Mililani BESS + PV, Oahu Island, Hawaii

Oahu island has high electricity rates compared to other U.S. states, due to reliance on imported fossil fuels, which motivates VRE investments. In 2024, the VRE share of generation was 30.8%, with a peak VRE share of 80% reached. Hawaii's goal is to supply load with 100% RE by 2045. (Hawaiian Electric, 2024)

The 39 MW/4h Mililani BESS project in Oahu is one of several BESS paired with VRE procured by Hawaiian utilities under the "Renewable Dispatchable Generation PPA" contract format. Under this format, utilities pay the project owner a fixed monthly lump sum and can control both the BESS and VRE dispatch freely in a manner more optimal for the grid, enabling increasing VRE integration, flexibility provision, contributing to operating reserves and power quality. These contracts resulted in calculated PPA prices ranging from 0.08 USD/kWh to 0.12 USD/kWh (0.09 USD/kWh for the Mililani project), which is lower than the c.a. 0.15 USD/kWh cost of fossil fuel generation on the islands. (EPRI, 2019)

The 2018 RFP to which the Mililani BESS responded to can be found in (Hawaiian Electric, 2018) and the 2022 RFP can be found in (Hawaiian Electric, 2022). The 2022 RFP document represents a clearer, more updated and improved RFP version and is therefore recommended for interested readers compared to the 2018 RFP.

Table 6:Mililani BESS+PV project overview.

Sources: (Clearway, 2022), (Hawaiian Electric Company, 2023), (Government of Hawai'i, 2025), (Power Technology, 2024), (Solar Builder, 2022), (Hawaiian Electric, 2025), (Wärtsila, 2024), (EPRI, 2019), (Hawaiian Electric, 2022).

Mililani PV + BESS – Oahu, Hawaii		
Power system information	Load	1.1 GW (peak, 2022)
	Generators/BESS (total system)	1.52 GW (oil, diesel, biodiesel) firm capacity 1.14 GW (solar + wind) non-firm capacity with 0.5 GWh storage as a hybrid 0.18 GW/ 0.5 GWh standalone storage
BESS project information	Project setup	39 MW/ 4h BESS (Li-ion LFP) 39 MWp PV
	Commercial operation date (COD)	2022
	BESS services	Energy shifting Reduce curtailment of renewables Other services as needed (utility has dispatch control and freedom to decide on BESS use), including frequency response, reactive power and voltage regulation, solar ramp rate control, synthetic inertia, other power quality services.
	Main value	Reduce electricity cost and its volatility, by reducing fossil fuel usage/costs
	Main BESS revenue stream	Monthly capacity payments by utility
	Ownership	Third Party (Clearway Energy – Independent Power Producer (IPP)
	Contract type	Capacity agreement with Hawaiian Electric: 20 years "RE dispatchable PPA" format used in Hawaii, where utility pays monthly capacity fee (regardless of use) and has dispatch control. BESS usage in contract is limited to one full cycle per day, nevertheless this fits well to intended use cases. In terms of the BESS capacity throughout the contract, the 2018 RFP specifies that the third party must meet performance metrics but no further specification was found. In the 2022 RFP, it is clearly specified that the contracted functionalities and characteristics of the storage must be maintained throughout the contract duration and no storage degradation for either capacity or efficiency can be proposed. The applicant can chose their preferred method to achieve this, which can include overbuilding or including price of replacement components.
	Procurement method	Competitive selection process: The utility set a Request for Proposal (RFP) for "variable renewable dispatchable generation" which was technology agnostic and allowed proposals with or without BESS. Projects that included BESS were required to provide a storage capacity of not less than the largest amount of projected energy during the plant's projected most productive continuous 4h period in a year (which led to Mililani BESS having the same power capacity as the PV plant). The BESS is not allowed to charge from the grid.

Mililani PV + BESS – Oahu, Hawaii		
BESS project information	Cost/pricing structure	• Utility pays a fixed monthly capacity fee and does not pay for kWh. The resulting LCOE is 0.09 USD/kWh (calculated based on the lump sum payments divided by expected output of the plant). • No explicit price ceiling in regulation. Competitive RFP from utility sets implicit price ceiling. Regulator reviews PPA and can reject those deemed not cost-effective or no in the public's interest.
	Regulatory context	• Project approved by Hawaii Public Utilities Commission (PUC) – regulator - as part of RE procurement initiatives. The PPA is also reviewed and approved by PUC. • No mandatory requirement in regulation for VRE plants to have BESS. Utility sets this condition via each RFP, for example when requesting bids for dispatchable VRE. • BESS treatment depends on ownership/use cases and there is no formal regulatory classification into e.g. generation, transmission, dual-use or BESS own class. For an IPP-owned BESS paired with VRE, BESS is functionally treated as a generator, subject to interconnection standards and PPA conditions. For a utility-owned BESS providing solely grid support services it is functionally treated as a regulated transmission asset.

4.3.1.2. Alaminos BESS+PV, Laguna, Philippines

The Philippines current energy mix is coal dominant (covering more than 60% of the total generation in 2023), supplemented by RE (hydropower, geothermal, wind and solar). There is a Wholesale Electricity Spot Market (WESM) in which batteries participate for energy arbitrage and ancillary services energy provided by BESS is registered in WESM as a transaction. (ADB, 2024).

The country aims to generate 35% and 50% of its electricity with RE by 2035 and 2040, respectively, and sees BESS as a supporting tool to enable higher VRE shares. (GTCAP, 2023). Several contracts for ancillary service provision were awarded to third-party-owned BESS, based on competitive bidding and subject to approval of regulator. This includes a contract with the BESS co-located with the Alaminos PV plant, connected to Luzon, the largest power system in the Philippines.

Table 7: Alaminos BESS+ PV project overview. Sources: (Department of Energy Phillipines, 2025), (NGCP, 2023), (Matuwind, 2023).

Alaminos PV+ BESS – Laguna, Philippines		
Power system information (in Luzon)	Load	12.55 GW (peak, 2023)
	Generators/BESS (2025)	15.65 GW thermal (coal + gas + diesel) 2.56 GW hydro 0.9 GW geothermal 2.4 GW solar 0.2 GW wind 0.2 GW biomass 0.36 GW BESS

Alaminos PV+ BESS – Laguna, Philippines

BESS project information	Project setup	2 x 20 MW/1.5h BESS (Li-ion), **co-located** with 120 MWp PV
	Commercial operation date (COD)	2023 (BESS) and 2021 (PV)
	BESS services	Energy Shifting (arbitrage at WESM) Load peak management/reduction Frequency regulation Voltage support
	Main values	Enhance grid stability and reduce ancillary services cost Support VRE integration (reduce fossil fuel use)
	Main BESS revenue stream	Capacity payments from grid operator Market-based earnings from energy arbitrage at WESM
	Ownership	Third Party (ACEN–IPP, part of Ayala group)
	Contract type	• Capacity agreement for BESS (including variable charge) called Ancillary Services Procurement Agreement (ASPA), between ACEN and grid operator, 5 years duration • The co-located PV (commissioned before the BESS) has a separate PPA between ACEN (third party) and Ayala Land (third party), both part of the Ayala Group, for the PV generation up to 2050
	Procurement method	Competitive selection process for ASPA Open to a variety of technologies, with the key criterion being the ability to meet the technical requirements for providing the service procured.
	Cost/pricing structure	• The regulator approved the ASPA for regulating reserve, but limited it to ±20 MW. • The pre-approved hourly rate for scheduled capacity regardless of energy dispatch was PhP 0.958/kW/hr (~0.017 USD/kW/hr) resulting from the competitive selection process. • Based on actual dispatch, the cost of generation will be recovered through settlement in WESM, where the incidental energy (IE) cost payment for regulating reserve is calculated as: • IE = Energy dispatched * (ancillary rate + var_O&M) – (Revenue$_{\text{Selling to WESM}}$-Payment$_{\text{Purchase from WESM}}$) • Where the var_O&M is also defined in the AS competitive selection process. Because the energy provided for AS is registered at the WESM as a transaction, to avoid double compensation/charging as the energy is already paid via the ancillary rate, the net market revenue associated to this energy is subtracted. • If IE is negative, due to higher revenue than payment in the market, then this will be used to offset the next billing period's value. • No explicit price ceiling in regulation for BESS+VRE. Competitive process for ASPA sets implicit price ceiling. Regulator reviews and approves ASPA rates resulting from the competitive selection on a case by case basis. • The total BESS project cost was c.a. 38 Million USD. (ADB, 2024)
	Regulatory context	• The grid operator (National Grid Corp of Philippines - NGCP) received approval from regulator to implement ASPA with Alaminos BESS for a duration of 5 years. The regulator approved the rate as well as the contracted regulating reserve capacity. • Ancillary services (AS) are pass-through costs of NGCP. Regulator aims to reduce AS costs for the benefit of consumers, using ASPA rates resulting from competitive selection process. Rates paid by NGCP as AS cost are passed on to consumers following the approved Ancillary Service Cost Recovery Mechanism in the Philippines, subject to regulatory oversight. • No mandatory requirement in regulation for VRE plants to have BESS. • BESS is classified in the regulation as a generator. (Energy Storage, 2022)

4.3.1.3. Sint Eustatius BESS+PV, Caribbean, Kingdom of the Netherlands

The Sint Eustatius example shows a grid-forming BESS paired with VRE in a small island system (2.3 MWp demand), owned and operated by the utility, with the main value of reducing fuel consumption and the dependency on imported fuel, enabling higher VRE shares and diesel-off operation (see example of diesel-off operation in Figure 7). With the commissioning of the BESS paired with VRE project and its expansions, the island's generation switched from purely diesel-based in 2016 to having 60% of the generation covered by PV by 2024. (SMA, 2024).

Table 8: Sint Eustatius BESS+ PV project overview. Sources: (SMA, 2017), (SMA, 2024).

Sint Eustatius PV + BESS – Caribbean		
Power system information	Load	2.3 MW peak, 1.6 MW average (2017)
	Generators/BESS	4 MVA Diesel 7.15 MWp PV 5.4 MW/ 2.3 h BESS (Li-ion NMC), of which 4.4 MW grid-forming
BESS project information	Project setup	5.4 MW/ 2.3 h BESS (Li-ion NMC), of which 4.4 MW grid-forming 7.15 MWp PV
	Commercial operation date (COD)	3 Stages, starting in 2016: • 2016 – Grid-following - 2 MWp PV, 0.57 MWh BESS • 2017 – Grid-forming, enabled 100% RE (diesel off operation) during the day, 46% PV generation share reached – Added 2.15 MWp PV and 4.4 MW grid-forming inverters with 5.35 MWh of batteries. • 2024 – 60% PV generation share reached - Added 3 MWp PV and expanded BESS to 12.5 MWh.
	BESS services	Energy shifting, avoid PV curtailment Balancing support, ramp rate control Fast frequency regulation Voltage support Grid-forming, black start Other as needed (utility owns and operates BESS – flexibility of use)
	Main values	Avoided fuel (>1.7 million litres of diesel/year), avoided emissions Reduce dependency on imported fuel Reduce electricity cost Enable higher VRE shares
	Main BESS revenue stream	Avoided cost of fuel
	Ownership	Utility
	Contract type	Turnkey
	Procurement method	Direct contract with SMA as project developer, no competitive process
	Cost/pricing structure	• Project received funding support from Dutch Ministry of Economic Affairs. • Capital and operational costs of hybrid system are recovered via regulated electricity tariffs. • No explicit price ceiling in regulation for BESS+VRE projects, however, generation costs are analysed by regulator, and only if approved are considered in the yearly tariff determination.

Sint Eustatius PV + BESS – Caribbean		
BESS project information	Regulatory context	• No explicit record found online of the utility receiving approval from the regulator to implement this specific project. However, as the project costs are included in the regulator's tariff decision, this indicates the project was accepted as part of the utility's regulated operations. As part of a yearly exercise, a maximum electricity tariff that the utility is allowed to charge end-users is defined by the regulator, to incentivise the utility to operate efficiently. For 2025, an overview is available in (Authority for consumers and markets, 2024) and detailed calculations are publicly available in (Authority for consumers and markets, 2025). • No mandatory requirement in regulation for VRE plants to have BESS. • No formal regulatory classification of BESS found.

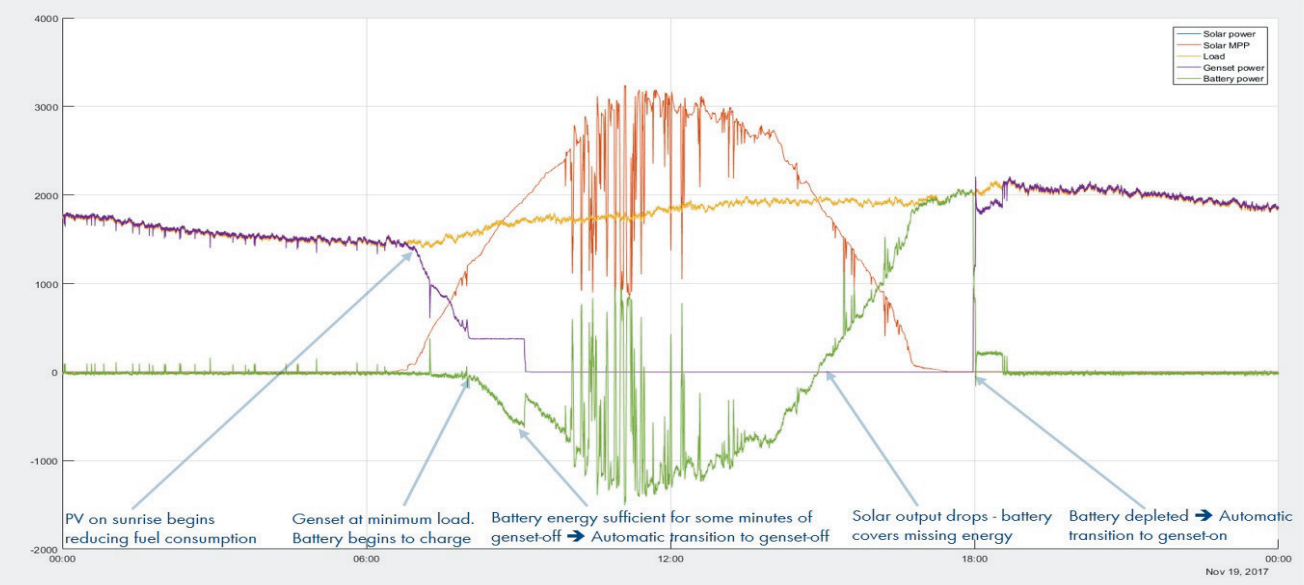


Figure 7: Operation of hybrid system in a cloudy day, showing diesel-off (purple) during the day and BESS active power (green) compensating PV output fluctuations (orange) to meet load (yellow). Expansion phase 2 (between 2017-2024). Source: (SMA, 2017).

4.3.2. Standalone BESS

4.3.2.1. Kilokari standalone BESS, Delhi, India

India has the target to achieve 50% of total installed capacity from non-fossil fuel-based resources by 2030 and plans to deploy 596 GW of RE and 47 GW/236 GWh of BESS by 2032 (Ministry of Power, 2023). The country has been working on regulations and policies to facilitate BESS integration, such as outlines in (Ministry of New and Renewable Energy, 2025).

Kilokari was the first commercial standalone BESS project at the distribution level in India to receive regulatory approval for a capacity tariff. Through this project, the BESS owner wants to demonstrate the viability of the business model (third-party-owned BESS supported by concessional financing) to other countries and plans to mobilise concessional capacity for c.a. 1 GW of BESS projects by 2026. The project had a fast development time of c.a. 20 months from conceptualisation to implementation and incurred no capital expenditures for the utility. The Global Energy Alliance for People and Planet (GEAPP) conducted techno-economic analyses to demonstrate the value of the BESS for the utility. Furthermore, the project has a comprehensive evaluation and learning plan and aims to share findings with national and international power sector stakeholders (Global Energy Alliance for People and Planet, 2024).

Table 9: Kilokari standalone BESS project overview. Sources: (Global Energy Alliance for People and Planet, 2024), (Mercom, 2024), (Energetica India, 2024), (The Times of India, 2025), (Central Electricity Authority, 2025), (TERI, 2023), (MInistry of Power, 2024), (CEIC, 2025), (Economic Times, 2025).

Kilokari standalone BESS – Delhi, India		
Power system information	Load	8.66 GW (peak in Delhi, 2024) 249.86 GW (peak in India, 2024)
	Generators/BESS (total system, as of 04/2025)	Delhi: 5.66 GW thermal (coal, gas) 0.15 GW nuclear 0.76 GW hydro 0.4 GW other RE (mostly solar + some biomass) All India: 240 GW thermal (coal, gas, diesel) 8.78 GW nuclear 47.93 GW hydro 107.95 GW solar, 51 GW wind, and 16.7 GW other RE
BESS project information	Project setup	20 MW/ 2h BESS (Li-ion LFP), installed at 33/11 kV Kilokari substation
	Commercial operation date (COD)	2025 (April)
	BESS services	Load peak reduction (transformer CapEx deferral) Frequency support during high ramp events Energy shifting
	Main values	Facilitate VRE integration (especially large shares of PV), enhance grid stability Reduce power procurement costs Improve power quality at a high demand substation
	Main BESS revenue stream	Monthly capacity payments by utility
	Ownership	Third Party (Kilokari BESS Private Ltd, an IPP which is a special purpose vehicle, i.e. a legally separate entity, owned by IndiGrid and Ampere-hour Energy)
	Contract type	Capacity agreement with distribution company (BSES Rajdhani Power Limited - BRPL) for 12 years. Single-part tariff structure, comprising only fixed monthly capacity charges (i.e. no energy charge). The utility provides a dispatch schedule and the third party operates the BESS to execute the schedule. The RFP requested 2 daily cycles for the duration of the contract, stated 12 years, and accounts for degradation by setting a minimum dispatchable energy that must be available at the end of each year.
	Procurement method	Tariff-Based Competitive Bidding. The regulator approved the tariff. The utility appointed TERI as the bid manager and the RFP is available in (TERI, 2023). The size was specified in the RFP as 20 MW/ 2h.
	Cost/pricing structure	• Monthly capacity tariff (~69 USD/kW/year) defined via competitive bidding and approved by regulator for a period of 12 years. The fixed capacity is to be paid based on availability basis, irrespective of actual utilisation. • The regulator mandated that any financial benefits derived from this project will be passed on to the utility's consumers as a net offset in the power purchase cost included in the annual revenue requirement. The utility did not incur any capital expenditure for this project.

Kilokari standalone BESS – Delhi, India		
BESS project information	Cost/pricing structure	• GEAPP gave a concessional loan of 70% of project's total cost, as requested in the RFP. • No explicit price ceiling in regulation. Competitive RFP sets implicit price ceiling. Regulator reviews tariff and can reject those deemed not cost-effective or not in the public's interest. For BESS projects that apply for the Viability Gap Funding (VGF), a committee defined by the Ministry of Power will specify for each RFP an upper cap on tariffs to be quoted by bidders as well as the applicable VGF (up to 40% of BESS capital cost). Conditions for VGF eligibility include a minimum capacity of 100 MWh (hence not applicable to the Kilokari project).
	Regulatory context	• A compilation of policies and guidelines for Energy Storage Systems (ESS) in India can be found in (Ministry of New and Renewable Energy, 2025). • Kilokari BESS project approved by the regulator, who verified that the bidding process followed the Ministry of Power guidelines, approved the tariff and the agreement between the utility and third party. • The regulation recognises BESS as part of the power system and its status is defined based on its application area and ownership, as clarified in (Ministry of Power, 2022). It can be developed, owned, leased and operated by a generating company, a transmission licensee, a distribution licensee, a system operator or a standalone BESS provider. When the BESS is owned, operated by, and co-located with a generating station, transmission licensee or distribution licensee, it will have the same legal status as the owner. If BESS is not co-located with but owned and operated by a generating station or distribution licensee, the legal status will be that of the owner but for the purpose of scheduling and dispatch it will be treated at par with a standalone BESS. The developer/owner of the BESS may sell/lease/rent out the storage space fully or partially to utilities engaged in generation, transmission or distribution or to a load dispatch centre. The BESS owner may also use the storage space partially or fully himself to buy electricity and sell at a later time. A standalone BESS is a delicensed activity at par with a generating company, and will be provided connectivity under the Electricity (Transmission System Planning, Development, and Recovery of Inter State Transmission Charges) Rules, 2021. • The Government of India already recognised the value of storage in the energy transition and, to encourage national adoption of energy storage, released the National Framework for Promoting Energy Storage (Ministry of Power, 2023), which explains the current framework including energy storage obligations, conditional waiver for transmission charges for BESS projects, guidelines for BESS procurement, eligibility of BESS for secondary and tertiary reserve ancillary services in India, viability gap funding, among others. • No mandatory requirement in regulation for all VRE plants to have BESS, conditional on a case by case. As per the National Framework for Promoting Energy Storage, new RE projects (excluding hydro) above 5 MW or as specified by the Government of India may be mandated to install BESS (of at least. 5% of the RE capacity and 1h duration). Such capacity may be considered in the bidding stage and the storage can be either co-located with the RE plant or integrated with any other storage located elsewhere.

4.3.2.2. Nantucket island standalone BESS, Massachusetts, United States

In the U.S., 23 states plus the District of Columbia and Puerto Rico have 100% clean energy targets, and 17 states have adopted some form of energy storage policy (e.g. procurement targets, demonstration programs, financial incentives). This includes Massachusetts, which had the target of procuring 1 GWh from storage by 2025 and in 2024 enacted a law directing Distribution companies to aggregate 5 GW of storage by 2030 (including long duration storage), the state also provided USD 20 Million in grant funding to demonstration projects. U.S. state targets can be found in (PNNL, 2022) and (Morgan Lewis, 2025).

The standalone BESS project in Nantucket Island, Massachusetts, was simultaneously procured with 10 MW diesel generators as a backup for the submarine cable, with the main value being to maintain system reliability whilst deferring the investment of a third submarine cable between the island and mainland.

PNNL supported with the business case analysis via detailed techno-economic studies, available at (U.S. Department of Energy, 2020), (PNNL, 2019). In the 20-year lifecycle of BESS plus diesel generators, the highest estimated benefit was from the deferred investment of the submarine transmission cable, representing 75% of the total quantified benefits.

Table 10: Nantucket Island standalone BESS project overview. Sources: (Nantucket Current, 2025), (U.S. Department of Energy, 2020), (PNNL, 2019), (Quanta Technology, 2020), (U.S. Department of Energy, 2022).

Nantucket Island standalone BESS, Massachusetts, United States		
Power system information	Load	49 MW (peak, 2018 – i.e. at project's planning time) – significant variation between summer (tourism season) and winter 55 MW (peak, 2025)[4]
	Generators/BESS (total system)	2 submarine cables (maximum combined capacity of 71 MW) 0.1 MW PV 10 MW diesel generator (backup) 6 MW/ 8h BESS (backup)
BESS project information	Project setup	6 MW/ 8h BESS (Li-ion)[5] 10 MW diesel generators (backup)
	Commercial operation date (COD)	2019
	BESS services	Backup power, support black start and island operation in case of loss of both submarine cables, meet N-1 criteria if one cable fails. Reactive power provision and voltage support Frequency regulation and spinning reserves via market participation
	Main values	System reliability, transmission CapEx deferral (reduces present value cost of the submarine cable by $109 million)
	Main BESS revenue stream	Transmission investment deferral of third submarine cable Services provision via the ISO-New England market
	Ownership	Utility
	Contract type	Turnkey
	Procurement method	Competitive selection process, with separate procurement steps for BESS and diesel generators. Procurements of public utilities are mandated in the regulation to be competitive and transparent. The utility set a Request for Proposal (RFP) for BESS with a defined size of 6 MW/ 8h but battery-technology agnostic. Tesla was awarded the project.

[4] In 2025, a higher than anticipated peak of 55 MW was reached, triggering new discussions about potential solutions, including the third submarine cable sooner than expected. Renewables are also being considered, however limited available land is a major challenge. (Nantucket Current, 2025)
[5] No information found online stating that the BESS has grid-forming capabilities.

Nantucket Island standalone BESS, Massachusetts, United States		
BESS project information	Cost/pricing structure	• No explicit price ceiling in regulation. Competitive RFP from utility sets implicit price ceiling. • Project costs are recovered via regulated electricity tariffs. • At present value, benefits of the 20-year lifecycle of BESS plus diesel generators are estimated at USD 145.9 Million, whereas revenue requirements plus energy costs are estimated at USD 93.9 Million, resulting in a return of investment of 155%. The majority of the estimated benefit (75%) is from the deferred investment of the submarine transmission cable for 13 years. The second largest revenue is expected from regulation services provided in the market. An overview of estimated costs and revenue considering the BESS plus diesel generators can be seen in Figure 5. • The BESS cost was c.a. USD 33 Million, including power conversion system, balance of plant, interconnection, construction, and commissioning, and excluding additional costs associated to tax, return on investment, depreciation, O&M.
	Regulatory context	• The Nantucket BESS is a regulated asset, included in the base rate of the utility New England Power (NEP) as a distribution investment, which required approval from regulator. • NEP would need to petition the regulator to allow a rate-based asset to participate in wholesale energy markets. If approved, NEP would return all market revenues to customers and have no monetary gain. • No mandatory requirement in regulation for VRE plants to have BESS. This may be encouraged or required by utilities via RFP. • The Nantucket BESS is classified as a utility distribution asset. • In the U.S., there is no single BESS classification in the regulation, it depends on several factors, including ownership, application, and states may have their own additional conditions. FERC Order 845 clarifies that BESS can be classified as generator and/or transmission (Trum, 2021, p. 304). In 2017 FERC issued a statement that it supports ESS deployment for dual use (as regulated transmission asset and as competitive energy market asset), stating that market revenues could be passed on to customers to reduce system costs. FERC invited (but did not require) regional energy market operators to propose enabling policies for this. In 2018, FERC issued Order 841 which required wholesale energy market operators to design products and rates that account for the technical characteristics of ESS. The minimum size for market participation is 0.1 MW.

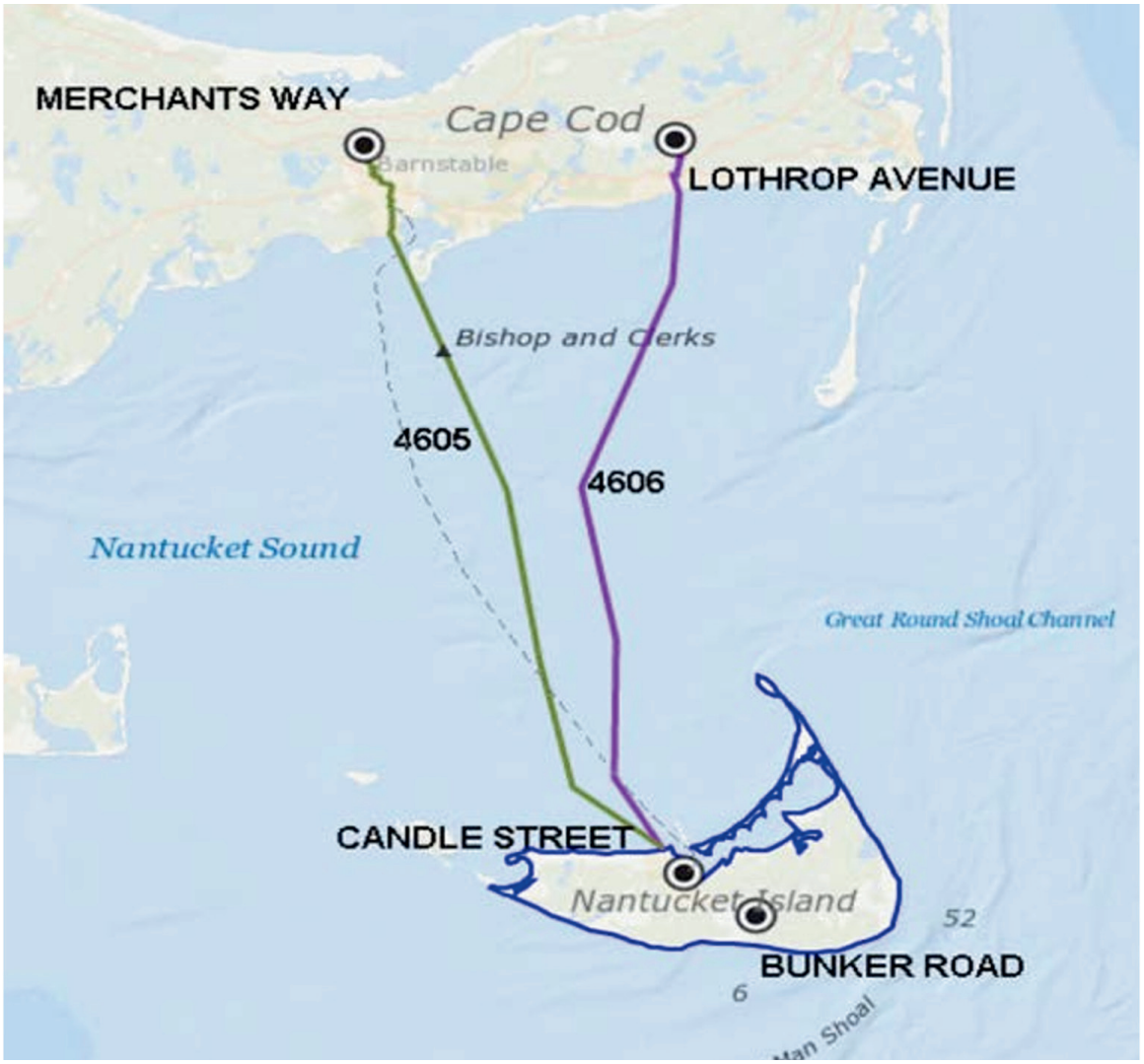


Figure 8:Existing submarine cables that connect Nantucket Island to mainland. The BESS + diesel generators for backup deferred the need for a third submarine cable. Source: (PNNL, 2019).

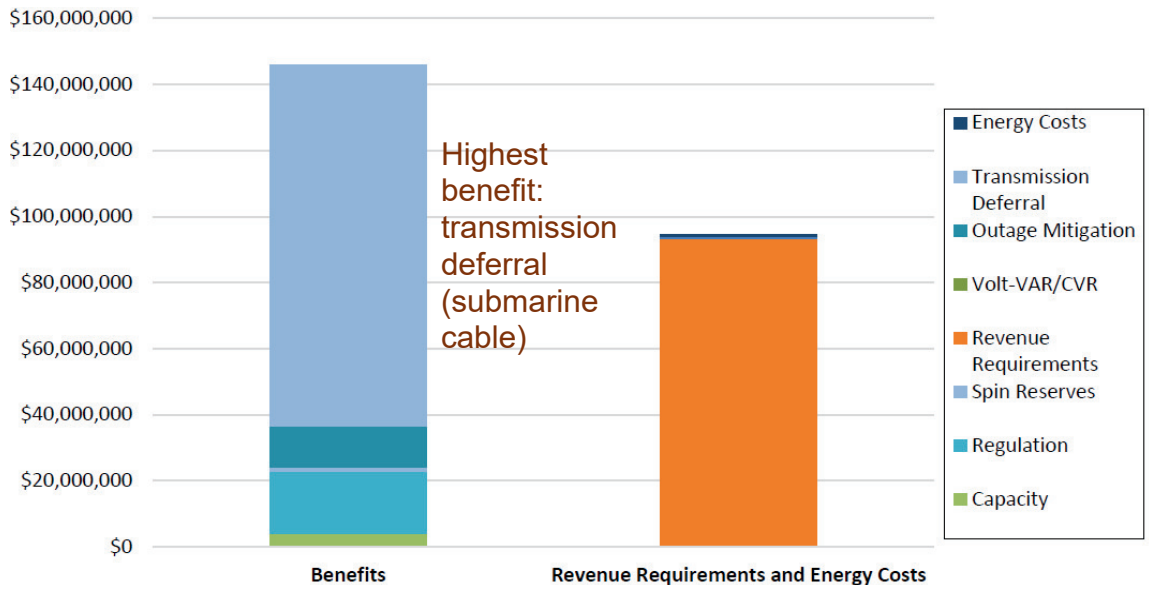


Figure 9: Estimated present value benefits and revenue requirements of Nantucket BESS plus diesel generators, from 20-year analysis. The diesel does not participate in market. Source: (PNNL, 2019).

4.3.2.3. Scatter Wash standalone BESS, Arizona, United States

A few utilities in Arizona have set the target of 100% carbon-free generation mix by 2050. This includes the utility Arizona Public Service (APS). Through a planning process, APS determines how to meet future demand reliably and affordably, while reducing environmental impacts, considering its plans to retire coal. As a result of this planning, APS launches "All-Source" request for proposals in a competitive selection process. In 2022, the All-source RFP requested 1-1.5 GW of resources, including 0.6-0.8 GW of renewable resources to meet the needs identified in the Integrated Resource Plan (2023 plan available at (APS, 2023)). The interim target of APS is reaching 45% RE share by 2030.

Arizona has planned several BESS utility-scale projects including tolling agreements with the utility. The Scatter Wash BESS is one of the tolling agreements awarded under the All-Source RFP 2022 process, in which the third party retains ownership and operates the BESS whilst the utility has full dispatch rights for 20 years. APS also signed tolling agreements with other BESS projects, e.g. the 150 MW/4h Justice BESS.

Table 11: Scatter Wash standalone BESS project overview. Sources: (Strata Clean Energy, 2025), (Strata Clean Energy, 2024), (EnergyTech, 2024), (Energy Global, 2024), (APS, 2023).

Scatter Wash standalone BESS, Arizona, United States		
Power system information	Load	8.2 GW (peak, 2024) in APS's area
	Generators/BESS (total system)	APS main resources (own + PPAs) in 2023: 1.1 GW nuclear 1.4 GW Coal 5.2 GW Natural Gas 0.78 GW Solar 0.64 GW Wind 0.3 MW Storage
BESS project information	Project setup	255 MW/ 4h BESS (Li-ion)
	Commercial operation date (COD)	2025 (planned COD in Q2, not yet operational)
	BESS services	Energy Shifting (to support RE integration, storing PV generation for later use) Load peak management, especially in summer Other services as needed (utility has dispatch control and freedom to decide on BESS use).
	Main values	Reduce electricity cost Support integration of further REs Support maintaining grid reliability during peak demand
	Main BESS revenue stream	Fixed capacity payments by utility (plus, utility pays for energy used to charge the BESS) (Strata Clean Energy, 2025)
	Ownership	Third Party (Strata Clean Energy)
	Contract type	Tolling agreement with utility (Arizona Public Service): • 20-year agreement, where the third party builds, owns and operates the BESS and the utility has full dispatch rights. • Utility pays fixed capacity payment plus the electricity used to charge the BESS. • As per RFP, all available capacity, energy and ancillary services are for exclusive use by the utility. Ancillary services may include frequency response, spinning reserve, non-spinning reserve, reactive power control, fixed power factor, and automatic voltage regulation.

Scatter Wash standalone BESS, Arizona, United States		
BESS project information	Contract type	• BESS must allow 365 full equivalent cycles per year (allowing flexibility for days with more than 1 cycle and days with no cycle), with an average annual state of charge of 50%, as per RFP. • The RFP states that for projects proposed under the tolling format, proposal pricing does not require an augmentation plan, i.e. a strategy for adding extra battery capacity over the contract duration to offset performance degradation and maintain 100% of initial capacity. Instead, the proposal (not available online) will likely state the capacity degradation over time. Furthermore, the strategy for BESS replacement at its end of life within the contract duration is not stated in the RFP. It is therefore expected to be stated in the proposal/ contract and likely includes end of life replacement in the proposal pricing.
	Procurement method	Competitive selection process: • The utility set an RFP in 2022, under the "All-source RFP" format, aimed at meeting the growing demand with affordable and clean electricity. The RFP is available at (Arizona Public Service Company , 2022). • The RFP was technology agnostic and allowed proposals with or without ESS. • The utility requested 1-1.5 GW of reliable capacity including 0.6-0.8 GW of RE, plus 1.4 GW of ESS contracts. Requirements included full completion by mid-2027 initiated no later than end-2026, minimum 5 W capacity with preference for projects above 200 MW, connection to transmission system, controllable remotely by APS, and resource must provide reliable capacity to meet summer peak plus reserve margins, and/or supporting increasing RE share in the mix. Non-dispatchable energy is stated as less favored. • Eligible technologies either alone or in combination (e.g. solar+ ESS) included solar, ESS, wind, biomass, geothermal, landfill gas, simple or combined cycle combustion turbines. • As per RFP, all available capacity, energy and ancillary services are for exclusive use by the utility. Ancillary services may include frequency response, spinning reserve, non-spinning reserve, reactive power control, fixed power factor, and automatic voltage regulation. • For bids proposing ESS, preference is for contract term of at least 5 years and not more than 20 years, the ESS technology is left open as long as it meets the RFP requirements, preference is for projects that allow full capacity for 4h duration or more. • The utility evaluates each proposal individually and also how well it fits the existing resources, other proposals, and projected resource needs. The utility utilises resource planning models and production cost modelling tools to assess how well the proposed project meets reliability requirements whilst minimising system costs. An independent monitor was appointed to ensure the selection is fair and unbiased.
	Cost/pricing structure	• Fixed capacity payment fee not found online. • Project is supported by the Investment Tax Credit for standalone ESS, created by the Inflation Reduction Act (2022). • The project owner secured USD 559 Million financing for the construction and ownership of the project, from a consortium of lenders. • No explicit price ceiling in regulation. Competitive RFP from utility sets implicit price ceiling.
	Regulatory context	• No indication found online that the regulator approved the Scatter Wash BESS project and the specific capacity tariff. However, the inclusion of project costs in the utility's base rates and "Adjustor" components are subject to Arizona regulator's approval (Pinnacle West, 2025), (APS, 2025). Furthermore, in the 2022 All-source RFP, it states that any final agreement resulting from the RFP may be conditioned upon actions and/or approvals by regulators, satisfactory to APS in its sole discretion. • No mandatory requirement in regulation for VRE plants to have BESS. Utility may sets this condition via each RFP. • In the U.S. there is no single BESS classification in the regulation, it depends on several factors, including ownership, application, and states may have their own additional conditions. FERC Order 845 clarifies that BESS can be classified as generator and/or transmission (Trum, 2021, p. 304).

4.4. Summary of Findings

In this section, an overview of the findings is provided, based on the analysed selected examples of international BESS applications where the utility is the main beneficiary.

4.4.1. Technology and Use Cases

In all examples analysed, which have commercial operation start dates ranging from 2016-2025, the battery technology applied was Li-ion, with stated subtypes varying between LFP and NMC. This is aligned with the international trend indicated in (IRENA, 2024), where Li-ion (especially LFP) has been the main deployed technology worldwide for new BESS projects since 2019, as mentioned in 4.1

From the examples of **BESS paired with VRE** providing services to utilities, the main services included **energy shifting** to support further RE integration and reduce/avoid VRE curtailment (e.g. shift solar PV to meet evening peak), support with **load peak management** (peaking capacity), **solar ramp rate control**, as well as **ancillary services** such as frequency regulation and voltage support.

For the cases of Mililani and Sint Eustatius, the utility has freedom over BESS dispatch and other BESS services than listed above are provided as needed. In both systems, VRE penetration has reached high shares (80% in Oahu and 100% in Sint Eustatius), therefore keeping flexibility in BESS operation is important. Furthermore, in the case of Sint Eustatius, as it is a small island system operating at times with diesels-off (only BESS+PV), BESS needs to provide further additional services as needed, which include grid-forming and inertia provision. In the case of Alaminos BESS, VRE shares in the Luzon power system are still low compared to the other two examples and the utility specifically procured ancillary services in a competitive selection process open to several technologies, aiming at reducing ancillary services cost.

From the examples of **standalone BESS** providing services to utilities, the main services included support with **load peak management** (peaking capacity), and **ancillary services** such as frequency regulation and voltage support. In the cases of Kilokari and Scatter Wash BESS, where the utility has dispatch flexibility and targets to support VRE integration, **energy shifting** to support RE integration is also a provided service. In all standalone BESS examples shown, the utility has dispatch flexibility and complements the above services as needed.

The main service provided in the examples was related to the utility's main technical needs for the specific power system. For example, in Nantucket island, with increasing demand the utility's concern was to maintain reliability of supply in case of failure of two existing submarine cables. Alternative solutions were compared to the BESS (e.g. a new submarine cable) to find the best techno-economic solution. In the case of Scatter Wash BESS, additional peaking capacity was needed due to increasing summer peak demand and the utility launched an RFP open to different technologies that provide reliable capacity to meet summer peak plus reserve margins, and/or support increasing RE share in the mix. For Kilokari BESS, the main need was to manage load peak in the high demand substation Kilokari whilst reducing the power procurement cost of the distribution utility and deferring grid upgrade investments, as well to support VRE integration via energy shifting to contribute to state targets.

4.4.2. BESS Size

BESS power and energy sizing depends on several factors, including but not limited to:

- The characteristics of the intended services and specific service provision requirements (e.g. market participation thresholds, size requirements requested by utility in RFP)
- The characteristics and needs of the power system (e.g. peak demand, existing VRE penetration, grid flexibility needs)
- Economic considerations, including the trade-offs between BESS costs (especially CapEx) and potential revenues
- Capacity constraints at the substation or interconnection point

The BESS is typically sized though a techno-economic assessment. This process identifies the optimal configuration (power and energy capacity) for which the projected benefits/revenues most significantly outweigh the costs. This is especially important given the high BESS investment costs, which scale with both power and energy capacity. The utility might define minimum BESS size requirements in their Request for Proposal or state the desired size.

For **both standalone BESS and BESS paired with VRE,** BESS energy capacity or duration is closely related to the stacked application types. Power-based services – such as frequency regulation – have a short operation timescale (seconds to minutes), requiring only short duration storage (c.a. 0.5 to 2 hours). In contrast, energy-based services, such as energy shifting (e.g. storing solar generation for evening use), require longer durations (e.g. 2 – 4 hours).

In the **BESS paired with VRE** examples shown, in terms of power capacity, systems with high VRE shares – such as Sint Eustatius and Mililani – featured larger BESS power capacity relative to their PV peak capacities, corresponding to 75% and 100%, respectively. In contrast, Alaminos, where VRE penetration in the power system remains relatively low, had a lower BESS-to-PV peak capacity ratio of 33%. This smaller ratio reflects its primary role of providing ancillary services (as opposed to energy shifting). The specific power capacity in Alaminos BESS was likely defined by utility procurement conditions specific to ancillary service requirements. The Alaminos BESS was commissioned 2 years after the PV plant and is co-located, having separate revenue streams from the PV plant.

In systems with low VRE shares, such as Luzon grid where the Alaminos BESS operates, short duration BESS (1-2 hours) are more common, as there is minimal need for PV energy shifting. However, in systems with higher VRE shares, such as Oahu (Mililani BESS), longer duration BESS (2-4 hours or more) become increasingly important to support grid balancing, reduce curtailment, and improve overall system flexibility.

In the case of Mililani, the Hawaiian utility specifically requested proposals for VRE dispatchable generation, with projects that included BESS being requested to provide a storage capacity of not less than the largest amount of projected energy during the plant's projected most productive continuous 4-hour period in a year.

In the **standalone BESS** examples shown, the BESS power and energy can vary significantly from project to project, strongly depending on the power system needs. In Nantucket Island, the long-duration BESS (8 hours) supports the reliability needs, and the power capacity was sized to complement the diesel generators and meet the load in case one submarine cable fails. In Delhi, the Kilokari BESS supports mostly load peak shaving and frequency regulation, and the power capacity was likely defined based on utility needs and load peak duration.

In Arizona, the Scatter Wash BESS was designed with longer duration to meet procurement requirements (based on the integrated resource plan of the utility), which requested projects that offer reliable capacity to meet summer peak plus reserve margins, and/or support increasing RE share in the mix, and gave preference to projects above 200 MW capacity.

As BESS investment costs continue to reduce, and VRE shares in power systems rise – driving greater need for energy shifting – longer duration BESS (e.g. 4 to 8 hours) are increasingly favoured. These offer higher flexibility to stack multiple services and deliver both power and energy-based services throughout its lifetime.

In the observed examples, and aligned with common international practice, there was **no mandatory BESS requirement in the regulation** (e.g. grid code) for VRE projects to include BESS, nor was there **a minimum BESS** size defined in the regulation when VRE was paired with BESS. Instead, utilities encouraged or directly requested BESS paired with VRE via each request for proposal, on a case by case and needs basis.

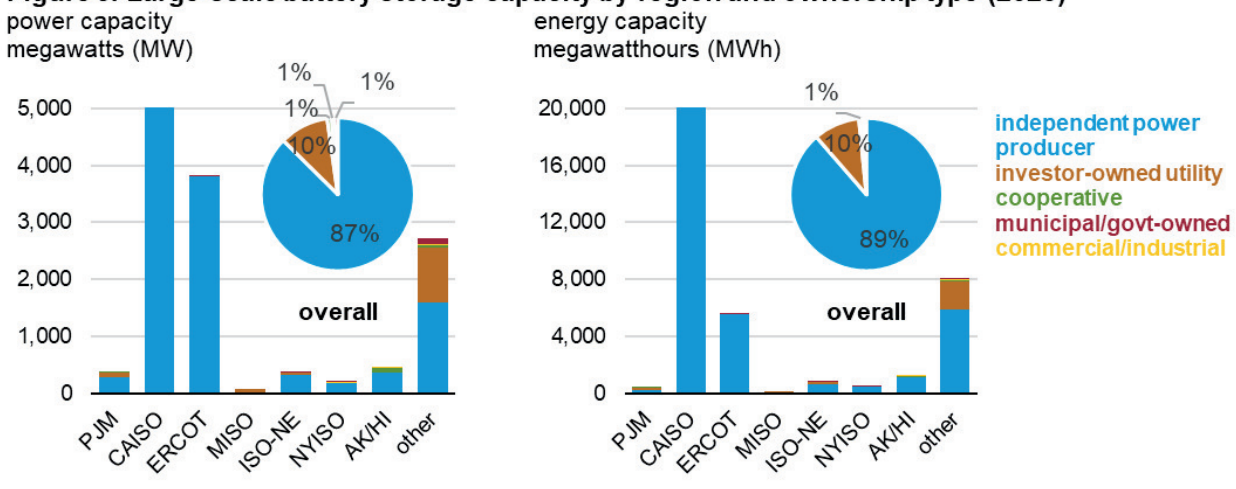
4.4.3. Ownership

The international examples shown were purposefully selected to represent a combination of utility-owned and third-party-owned cases.

Advantages and disadvantages of third-party-owned versus utility-owned BESS were outlined in Section 4.2. BESS ownership therefore highly depends on each utility's willingness to invest the high CapEx and/or identified need for a set of BESS use cases to justify the investment.

Due to the flexibility of many third-party-owned BESS contract models, the utility can still have dispatch flexibility without incurring the upfront capital investment or operational risks. Therefore, this has been the preferred ownership model by utilities. This is shown in for the U.S. example market in the figure below, which shows that 87% of the total installed power capacity of utility-scale BESS was owned by IPPs.

Figure 5. Large-scale battery storage capacity by region and ownership type (2023)



Data source: U.S. Energy Information Administration, *2023 Form EIA-860, Annual Electric Generator Report*

Figure 10: Utility-scaleBESS ownership for projects up to 2023 in the United States. Source: (EIA, 2024).

4.4.4. Contracting Strategy and Procurement Method

From the analysed examples, locations where the utility is still familiarising with BESS such as in the Philippines and in India/Delhi, the procurement process tended to define more specific requirements and contracts had a shorter duration, whereas in Arizona and Hawaii the utilities made 20-year agreements and RFPs tended to have more open requirements, with the Arizona procurement requirement being the most flexible of all cases analysed.

Procurement method

In all international examples shown, except for the Sint Eustatius case (smallest island power system), the BESS was procured via **a competitive selection process,** with the utility setting requirements, which ranged from specifying BESS size to keeping size and technology open, as long as technical requirements were fulfilled. Utilities that kept RFPs more open, such as in Arizona, also stated preferred characteristics (e.g. preference for bids above a certain size, preference for dispatchable capacity).

In the **BESS paired with VRE** examples shown, whereas the Mililani example specifically requested "variable renewable dispatchable generation" and specified that projects with BESS should be sized to at least store the VRE plant's projected most productive continuous 4h period in a year, the Alaminos example left the RFP open to any technology that fulfils the technical requirements to provide the ancillary services procured. In the case of Sint Eustatius BESS, there was no competition but rather a direct contract with the project developer to provide the utility-owned BESS as Turnkey.

In the **standalone BESS** examples shown, for both the utility-owned Nantucket BESS and third-party-owned Kilokari BESS, the BESS was procured via a competitive process in which the BESS size was pre-defined by the utility. For the third-party-owned Scatter Wash BESS, the procurement was done via a rather open "All source RFP" format which was technology agnostic, allowing bids with and without ESS, and requesting bids aligned with the integrated resource plan targets, such as to provide reliable capacity to meet summer peak plus reserve margins, and/or to supporting increasing RE share in the mix. Proposals were analysed individually but also as part of the proposal group, allowing the utility to select the combination of projects that best meets their needs at the lowest cost. In the 2022 RFP, the utility requested 1-1.5 GW of reliable capacity including 0.6-0.8 GW of RE, and 1.4 GW of ESS contracts, to be completed by 2027. The RFP required a minimum of 5 MW with preference for projects larger than 200 MW.

Contract conditions

The international examples shown were purposefully selected to represent a combination of different contract types. In third-party-owned BESS cases, contracts ranged from 5 years to 20 years. Each contract agreement has a different risk allocation within parties, which is reflected in the agreement costs.

In the third-party-owned **BESS paired with VRE** examples shown, the contract with the utility followed a **capacity agreement** format, with and without an energy charge, for Alaminos and Mililani, respectively. For Mililani, a 20-year contract was established in which the utility can use the BESS as needed and exclusively. For Alaminos, a 5-year contract was established for ancillary services provision and the BESS also earns from energy arbitrage in the wholesale electricity spot market.

In the third-party-owned **standalone BESS** examples shown, Kilokari BESS owner has a 12-year **capacity agreement** with the utility (no energy charges) whereas the Scatter Wash BESS owner has a 20-year **tolling agreement** with the utility, in which the utility pays a capacity agreement plus energy charges. In both cases the utility has flexibility to dispatch the full BESS capacity as needed. For Kilokari BESS, the RFP requested a BESS with a specific size and the contract duration was defined, whereas for Scatter Wash BESS, the RFP was technology agnostic and the contract duration was left to be determined by bidders within the range of 5 to 20 years.

BESS tolling agreements are still recent and less frequent than capacity agreements. Their main application today is between the BESS owner and typically an energy trader, who pays a capacity charge to the owner and has freedom to control the BESS and exclusive rights to its full capacity, which in turn they control aiming to maximise profit via energy arbitrage in markets. In this business model the asset owner has a fixed revenue and the risk lies with the toller, as they must pay a capacity payment to the owner even if the asset underperforms. In some cases, revenue sharing applies, in which a percentage of the profits generated by the toller are passed on to the BESS owner. Many tolling contracts found had short durations in the range of 2-7 years. The main reason for the yet limited number of tolling agreements is the challenge in finding a fixed capacity tariff that is attractive to the toller and to the owner, with most owners preferring to be the trader themselves in the market when there are interesting revenue opportunities. (ModoEnergy, 2024)

Furthermore, the RFP typically define how many cycles per day or year the BESS must fulfil. This depends on the combination of provided services and power system characteristics. In the examples analysed, 1-2 cycles per day were requested, with the Scatter Wash BESS keeping it specified as 365 cycles per year, to allow flexibility for days of higher cycling and days of no cycling.

4.4.5. Revenue Sources

For **third-party-owned** BESS, the BESS revenue came from the monthly capacity payments based on contracts with the utility. Additional revenues could include those from market participation, when a market for grid support services exists, and avoidance of any performance penalty stated in PPA when paired with VRE.

For **utility-owned** BESS, in the case of Sint Eustatius' BESS paired with VRE the main economic value came from avoided diesel fuel costs and associated reduction in electricity costs, whereas in the case of Nantucket standalone BESS, the main economic value was the deferral of investment in grid infrastructure (submarine cable). Other revenue streams include avoided PPA costs (fixed and/or variable).

4.4.6. Cost/Pricing Structure

In the international cases reviewed, there **was no explicit price ceiling in the regulation** for BESS contracted under any of the contract models. Instead, **cost competitive procurement processes** are the recommended practice and set an implicit price ceiling, subject to **regulatory approval**. The regulator reviews the selected project/bid for each procurement case either during the procurement phase and/or when **approving cost recovery via the utility's tariffs,** and can reject if deemed not cost effective or not in public's interest. In the Alaminos BESS example, the regulator also approved only part of the BESS capacity for the AS contract.

Furthermore, in the case of Kilokari BESS, the regulator mandated that any financial benefits derived from the project will be passed on to the utility's consumers as a net offset in the power purchase cost included in the annual revenue requirement.

In some cases, such as in India, there are price ceilings defined for BESS projects that wish to participate in specific programs, such as the Viability Gap Funding (VGF), in which a committee from the ministry defines for each RFP an upper cap on the tariffs to be quoted by bidders as well as on the applicable funding (up to 40% of BESS capital cost). The VGF only applies for BESS above 100 MWh (therefore not to the Kilokari BESS).

A location factor was not observed in the examples in terms of price ceilings, as there were none, however the utilities could specify directly the desired BESS location (as in the Delhi example) or indicate preferred areas for BESS development within each procurement process based on grid needs.

The quantitative cost information found online for the different examples is limited, and is summarised in Table 12. Such cost information is **case-specific,** as it depends on local conditions and costs, and can only provide a high-level indication for Indonesia.

Table 12: Overview of collected cost information

	BESS Setup	Contract Model (duration)	Price structure (and quantification when available)
Mililani - Oahu, Hawaii	BESS+ PV	Capacity agreement (20 years)	**Fixed monthly capacity fee** The resulting LCOE is 0.09 USD/kWh (calculated based on the lump sum payments divided by expected output of the plant).
Alaminos - Laguna, Philippines	BESS+ PV (co-located)	Ancillary service procurement agreement (ASPA), (5 years)	**ASPA: Fixed monthly capacity fee + energy fee** Pre-approved rate for scheduled capacity: ~0.017 USD/kW/hr (regardless of dispatch) + energy fee
Sint Eustatius - Kingdom of the Netherlands	BESS+ PV	Turnkey	**Lumpsum value**
Kilokari - Delhi, India	Standalone BESS	Capacity agreement (12 years)	**Fixed monthly capacity fee** Approved rate: 69 USD/kW/year
Nantucket Island, U.S.	Standalone BESS	Turnkey	**Lumpsum value** BESS cost ~33 Mio USD, including power conversion system, balance of plant, interconnection, construction, and commissioning, and excluding additional costs associated to tax, return on investment, depreciation, O&M.
Scatter Wash, Arizona, U.S.	Standalone BESS	Tolling (20 years)	**Fixed capacity fee + energy fee** BESS owner secured USD 559 Million financing for construction and ownership. Unclear which costs are included.

4.4.7. Regulatory Framework

In the international examples analysed, there was **no BESS price ceiling** defined in the regulation, as already mentioned in Section 4.4.6. The regulator reviews the selected project/bid for each procurement case either during the procurement phase and/or when **approving cost recovery via the utility's tariffs,** and can reject if deemed not cost effective or not in public's interest.

Furthermore, there was **no mandatory requirement for VRE projects to include BESS** set in the regulation and this is not common international practice, instead the utility may encourage this within its procurement processes. In the Oahu example shown, in a context where power system VRE shares are already high, the deployment of VRE paired with ESS was encouraged based on the technical requirements defined at the RFP when the utility specifically requested VRE to be dispatchable. In the case of Alaminos, it was not a requirement for BESS providing ancillary services to be paired with VRE, and the procurement process was open to a variety of technologies as long as they met the technical requirements. Furthermore, for VRE IPPs, BESS will naturally emerge as a business case for VRE smoothing for ramp rate support or VRE forecast error correction, depending on the grid code/PPA requirements and penalties, where it makes techno-economic sense.

BESS classification varies by country and largely **depends on the application, BESS ownership and beneficiary** of the service. Given the range of possible applications, BESS can fall under different regulatory categories and (World Bank, 2020) **recommends to have BESS as a resource of its own regulatory class** and not arbitrarily placing it into existing categories such as generators.

This is aligned with the U.S (Oahu, Nantucket, Arizona) as well as Delhi examples. In Oahu for example, an IPP-owned BESS paired with VRE is functionally treated as a generator, subject to interconnection standards and PPA conditions. For a utility-owned BESS providing solely grid support services it is functionally treated as a regulated transmission asset. In the Delhi example, when the BESS is owned, operated by, and co-located with a generating station, transmission licensee or distribution licensee, it will have the same legal status as the owner. If BESS is not co-located with but owned and operated by a generating station or distribution licensee, the legal status will be that of the owner but for the purpose of scheduling and dispatch it will be treated at par with a standalone BESS. A standalone BESS is a delicensed activity at par with a generating company. The regulator can also support making certain services accessible to ESS such as done by FERC in the U.S. via Order 841 which required wholesale energy market operators to design products and rates that account for the technical characteristics of ESS.

The main regulatory barriers identified in (IEA, 2024) are:

- Uncertainty over long-term revenues.
- Complex regulatory processes for grid connection approvals and permits
- Lack of strategy to remunerate grid support services from BESS
- Double charging of grid tariffs (due to dual characteristic as generator and load, BESS might be charged both when charging and discharging posing a disadvantage compared to other technologies).
- Restrictions on BESS participation in competitive procurement for grid services (typically for countries transitioning from regulated to liberalised systems)
- Restrictions on services provision which limit BESS contribution (typically in more advanced power markets)
- Restrictions on use due to ownership (due to system operators generally not being able to own and operate BESS, they need to procure services such as grid congestion relief through tenders or on local flexibility markets, which is not yet a common product).

- Clear rules for ownership, operation and service procurement are needed. In countries with strict unbundling between generation, transmission and distribution, enabling system operators to procure services from third parties offers a potential solution. In regulated and vertically integrated power systems, it is important to have an integrated power system planning that recognises the benefits of BESS and helps set targets for BESS and provide a roadmap for BESS development which in turn helps secure investments.

The local regulatory context and the technical grid characteristics are the main factors defining the viable services. In (IEA, 2024), the eligibility of BESS in the regulation by type of service has been mapped for selected countries and is shown in Figure 11.

	Type of use			
	Wholesale arbitrage	Ancillary services	Capacity	Grid congestion relief and/or grid deferral
Australia	🟢	🟢	🟡	🔴
Canada	🟡	🟡	🟡	🟡
China	🟡	🟡	🔴	🔴
Germany	🟢	🟢	🟢	🟢
India	🟢	🟡	🟢	🟡
Italy	🟢	🟡	🟢	🟡
Japan	🟢	🟢	🟢	🔴
Korea	🔴	🔴	🟢	🔴
United Kingdom	🟢	🟢	🟢	🟢
United States	🟢	🟢	🟡	🟡

Status of battery eligibility:

🟢 Legally eligible

🟡 Eligible only in some jurisdictions, or in pilot projects, or for some services only

🔴 Not eligible or type of use not available

Figure 11: Eligibility of BESS per service type according to regulation of selected countries. Source: (IEA, 2024).

BESS in Indonesia

BESS deployment in Indonesia is still at an early stage. (IESR, 2024) estimated that more than 20 MWh of BESS has been installed by the end of 2024, approximately 12 MWh by PLN, and another 12 MWh by the private sector. Majority of the installations did not report the battery technology, but those that did employed lithium-ion, especially LFP, BESS. Most of these installations have been off-grid/microgrid BESS. Examples include 3 MWp PV + 2 MW/2 MWh BESS at a coal mining site in East Kalimantan in 2020 (Colthorpe, 2021) and 3.5 MWp PV + 1.84 MWh BESS installed in Nusa Penida in 2022 (PLN, 2023). PLN has also launched large-scale diesel replacement programme in 2022 to convert 5,200 diesel power plants (PLTD) into PV-BESS hybrid plants or to connect them to the grid (Nurrahmat, 2024). Phase 1 of the tender – 485 PLTD in 94 locations totalling 116 MW to be converted into 165 MWp PV + 322 MWh BESS – has been awarded and is expected to operate by 2027 (IESR, 2024). Futures phase aim to add a total of 847 MWp PV and 1,693 MWh BESS to be commissioned by end of 2028 (Phase 2) and end of 2030 (Phase 3). These PV-BESS installations will serve to reduce diesel consumption and to replace PLTD whether partially or fully.

BESS has also been paired with on-grid VRE with many strategic projects due to be commissioned soon – the 50 MW PV + 14.2 MWh BESS in the new Indonesian capital (IKN) is expected to be operational by 2025 – with many more projects in the pipeline. Some of the high-profile projects include GW-scale PV + BESS projects in Riau Islands Province whose electricity would be exported to Singapore, and 70 MW Tanah Laut wind power plant (PLTB) + 10 MW/10 MWh BESS. Considering the relatively small capacity of the BESS (less than 1-hour of the VRE capacity), the BESS's primary function is likely to absorb the VRE intermittency.

Some high-end residential consumers who installed rooftop PV have also added BTM BESS as backup power, replacing diesel generators. The BESS can also store any excess PV energy during daytime, a desirable function since the removal of net billing in MEMR Regulation 2/2024. To date, there is no known Standalone BESS installation in Indonesia, perhaps partly due to lack of clarity in the regulation and commercial arrangement for Standalone BESS. That being said, in the new PLN RUPTL 2025–2034, 6 GW/27 GWh of BESS (and 4.3 GW of pumped hydro storage) is planned by 2034, which likely includes Standalone BESS (PT. PLN (Persero), 2025).

5.1. Existing Regulatory and Policy Framework of BESS in Indonesia

5.1.1. Overview of Electricity Business in Indonesia

The primary regulatory framework on electricity in Indonesia is Law No. 30 of 2009 on Electricity as lastly amended by Law No. 6 of 2023 on Enactment of Government Regulation in Lieu of Law Number 2 of 2022 on Job Creation into Law **(Omnibus Law)** (collectively referred to as **Electricity Law**) and its implementing regulations. Article 3 of Electricity Law stipulates that electricity is one of the most important and strategic production branches, and therefore, the electricity supply is controlled by the state while the operation is carried out by government and regional governments based on the principle of regional autonomy. This is to ensure that the implementation maximizes the welfare and prosperity of the people as mandated by the 1945 Constitution of the Republic of Indonesia.

The scope of business under Electricity Law and MEMR Reg 11/2021 covers: (i) Electricity Supply Business (either for public purposes or own use); and (ii) Electricity Supporting Business.

(a) Electricity Supply Business

(a) Electricity Supply Business for Public Purposes

Under Article 10 of the Electricity Law, there are four types of businesses under the scope of Electricity Supply Business for public use, namely: (i) electricity generation; (ii) electricity transmission; (iii) electricity distribution; and (iv) sales of electricity.

Electricity supply business that provides electricity for public interest in an integrated manner must be carried out by one business entity in a business area (wilayah usaha).[6] This includes the distribution and/or sale of electricity, which must also be carried out by one business entity in a business area.[7] The eligible business entities authorized to conduct the electricity supply for public interests include State-Owned Enterprises **(SOE),** regional-owned enterprises, private business entities, cooperatives, and non-governmental organizations.[8] While this seems to promote competition among multiple entities, in practice, PT PLN (Persero) **(PLN)** remains the primary electricity provider across Indonesia as the holder of most of the business area of Indonesia (other than those areas that have been specifically granted to an entity as may be approved by the Minister of Energy and Mineral Resources **(MEMR)**). This is mandated under Article 11 of Electricity Law that the government will give first priority to SOE operating in electricity supply sector (i.e., PLN) in the implementation of electricity supply for public purpose in Indonesia.[9]

Based on Article 33 of Electricity Law, the price of electricity purchased by Business Area holder **(Electricity Purchase Price)** must be stipulated based on the principles of fair competition. The holders of Electricity Generation Business License/Izin Usaha Penyediaan Tenaga Listrik untuk Kepentingan Umum **(IUPTLU)** must first obtain an Electricity Purchase Price approval from the central Government. Furthermore, based on Article 34 of Electricity Law, the central Government must stipulate the electricity tariffs for customers with the approval of House of Representative/Dewan Perwakilan Rakyat **(DPR)**.

To operate electricity supply business for public interest, the relevant company must obtain business licensing that is in line with its business activities, as follows:

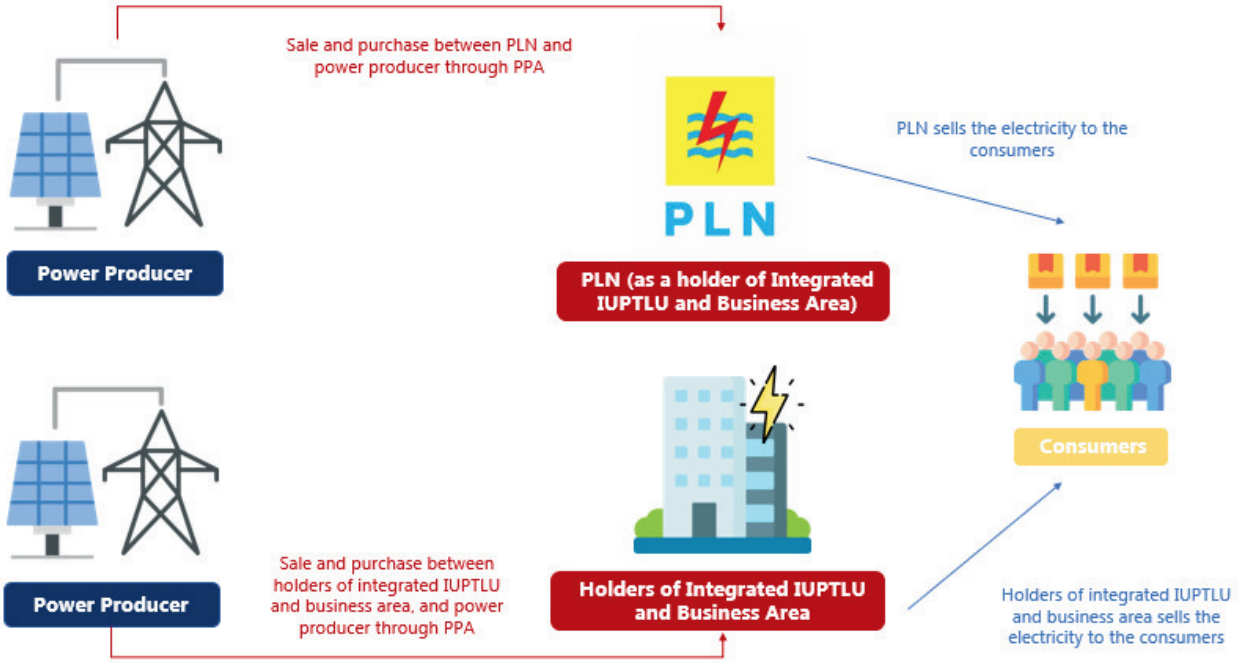
- IUPTLU, that serves as the primary license for operation of electricity supply business for public interest;[10]
- stipulation of business area, that is necessary for the operation of distribution and/or sale of electricity;[11]
- validation of Electricity Supply Business Plan/Rencana Usaha Penyediaan Tenaga Listrik **(RUPTL)** that serves as the plan for electricity provision, including the sectors of generation, transmission, distribution, and/or sale of electricity to customers within a business area.[12] RUPTL must be possessed by business area holders;[13] and
- license for export, license for import, and/or license for interconnection of cross-border electricity grid, that may only be obtained by holders of IUPTLU for electricity business activities that are operated in an integrated business.[14]

The connection between types of electricity supply business for public interest and their primary licenses are detailed in the table below:

[6] Article 10(3) of Electricity Law.
[7] Article 10(5) of Electricity Law.
[8] Article 11 of Electricity Law.
[9] Article 11 of Electricity Law.
[10] Article 1(4) of MEMR Reg 11/2021.
[11] Article 1(7) of MEMR Reg 11/2021.
[12] Article 1(9) of MEMR Reg 11/2021.
[13] Article 21 of MEMR Reg 11/2021.
[14] Article 36(1) of MEMR Reg 11/2021.

Types of Electricity Business	Primary Licenses
Electricity generation	Generation IUPTLU
Integrated Business 1 **Generation, transmission, distribution and sale of electricity in an integrated business**	1. Integrated IUPTLU. 2. Stipulation of Business Area. 3. Validation of RUPTL.
Integrated Business 2 **Generation, transmission and sale of electricity in an integrated business**	
Integrated Business 3 **Generation, distribution and sale of electricity in an integrated business**	

Below is the scheme of electricity supply power business under Electricity Law:



(b) Electricity Generation Business for Own Use

For electricity generation business for own use, the relevant business entity who intends to generate electricity for its own use (not for public purposes) with (i) total capacity more than 500 kW in one system of electricity installation, are required to secure Electricity Generation Business License for Own Use/Izin Usaha Penyediaan Tenaga Listrik untuk Kepentingan Sendiri **(IUPTLS)** from MEMR/governors, and (ii) capacity less than 500 kW, are only required to report to MEMR/governors.

(b) Electricity Supporting Business

Under Electricity Law – Article 16(1), electricity supporting business is part of electricity business, consisting of Electricity Supporting Service Business/Usaha Jasa Penunjang Tenaga Listrik **(UJPTL)** and electricity supporting industry business.

UJPTL consists of:[15]

1. consulting services in the field of electric installation;
2. construction and installation of electric installations;
3. inspection and testing of electrical installations;
4. operation of electrical installations;
5. maintenance of electrical installations;
6. research and development;
7. education and training;
8. testing laboratory for electrical equipment and electricity utilization;
9. certification of electrical equipment and electricity utilization;
10. certification of electrical engineering competency;
11. certification of electricity supporting service business entities; and
12. other services directly related to electricity generation.

BESS is expressly included as part of UJPTL for consultation, construction and installation, inspection and testing, operation, maintenance, education and training of power plants.

GR 25/2021 expands the scope of 'other services directly related to electricity generation' to at least include:

1. inspection and assessment of local content requirement in the electricity sector;
2. inspection and assessment of the implementation of electricity safety management system;
3. electricity environmental control;
4. electricity greenhouse gas emission control; and
5. inspection and assessment of compensation of land, buildings, and/or plants located under the clearance space of electricity transmission grid.

Article 42 of GR 25/2021 further states that other services directly related to electricity generation will be further stipulated in MEMR regulation. The applicable MEMR regulation for UJPTL currently is MEMR Reg 12/2021 regarding the Classifications, Qualifications, Accreditations, and Certifications of UJPTL.

UJPTL can be conducted by SOE, region-owned enterprises, private entities, public service agencies, and cooperatives.[16] Based on Article 32(3) of GR 25/2021, entities carrying out UJPTL must obtain business license for UJPTL and a certificate. Those entities must also obtain the relevant Indonesian Business Sector Classification/Klasifikasi Baku Lapangan Usaha Indonesia **(KBLI)**. Each classification of UJPTL may require different KBLI. For example, operation of electrical installations may require KBLI 35121 (Operation of Electric Power Supply Installation) or KBLI 35122 (Operation of Electric Power Utilization Installation) and maintenance of electrical installations may require KBLI 43211 (Electrical Installation).

[15] Article 16(1) of Electricity Law.
[16] Article 16(2) of Electricity Law.

5.1.2. Procurement Methods and Price Mechanisms Related to Battery Energy Storage Systems (BESS) Functions

According to PLN's Electricity Business Plan for 2025–2034 as ratified by MEMR on 26 May 2025 through the MEMR's Decree No. 188.K/TL.03/MEM.L/2025 on Ratification of PT PLN (Persero) RUPTL Year 2025 to Year 2034 **(New PLN's RUPTL),** the use of Hybrid BESS (in conjunction with VRE power plants) is intended to reduce power output fluctuations, minimize variability, and support power adequacy in accordance with demand, thereby enabling such systems to compete with conventional baseload power plants.[17] Applications of Hybrid BESS include, among others: (i) frequency regulation; and (ii) firming capacity.[18] New PLN's RUPTL now incorporates projects including but not limited to:

1. Sumatera: PLTS + BESS Natuna, with a capacity of 4 MW, which is targeted to achieve COD in 2027 and 2032[19] and PLTS + BESS Sinabang, with a capacity of 2 MW, which is targeted to achieve COD in 2028.[20]
2. Kalimantan: PLTS + BESS Kalseltengtimra-1, with a capacity of 80 MW, which is targeted to achieve COD in 2027[21] and PLTS + BESS Isolated Kalteng, with a capacity of 0.21 MW, which is targeted to achieve COD in 2033.[22]
3. Sulawesi: PLTS + BESS Isolated Sulawesi Utara, with a capacity of 3 MW, which is targeted to achieve COD in 2030[23] and PLTS + BESS Isolated Sulawesi Utara with a capacity of 19.07 MW, which is targeted to achieve COD in 2033.[24]
4. Java, Madura, and Bali: PLTS + BESS Goa-Goa, with a capacity of 0.15 MW, which is targeted to achieve COD in 2025[25] and PLTS + BESS Gili Raja, with a capacity of 0.4 MW, which is targeted to achieve COD in 2025.[26]
5. Maluku, Papua, and Nusa Tenggara: Distributed PLTS + BESS Lombok (Quota), with a capacity of 30 MW, which is targeted to achieve COD in 2030[27] and Distributed PLTS + BESS Sumbawa-Bima (Quota), with a capacity of 50 MW, which is targeted to achieve COD in 2027.[28]

5.1.3. BESS paired with VRE

<u>a. Existing Regulatory Framework in Indonesia on the Procurement Aspect of BESS paired with VRE</u>

If BESS is combined with variable renewable power plants, the procurement for electricity purchase from such BESS is conducted together with the procurement for electricity purchase from the variable renewable power plants. Electricity Law does not specifically provide any provision regarding procurement mechanisms for electricity purchase from renewable power plants. Under Article 25(2) of GR 14/2012, electricity procurement is conducted through public tender. Procurement for electricity purchase which is carried out for energy diversification purposes to power plants utilizing non-fuel oil energy sources may be conducted through a direct selection mechanism, as stipulated under Article 25(3) of GR 14/2012. It is understood that MEMR is of the view that Article 25(2) of GR 14/2012 applies if an existing oil/diesel power plant is diversified into non-oil power plant. Direct selection may also be carried out for electricity purchase from capacity expansion located in a different location within a local system with an already operational power plant. Such expansion may be carried out by an IUPTLU holder or a new business entity established by an interested developer.[29]

[17] PLN, Rencana Usaha Penyediaan Tenaga Listrik (RUPTL) PT PLN (Persero) 2025-2030, pg. II-25.
[18] PLN, Rencana Usaha Penyediaan Tenaga Listrik (RUPTL) PT PLN (Persero) 2025-2030, pg. II-25 – II-26.
[19] PLN, Rencana Usaha Penyediaan Tenaga Listrik (RUPTL) PT PLN (Persero) 2025-2030, pg. V-14.
[20] Ibid.
[21] PLN, Rencana Usaha Penyediaan Tenaga Listrik (RUPTL) PT PLN (Persero) 2025-2030, pg. V-32.
[22] PLN, Rencana Usaha Penyediaan Tenaga Listrik (RUPTL) PT PLN (Persero) 2025-2030, pg. V-33.
[23] PLN, Rencana Usaha Penyediaan Tenaga Listrik (RUPTL) PT PLN (Persero) 2025-2030, pg. V-38.
[24] Ibid.
[25] PLN, Rencana Usaha Penyediaan Tenaga Listrik (RUPTL) PT PLN (Persero) 2025-2030, pg. V-28.
[26] Ibid.
[27] PLN, Rencana Usaha Penyediaan Tenaga Listrik (RUPTL) PT PLN (Persero) 2025-2030, pg. V-45.
[28] Ibid.

Article 25(4) of GR 14/2012 also allows direct appointment for electricity purchase in certain circumstances, as follows:[30]

- procurement of electricity from **power plants utilizing renewable energy,** marginal gas, mine-mouth coal, and other local energy sources;
- procurement of excess electricity;
- procurement for local electricity systems in a crisis or emergency condition. A crisis or emergency condition in electricity supply refers to a situation where electricity supply capacity is insufficient to meet the demand in a particular region, which may be caused by, among other factors, load growth significantly exceeding electricity supply capacity, natural disasters, and/or conflicts/unrest. The determination of a crisis or emergency condition in electricity supply must be carried out in accordance with the applicable regulations in the energy sector; and/or
- capacity expansion at an already operational power plant located at the same site. The term "same site" refers to a location where the additional power generation capacity has facilities that can be partially shared with an already operational power plant. The capacity expansion at an already operational power plant located at the same site may be carried out by an electricity supply business entity or a new business entity established by a developer at the same location.

Particularly for renewable power plants, the procurement mechanisms for said electricity purchase are regulated in PR 112/2022. According to Article 14(4)(b) of PR 112/2022, procurement for electricity purchase from **PLTS or PLTB – regardless of whether (i) they are equipped with BESS or other ESS or not** and (ii) they utilize government-provided land or privately owned land, **must be conducted through a direct selection process.** Such direct selection is carried out through a lowest-price bidding mechanism based on the ceiling price and must be conducted transparently and fairly, without granting any privileges to any party.[31] Furthermore, PR 112/2022 regulates that the procurement process for electricity purchase must begin with the submission of documents and conclude with the signing of a Power Purchase Agreement **(PPA),** including document evaluation and Electricity Purchase Price negotiations, all of which must be completed within a maximum period of 180 calendar days.[32]

However, if the electricity purchase is made from **expansion of PLTS and PLTB,** the procurement uses **direct appointment** method. This method includes the submission of the required documents up to the execution of the PPA, including the evaluation process of the administrative, technical, and financial aspects, which must be completed within a maximum period of 90 calendar days.[33]

<u>b. Existing Regulatory Framework in Indonesia on the Pricing Aspect of BESS paired with VRE</u>

Ihe Electricity Law stipulates that Electricity Purchase Price, which consists of all costs associated with the sale of electricity from power plants, must be determined based on the principles of fair competition/business practice.[34] The approval of Electricity Purchase Price is granted by the central government or regional governments, in accordance with their respective authorities, based on the norms, standards, procedures, and criteria established by the central government.[35]

In line with the provisions set forth in the Electricity Law, GR 14/2012 stipulates that the Electricity Purchase Price must receive approval from the MEMR, governor, or regent/mayor (based on their authority), which can be in the form of a ceiling price.[36]

[30] Article 25(4) of GR 14/2012.
[31] Article 16(1) of PR 112/2022.
[32] Article 16(2) of PR 112/2022.
[33] Article 15 of PR 112/2022.
[34] Article 33(1) of Electricity Law.
[35] Article 33(2) of Electricity Law.
[36] Article 39(1) and (2) of GR 14/2012.

As for the Electricity Purchase Price from BESS paired with VRE, Article 10 of PR 122/2022 has specifically provides that for all capacities of PLTS and PLTB equipped with BESS or other ESS, the maximum Electricity Purchase Price from such hybrid PLTS/PLTB + BESS or other ESS is 160% of the VRE Electricity Purchase Price (i.e. the addition of BESS or other ESS could potentially increase the Electricity Purchase Price by 60%).[37] Such price is deemed as an Electricity Purchase Price approval from the MEMR.[38] However, if the price exceeds 160% of the Electricity Purchase Price, an approval from MEMR is required.[39]

Furthermore, Article 39(1) and (2) of MEMR Regulation No. 5 of 2025 on Guidelines for Power Purchase Agreements from Power Plants Utilizing Renewable Energy Sources (MEMR Reg 5/2025) stipulates that if a power plant utilizing VRE sources is equipped with BESS paired with VRE—where it is considered an inseparable part of the renewable power plant, the electricity sale and purchase transaction must be calculated based on the amount of energy recorded at the transaction point, either such energy originating from the power plant or from the BESS or other ESS.

c. Existing Regulatory Framework in Indonesia on the Operational Aspect of BESS paired with VRE

Under MEMR Reg 5/2025, IPP is obliged to replace BESS paired with VRE that has reached the end of its life cycle with a new BESS paired with VRE in order to maintain performance, where the replacement cost must be borne by IPP.[49] The new BESS paired with VRE must utilize technology that is the same as or superior to the old BESS paired with VRE.[50] Article 22(5) of MEMR Reg 5/2025 also indicates that solar, wind, and ocean energy power plants equipped with BESS or other ESS may be imposed with frequency penalty and ramp rate penalty.

Furthermore, usage of BESS is also recognized in MEMR Regulation No. 20 of 2020 on Grid Code, specifically under the Sulawesi power system grid code. The Sulawesi power system grid code requires operators (i.e., IPPs) of VRE power plants to provide a compensator in the form of BESS with a minimum capacity of 10% of the total capacity of the power plant being developed.[51]

[37] Article 16(1) of PR 112/2022.
[38] Article 16(2) of PR 112/2022.
[39] Article 15 of PR 112/2022.
[40] Article 40(1) and (3) of MEMR Reg 5/2025.
[41] Article 40(2) of MEMR Reg 5/2025.
[42] Appendix of MEMR 20/2020.
[43] Article 33(1) of Electricity Law.
[44] Article 33(2) of Electricity Law.
[45] Article 39(1) and (2) of GR 14/2012.
[46] Article 10(1) of PR 112/2022.
[47] Article 10(2) of PR 112/2022.
[48] Article 10(3) of PR 112/2022.
[49] Article 40(1) and (3) of MEMR Reg 5/2025.
[50] Article 40(2) of MEMR Reg 5/2025.
[51] Appendix of MEMR 20/2020.



5.1.4. Standalone BESS

Regarding Standalone BESS, the primary functions of Standalone BESS that have a major financial, operational, and environmental benefits are as follows:[52]

- Energy shifting/arbitrage;
- Resource adequacy/peak capacity and peaker replacement;
- Ancillary services, such as frequency regulation, voltage support, black start, and congestion relief.

In contrast to BESS paired with VRE, Standalone BESS is not specifically regulated under the electricity laws and regulations in Indonesia.

a. Existing Regulatory Framework in Indonesia on the Procurement Aspect of Standalone BESS

Energy arbitrage by Standalone BESS involves purchasing electricity from the grid and subsequently selling it back to the grid at a later period. Currently, there are no regulations specifically addressing procurement mechanisms for electricity purchase from Standalone BESS.

As for BESS's function for grid services, this may be considered as BESS developers providing services to support the grid. In this case, the procurement mechanism is subject to goods and services procurement mechanisms. The procurement mechanisms for goods and services are usually regulated in a company's internal regulations, but for SOEs (such as PLN), the goods and services procurement mechanisms are subject to Minister of SOE Regulation No. PER-2/MBU/03/2023 on Guidelines for Governance and Significant Corporate Activities of State-Owned Enterprises **(MSOE Reg 2/2023)**.

MSOE Reg 2/2023 provides for the procurement of goods and services carried out by SOEs whose financing is derived from the SOE budget. The procurement of goods and services can be carried out, among others, through:[53]

- **public tender/selection,** which is the procurement of goods and services that is widely announced through mass media to provide the widest opportunity for prospective providers who meet the qualifications to take part in the auction;
- **limited tender/selection,** which is the procurement of goods and services offered to limited parties with at least 2 bids;
- **direct appointment,** which is the procurement of goods and services carried out directly by appointing 1 provider or appointment through a beauty contest; or
- **direct procurement,** namely the procurement of goods and services carried out through the purchase of goods on the market based on market prices, including in this case e-purchasing.

Furthermore, Article 155(2) of MSOE Reg 2/2023 provides that a direct appointment may be made if it meets at least one of the following requirements:

- the goods and services are essential to the company's core performance and cannot be delayed (business critical assets);
- there is only one provider who can carry out the work as required by the user requirements or in accordance with the provisions of laws and regulations;
- the goods and services require knowledge-intensive continuity, where using and maintaining the goods and services requires knowledge continuity from the provider;

[52] "Standalone Battery Energy Storage: What You Need to Know," https://www.powerflex.com/blog/standalone-battery-energy-storage#:~:text=How%20Do%20Standalone%20Batteries%20Work,depends%20on%20a%20business'%20needs., accessed on 23rd of April 2025.
[53] Article 152(2) of MSOE Reg 2/2023.

- if the procurement of goods and services using public tenders/selections or limited tenders/selections has been carried out 2 times, but does not get the required provider or there are no parties that meet the criteria or there are no parties participating in the tender/selection;
- the goods and services are owned by an intellectual property rights holder or have an original equipment manufacturer's warranty;
- in the event of emergency handling for security, public safety, and the company's strategic assets;
- the goods and services are repeat order purchases, as long as the price offered is not disadvantageous and does not compromise the quality of the goods or services;
- for emergency handling due to natural disasters (force majeure), both local and national in nature;
- the goods and services are a continuation that technically constitutes a unity that cannot be broken down from work that has been carried out previously;
- the provider may be an SOE, a subsidiary of an SOE or an affiliated company of an SOE as long as the quality, price and purpose can be accounted for, and the goods and services required are products or services in accordance with the line of business of the provider concerned;
- procurement of goods and services in a certain amount and value determined by the board of directors with prior approval of the board of commissioners/supervisory board; and/or
- consulting services that are not previously planned to deal with certain problems whose nature of work implementation must be immediate and cannot be delayed.

Following the SOE's procurement of goods and services, MSOE Reg 2/2023 mandates that the implementation of the procurement of goods and services be set out in an agreement that clearly stipulates the rights and obligations of the parties or in another form of engagement between the user and the provider in accordance with the provisions of the applicable laws and regulations.[54]

b. Existing Regulatory Framework in Indonesia on the Pricing Aspect of Standalone BESS

With respect to pricing matters for Standalone BESS, PR 112/2022 only establishes the ceiling price for BESS paired with VRE.

From the perspective of goods and services procurement, MSOE Reg 2/2023 does not provide specific provisions on pricing matters in regards with goods and services procurement. However, MSOE Reg 2/2023 provides that if a procurement is categorized as a long-term goods and service procurement, pursuant to Article 154(2) MSOE 2/2023, the board of directors are allowed to propose a price adjustment in order to reach the reasonable price in accordance with (i) best practice; (ii) market condition; and/or (iii) price fluctuation of raw materials/fuel. MSOE Reg 2/2023 itself categorizes a long-term goods and service procurement as those which:[55]

- completion is more than 12 months or more than one budget year;
- provides more benefits if contracted for a period of more than one budget year and a maximum of three budget years;
- provides more benefits if contracted for a period of more than one budget year and a maximum of five budget years, based on criteria determined by the Board of Directors with the approval of the Board of Commissioners/Supervisory Board;
- requires long-term investment; or
- is routine in nature and must be available at the beginning of the year.

[54] Article 157(1) of MSOE Reg 2/2023.
[55] Article 154 (1) MSOE 2/2023.

As such, if the procurement of Standalone BESS fulfils the long-term requirement as stated above, then the board of directors may propose the price adjustment formula in the underlying agreement.

It is also understood that BESS operators may also purchase electricity from PLN to charge its BESS. In this case, BESS operators purchasing electricity from PLN could be considered as consumers. Hence, under the current regulatory framework, those BESS operators are subject to electricity tariff charged by PLN to end consumers under MEMR Regulation No. 7 of 2024 on Electricity Tariff Provided by PLN.

5.2. Project Precedents regarding BESS in Indonesia

To-date, there is a PPA that has been signed for PLTB using BESS, namely the 70 MW wind power project with 10 MWh battery energy in Tanah Laut, South Kalimantan (PLTB Tanah Laut). This project is carried out by PLN group together with partners to mitigate the intermittency of PLTB.[56] The partnership of various parties from within and outside the country is very much needed to realize Indonesia's commitment to achieving the expected energy mix target through accelerating the clean energy transition. For this reason, the realization of the PLTB Tanah Laut is targeted to support the achievement of the mix of new renewable energy sources, as well as to play a role in reducing CO_2 emissions by 220,000 tons per year and contributing to the achievement of the national CO_2 emission reduction target of 34.8%.[57] In the PLTB Tanah Laut project, the BESS is placed at the grid connection point to the power plant.

The procurement of electricity from BESS continues to progress. One such example is PT PLN MCTN, which is currently in the process of procuring BESS with capacities of 100 kW/100 kWh, 200 kW/200 kWh, 500 kW/500 kWh, 1000 kW/1000 kWh, and 2000 kW/2000 kWh.[58] This initiative aims to enhance grid reliability and support the broader integration of renewable energy through innovative and efficient energy storage solutions.[59]

Additionally, a recent project of 50 MW PLTS in Nusantara Capital City/Ibu Kota Nusantara **(IKN)** is also equipped with 14.2 MWh BESS **(PLTS IKN)**.[60] The PLTS IKN project is a shareholder assignment project to PLN Nusantara Renewables to support electricity in the planned IKN.[61]

PPA for electricity purchased from renewable power plants equipped with BESS usually governs the function of the BESS, components of the BESS, a standard operating procedure for the BESS, BESS price which is included in the electricity purchase price, and other related provisions.

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[56] "Siaran Pers Dukung Upaya Pemerintah Capai Bauran EBT di Tahun 2025 PLN dengan Total Eren - Adaro Power - PJBI Tandatangani Perjanjian Jual Beli Listrik untuk Proyek PLTB Tanah Laut Berkapasitas 70 MW," https://www.alamtri.com/files/news/berkas/2201/Siaran%20Pers%20-%20Penandatanganan%20Perjanjian%20Jual%20Beli%20Tenaga%20Listrik%20PLTB%20Tanah%20Laut.pdf

[57] "Siaran Pers Dukung Upaya Pemerintah Capai Bauran EBT di Tahun 2025 PLN dengan Total Eren - Adaro Power - PJBI Tandatangani Perjanjian Jual Beli Listrik untuk Proyek PLTB Tanah Laut Berkapasitas 70 MW," https://www.alamtri.com/files/news/berkas/2201/Siaran%20Pers%20-%20Penandatanganan%20Perjanjian%20Jual%20Beli%20Tenaga%20Listrik%20PLTB%20Tanah%20Laut.pdf

[58] PT PLN Mandau Cipta Tenaga Nusantara, "Battery Energy Storage System (BESS)," https://mctn.co.id/battery-energy-storage-system-bess/.

[59] Ibid.

[60] "Sembcorp dan PLN Resmikan PLTS Berkapasitas 50 MW dan Proyek BESS di IKN", https://hijau.bisnis.com/read/20250122/652/1833882/sembcorp-dan-pln-resmikan-plts-berkapasitas-50-mw-dan-proyek-bess-di-ikn.

[61] Ibid.



Initial Recommendations for BESS deployment in Indonesia

6.1. Context Overview

Indonesia is an archipelago with more than 17,000 islands, of which c.a. 900 are permanently inhabited. There are several power systems sizes, ranging from kW to GW scale such as Java-Bali, as well as multiple diesel-based small island systems. The varied system sizes, generation mix, generation cost and flexibility needs will lead to techno-economically feasible BESS use cases significantly varying per system.

The electricity generation is mainly coal-based, as shown in Figure 12. In 2023, coal represented 69% of total generation and the RE share was 16% (mostly from hydro, biofuels and geothermal). There are to date very few wind and solar power plants, however this is expected to change as targets from RUPTL 2025-2034 include 69.5 GW of new generation/storage capacity by 2034, 61% from RE (including: 17.1 GW solar, 7.2 GW wind, 11.7 GW hydropower, 5.2 GW geothermal) and 10.3 GW of storage (6 GW batteries and 4.3 GW pumped hydroelectricity storage). (Ministry of Energy and Mineral Resources, 2025) BESS applications in Indonesian power systems remain limited. Therefore, challenges are expected in the implementation of initial projects, whether technical, commercial, or otherwise. This section outlines some of the potential challenges as well as opportunities, considering the Indonesian context.

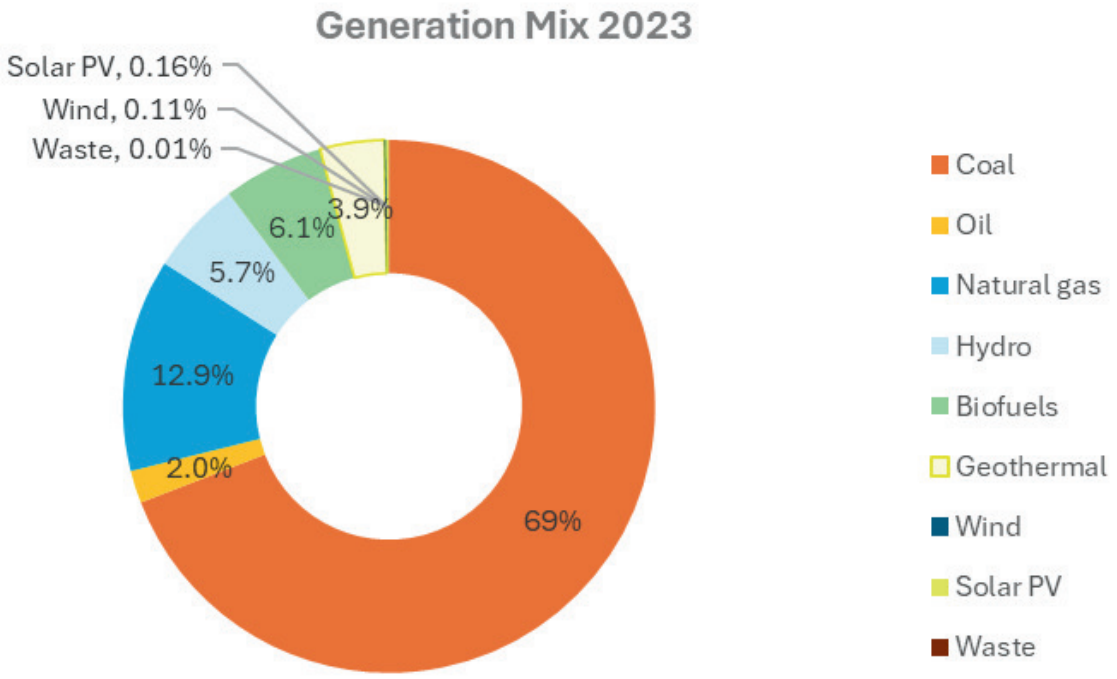


Figure 12: Indonesian electricity generation mix in 2023. Source: (IEA, 2025).

Regulatory and commercial challenges for BESS deployment

Indonesian regulations surrounding BESS are still evolving. Currently, Presidential Regulation 112/2022 regulates tariff ceiling for BESS paired with VRE to 160% of the VRE PPA (which might limit the size of BESS), while the Sulawesi Grid Code mandates that VRE installations include BESS with minimum capacity equal to 10% of the VRE's installed capacity. BESS is a versatile asset: it can act as a generator and a load, and can be installed at utility-scale as well as behind the meter. Hence, the regulations have to be sufficiently comprehensive and flexible in regulating BESS to allow further technological and commercial development. Clear regulations considering BESS ownerships, applications, and operations are necessary to facilitate BESS deployment in Indonesia. Section 5.1 further discusses the regulatory framework of BESS in Indonesia.

While regulations are necessary, they are not sufficient to facilitate BESS deployment; commercial frameworks are also needed to make BESS economically viable. Despite BESS being able to deliver enormous value, if the BESS is not rewarded for its services, no party will be interested to invest in BESS. Currently, Indonesian electricity sector has a single-buyer structure, where the monetary value of BESS' services is largely determined by the system operator. Moreover, there is no dynamic electricity price for generation, and limited time-of-use tariffs for industrial consumers. This means that energy arbitrage is not possible and that energy shifting needs to be incentivised by the system operator, if deemed valuable. Similarly, there is currently no commercial framework for procurement of ancillary services from private entities, whether they are generators, BESS, or otherwise. Ancillary services are provided by PLN assets and costs are considered in the average cost of generation (BPP – Biaya pokok penyediaan) calculation and recovered via tariffs.

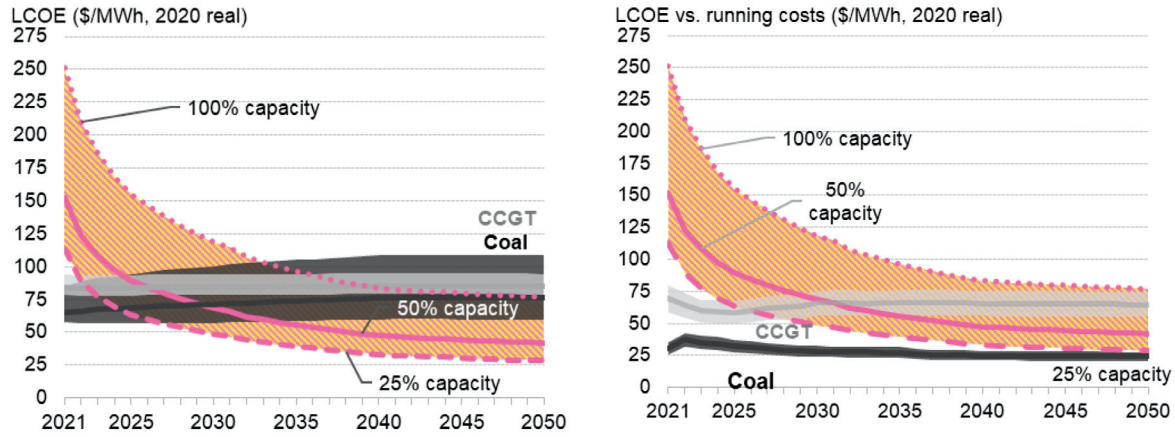
In addition to stable regulatory and commercial frameworks, BESS investors also need the project to be bankable and profitable. This may require guaranteed revenue, low/no risk of delayed payments, and revenue stacking from multiple services. If the commercial framework and project bankability are lacking, then subsidies or other financial incentives are required to enable BESS investment and installations by private entities. Depending on these factors, certain applications may be favoured in certain countries. For example, in China most deployments are for utility-scale BESS driven by government mandates, as well as large-scale commercial BTM BESS incentivised by subsidies and time-of-use tariffs (IEA, 2024). Meanwhile, in the European Union, most BESS deployed are BTM in residential areas because of the high retail electricity prices as well as tax breaks and low-interest loans for hybridising rooftop PV with BESS (IEA, 2024).

Potential opportunities for BESS deployment

Despite the challenges previously identified, potential opportunities for BESS deployment in Indonesia include:

- For BESS coupled with PV in Indonesia, (BloombergNEF, 2021) calculates that the LCOE is reaching cost competitiveness with new coal and gas projects by 2027 and with marginal costs of existing gas units by 2029, when considering a BESS power sized as c.a. 25% of the PV capacity, as shown in Figure 13.
- The Government is interested in becoming a Li-ion battery manufacturing hub, due to large Nickel resources, which would further reduce BESS investment costs nationally. However, the reliance on coal decreases the sustainability of production compared to competitors. (BloombergNEF, 2021).

- Some large Indonesian grids have surplus generation capacity (due to overbuild of coal), incurring large costs for unused capacity due to take-or-pay PPAs, where IPPs have guaranteed capacity payments regardless of utilization. Integrating higher shares of VRE into such systems increases the need for operational flexibility; Storage can help by shifting energy and providing fast balancing services, potentially reducing curtailment and integration costs.
- Grid congestions occur in certain islands (e.g. Sumatra) due to generation/load geographical mismatch. This is a potential use case for BESS, that could be investigated and compared to alternative solutions. Other potential use cases are explored in Section 6.2.



Source: BloombergNEF. Note: LCOE range for PV-plus-storage system represents storage sized between 25% and 100% of PV capacity. Does not account for additional costs incurred through local cost provisions on battery storage.

Figure 13: LCOE of PV paired with storage compared against LCOE of new (left) and short run marginal costs (right) of coal and gas plants. Source: (BloombergNEF, 2021).

6.2. Technology and Use Cases

As seen in the international examples, procurement processes keep the specific BESS technology open and specify the minimum technical requirements that it must be able to fulfil. This way, bidders can specify the BESS technology that best fits the technical requirements and application needs, at the lowest cost. A similar approach is recommended for Indonesia. In the examples analysed, Li-ion was the selected technology. Among the Li-ion subtypes, LFP is the dominant technology deployed globally today, and this trend is expected to continue at least by 2030 (IEA, 2024).

The BESS recommended use cases when the utility is the main beneficiary are defined by each specific power system technical needs (in terms of system adequacy, short-term flexibility and ancillary services) in consideration of cost reduction opportunities and planning targets (e.g. RE targets). If BESS is the recommended solution and if it is economical depends on a case-by-case analysis considering the characteristics of the specific power system and the regulatory context. In the international examples analysed, the utility identified a need for a grid support service and in most cases launched an RFP for ESS projects as part of competitive selection process.

When the utility owns the BESS, as seen in the examples of Sint Eustatius and Nantucket Island, there is flexibility to dispatch the BESS to provide services as needed to meet the needs of the power system. In the third-party-owned BESS examples analysed, many contract agreements also allow the utility to dispatch the BESS flexibly, to provide services as needed.

Given the context in Indonesia, potentially interesting BESS use cases were outlined in Section 3.3 For utility-scale BESS, standalone or paired with VRE, when PLN has the flexibility to dispatch the BESS, services that could be interesting and further investigated if there is a business case for applications in the short-term (COD next 1-5 years) include:

- BESS could reduce the BPP by doing **energy shifting (arbitrage)** to reduce variable PPA costs from existing contracts. This would require PLN to dispatch the BESS, as they are the only ones with BPP visibility.
- BESS can provide a **range of ancillary services (e.g. frequency regulation, voltage support, spinning reserves),** and provide faster response compared to conventional power plants. This capability may be sought by the utility especially in systems with higher VRE shares, less inertia and higher rate of change of frequency. For example, BESS can replace more expensive spinning reserves and reduce capacity payment of future PPA contracts, reducing BPP.
- BESS can provide the service of **grid congestion relief,** to avoid grid congestions that already occur in certain islands (e.g. Sumatra).
- BESS can contribute to load peak management by providing **peak capacity,** which can also support **deferring grid upgrade costs.** As mentioned in section 3.3.1, BESS is projected to become more cost competitive than gas turbine power plants (typically used as peakers) by 2030.
- For systems that reach higher VRE shares:
    - With expected high rise in PV share and the inflexibility of coal-fired generation (to ramp down and accommodate PV generation on a daily basis), BESS can support with **energy shifting (to increase VRE integration by shifting PV generation for later use and avoid RE curtailment).**
    - BESS can help reduce the dependency on imported fuels in small power systems, supporting VRE integration and taking over many grid support services from diesel generators, including contributing to diesel off operation via **grid-forming capability.**

Furthermore, a BESS paired with VRE can contribute **to smoothing VRE output (absorbing VRE intermittency)** to mitigate rapid fluctuations and help **meet ramp rate limits** set in grid codes/PPAs. The BESS can also smooth VRE output with the purpose to **correct VRE forecast** inaccuracy and avoid related performance penalties that might be set in PPAs. Neither of these require the BESS to be dispatched by the utility. The size of the BESS depends on the requirements it tries to fulfil and on typical unsmoothed VRE ramp rates observed at the specific location. Imposing BESS integration for VRE smoothing service is not common. BESS will naturally emerge as a business case for such service depending on the grid code/PPA requirements and penalties, where it makes techno-economic sense.

The list above is not exhaustive. A dedicated study is recommended, to identify the most interesting services and potential revenue streams for selected locations based on grid needs and, via a techno-economic analysis for selected locations and services, verify quantitatively if there are business cases for BESS and what the optimal BESS size is.

6.3. BESS Sizing

As indicated in Section 4.4.2, BESS power and energy sizing depends on several factors, including but not limited to:

- The provided grid support services and characteristics (energy based versus power based)
- The characteristics and needs of the power system (e.g. peak demand times, existing VRE penetration, grid flexibility needs)
- Economic considerations, including the trade-offs between BESS costs (especially CapEx) and potential revenue streams
- Capacity constraints at the substation or interconnection point that might limit BESS operation/size

The BESS is typically sized though a case-by-case techno-economic assessment, and this process is recommended for BESS in Indonesia. For each power system, the priority services need to be defined based on system needs and a detailed economic assessment conducted to define which BESS size is economically feasible for selected services and grid location (when location is relevant, e.g. voltage support, congestion management, etc). In this process, the optimal configuration (power and energy capacity) will be identified which fulfils the stacked services power/energy requirements and for which projected benefits/revenues most significantly outweigh the costs. PLN can define minimum BESS size requirements in their RFP based on the intended applications and system needs.

International examples show that systems with higher VRE shares tend to deploy BESS with longer durations (2-4+ hours), and when paired with VRE, the BESS power capacity in such systems often approaches or matches the PV peak capacity, leaving the BESS versatile to provide a range of stacked services, that combine both power and energy-based applications. In contrast, as VRE shares in Indonesia's larger power systems are currently low, BESS of shorter duration (e.g. 1-2 hours) might be sufficient in the short-term – similar to the Delhi and Alaminos examples, where BESS primarily supports frequency regulation and peak management. For VRE-paired BESS projects in these larger power systems, the economically optimal BESS-to-PV ratio may be less than 100% of PV peak capacity, but will depend on the service provided, on how much of the PV production is intended to be shifted for later use and on whether the BESS is allowed to charge from the grid.

Therefore, **optimal BESS sizing must be determined on a case-by-case basis, through detailed techno-economic analysis, considering location-specific grid needs, desired stacked applications, and power system characteristics (e.g. existing VRE shares, load curve, and existing generation fleet flexibility).**

Furthermore, in the international examples reviewed, there was **no mandatory BESS requirement in the regulation** (e.g. grid code) for VRE projects to include BESS, nor was there **a minimum BESS size** defined in the regulation when VRE was paired with BESS. Requiring in the regulation that VRE power plants must have a BESS is not aligned with international best practices. Instead, it was observed that the utilities may encourage or directly request BESS paired with VRE via each request for proposal, on a case-by-case and needs basis. Therefore, instead of setting a mandatory requirement for VRE plants to come with a certain BESS capacity, such as in the Sulawesi grid code, other strategies may naturally lead to BESS deployment when/where it makes techno-economic sense. These include, for example:

- Setting penalties in PPAs for VRE forecast errors, which might naturally motivate IPPs to install BESS for VRE smoothing in order to correct VRE forecast inaccuracies.
- Utility identifying power system needs and shaping competitive procurement processes for solutions, in which minimum requirements are defined and technology options are kept open. Such processes would ideally be based on system needs identified via an integrated resource planning process of the utility, such as in the Arizona example. When technically and economically feasible based on RFP conditions, BESS projects will compete.

6.4. Business Models (Ownership and Revenues Sources)

In terms of BESS ownership, third-party-owned BESS are recommended for PLN as they can provide dispatch flexibility without incurring the upfront capital investment or operational risks, and is the most common model as per international trends. A PLN-owned BESS would be recommended for locations where PLN identifies clear BESS use cases and if PLN is willing to make the capital investment on the BESS.

An analysis of potential business cases is recommended, which can consist of the following steps:

- For selected locations, define the most interesting services.
- Identify range of potential service values. The utility values could include deferring grid infrastructure upgrade, avoided PPA variable costs of existing contracts, avoided more expensive costs of new PPAs, avoided energy not served (e.g. linked to grid congestions), avoided fuel costs, etc. When the BESS is third-party-owned and provides services to the utility, the revenue stream will be from the contract with the utility.
- Conduct techno-economic assessments to quantify costs and benefits and verify if there is a potential business case for BESS in those locations considering grid characteristics. Select BESS size for which benefits are highest compared to costs.

A detailed techno-economic analysis is recommended to better identify the value from the project. The modelling approach can have varying complexity and the recommended model depends on the BESS applications and BESS project scale compared to the power system size. For example, (World Bank, 2020) indicates that detailed production simulations (comparing scenarios with and without the BESS) might be suitable when ancillary services is the main service, power system analysis might be suitable when deferral of transmission investment is the main service to assess reliability and stability impacts, and capacity expansion planning models or production simulations might be suitable to assess benefits of BESS providing peaking capacity. Whereas for small power systems, a spreadsheet analysis might be sufficient, e.g. to assess benefits of energy shifting. The approach highly depends on the case. When the interaction between BESS and VRE is relevant, the model must allow modelling sufficiently high temporal resolution.

6.5. Contracting Strategy and Procurement Method

6.5.1. Contract Type

For third-party-owned **BESS paired with VRE** in Indonesia providing services to the utility, **a hybrid PPA contract** model would be recommended. The BESS could support **smoothing the intermittent output of VRE** to meet PPA requirements (e.g. ramp rate limits or VRE forecast error correction) and, as VRE shares increase, also support **shifting PV energy** for evening use to increase RE integration and **avoid RE curtailment.** As outlined in Table 4 the utility may require limited dispatchability during certain periods, and the seller will typically reflect the additional cost for metered output, either by increasing the energy charge itself or by adding a separate "add-on" charge or the utility may motivate bidders to shift generation to peak times by setting a time-of-use tariff structure in the PPA.
In the hybrid PPA contract model, the BESS owner has the flexibility to use the BESS for other services as long as PPA requirements are met.

In the Philippines example, the BESS is co-located with the PV and therefore has separate revenue streams. The revenue streams of the BESS are mainly a capacity agreement for ancillary services with the utility and energy arbitrage in the wholesale energy spot market. The BESS contract was selected through a cost competitive selection process where the utility specifically procured ancillary services, technology agnostic, aiming to reduce AS costs. For Indonesia, the feasibility of a similar approach to the Philippines could be investigated further (i.e. launch separate competitive RFP for AS) for co-located BESS or standalone BESS.

In power systems that reach high VRE shares in Indonesia in the future, other contract models could become interesting to unlock more flexibility by e.g. granting the utility full dispatch control of the third-party-owned VRE+BESS, such as in the "RE dispatchable PPA" format in Hawaii, which is a capacity agreement. When the utility does not have dispatch control, it can require the BESS owner to provide a forecast subject to deviation penalties. For third-party-owned **standalone BESS** in Indonesia providing services to the utility, **a capacity agreement or tolling agreement** is recommended, depending on the intended use cases.

When multiple services are expected to be stacked, and/or when more dynamic/faster services are planned (e.g. frequency control, fast frequency response), **a tolling agreement may offer higher flexibility** for the utility, as the utility has **direct dispatch control over the full BESS capacity.** Furthermore, by allocating the charging costs to the buyer (utility) these costs don't have to be estimated in advance by the third party, which requires an estimation of how the BESS will be used.

On the other hand, when planned services are less dynamic (e.g. black start capability, deferral of transmission upgrades), and/or when the utility only requires the BESS availability for a limited duration or portion of the BESS capacity, and/or prefers not to control the BESS directly, **a capacity agreement** may be more appropriate. In this case, **the BESS owner retains operational control,** with the utility dictating the dispatch (e.g. via submitting a schedule such as in the Kilokari BESS case) in contracted periods and with penalties defined in the contract if dispatch instructions are not fulfilled.

As recommended in (World Bank, 2023), for either contract type, a detailed and robust cost-benefit analysis is recommended to better identify the value from the project and avoid being locked into long-term unsuitable capacity-based payments.

6.5.2. Procurement Method and Requirements

For Indonesia, it is recommended that the utility procures **standalone BESS and BESS paired with VRE** via a **competitive procurement process** with requirements as open as possible (e.g. **technology agnostic,** no BESS capacity specified, allowing the utility to have BESS dispatch flexibility such as in capacity agreements or tolling agreements) with the utility setting minimum technical conditions that must be fulfilled, to be defined aligned with its integrated resource plan. This allows bidders to propose the most techno-economically feasible solution. Setting a price ceiling in the regulation is not recommended, as will be explained in Section 6.6.1.

The utility can also steer the process to align with their RE targets, such as in the Arizona example where the utility indicated that the bids selected combined will meet their RE targeted capacities specified. In both cases, contracts could aim at a duration between 12 and 20 years, aligned with the international examples shown, which align contract durations with the BESS assumed calendar lifetime or with the VRE lifetime. For standalone BESS, having contract duration aligned with BESS calendar lifetime (i.e. 10–12 years) avoids the developer accounting for the replacement of the BESS considering presently known cost projections, which might be overestimated given the rapidly decreasing BESS costs. However, for BESS paired with VRE, longer contracts might be also considered, aligned with VRE lifetime, as recommended in (World Bank, 2023).

In terms of BESS cycles, it is recommended that PLN assesses the expected services in each case, to define the minimum number of cycles the BESS should be able to perform. To enable higher flexibility, specifying the number of minimum cycles per year as opposed to cycles per day in the contract would be recommended.

6.5.3. Procurement Method and Requirements

Currently in Indonesia, according to the presidential regulation No. 112 of 2022, **RE paired with BESS** will be procured under a purchase price ceiling, which varies based on type and capacity of RE (higher ceilings apply for smaller power plants). The pre-approved price of the hybrid RE + ESS plant is capped at 160% of the electricity purchase price for the RE. Prices higher than the cap must obtain a new approval from MEMR. Such ceiling prices are evaluated annually, considering the recent average contract value of PLN for each RE type. (UMBRA, 2022) **Standalone BESS** are not yet regulated in Indonesia and no such price ceiling currently applies.

Having a regulatory price ceiling on BESS brings several challenges, including:

- Setting a price ceiling might lead to sub-optimal BESS size installed or discourage its deployment completely, if the price ceiling is below true economic levelized cost of electricity (LCOE).
- BESS and VRE economics evolve differently and linking the BESS price ceiling to the RE LCOE is not recommended. For example, as shown in Figure 1, BESS costs can significantly vary from year-to-year due to the volatility of raw materials cost. Furthermore, linking these costs increases perceived financing risks because if VRE LCOE falls sharply, the allowable BESS ceiling tightens.
- Tying the BESS price ceiling to the production cost of VRE might not account for other BESS values besides e.g. VRE smoothing, such as transmission benefits, ancillary services, etc.

In the international examples reviewed, there was no explicit price ceiling in the regulation for BESS. Instead, cost competitive procurement processes are the common practice and set an implicit price ceiling which is market driven, subject to regulatory approval. The regulator reviews the selected project/bid for each procurement case and can reject it if deemed not cost effective or not in public's interest. This is the recommended practice for Indonesia for both standalone and BESS paired with VRE.

Furthermore, in third-party-owned BESS paired with VRE providing multiple services, in which the BESS is also used e.g. for ancillary services and/or for services where the dispatch is controlled by the utility, having **a separate meter for VRE generation** might be a solution to mitigate the issue of having the revenue (when paid based on exported energy from site) impacted by the dispatch decisions of the utility as this incurs roundtrip losses resulting from BESS (dis)charge, as recommended in (World Bank, 2023).

6.6. Cost/Pricing Structure

6.6.1. Current Price Ceilings for Hybrid Power Plants in Indonesia

Figure 14 shows current price ceilings for batteries paired with solar PV or wind, from the regulation No. 112/2022. For example, a hybrid power plant (HPP) consisting of a battery paired with a solar PV larger than 20 MW will have a PPA price ceiling of 0.0932 USD/kWh, which corresponds to 160% of the PV-only cost shown.

Solar PV Power Plant - with Battery

Capacity (MW)	Ceiling Price (HPT)																	
	(≤ 1 MW)			>1 MW s.d. 3 MW			>3 MW s.d. 5 MW			>5 MW s.d 10 MW			>10 MW s.d. 20 MW			>20 MW		
	Stg th 1-10	Stg th 11-30	Battery	Stg th 1-10	Stg th 11-30	Battery	Stg th 1-10	Stg th 11-30	Battery	Stg th 1-10	Stg th 11-30	Battery	Stg th 1-10	Stg th 11-30	Battery	Stg th 1-10	Stg th 11-30	Battery
(cent $/kWh)	11,47 x F	6,88	5,85	9,94 x F	5,97	5,07	8,77 x F	5,26	4,35	8,26 x F	4,96	4,09	7,94 x F	4,76	3,94	6,95 x F	4,17	3,49
LCOE c$/kWh)	9,75			8,45			7,25			6,83			6,56			5,83		

Wind Power Plant - with Battery

Capacity (MW)	Ceiling Price (HPT)								
	≤ 5 MW			>5 MW s.d 20 MW			>20 MW		
	Staging Year 1-10	Staging Year 11-30	Battery	Staging Year 1-10	Staging Year 11-30	Battery	Staging Year 1-10	Staging Year 11-30	Battery
(cent $/kWh)	11,22 x F	6,73	5,64	10,26 x F	6,15	5,16	9,54 x F	5,73	4,80
LCOE c$/kWh)	9,41			8,60			8,00		

Figure 14: Hybrid power plant PPA ceiling prices for ESS paired with PV or Wind. Source: Presidential Regulation No.112/2022 on Acceleration of Renewable Energy Development for Electricity Supply.

For a HPP to be economically feasible, it must be able to recover its full capital and operational costs within the applicable regulatory price ceiling. Price ceilings should therefore be set based on a careful assessment of expected costs and performance conditions; if set too low, they risk undermining the business case and discouraging deployment of battery-VRE HPPs.

In this context, ranges of LCOE and PPA values were calculated, accounting for sensitivities on key parameters. The intent is to provide a high-level basis for comparison with current regulatory ceilings, rather than a project-specific tariff recommendation. In addition to the calculations, two Excel-based tools were delivered to EBTKE to enable further explorations of how changes in key inputs affect LCOE and PPA outcomes, supporting future reviews and potential updates of price ceilings. The resulting LCOE and PPA ranges, together with the underlying inputs and assumptions, are presented in section 6.6.2.

Given that several parameters can vary significantly based on project location within Indonesia, plant configuration, installation year, and the characteristics of the services provided, the results shown should be interpreted with care. They are best understood as indicative ranges derived from the stated assumptions and sensitivities, intended to inform the ceiling setting discussion at a high-level. Their applicability to a specific project should be checked using site- and project-specific data and, where relevant, adjusted to reflect local conditions and the services required from the HPP.

6.6.2. Calculated LCOE and PPA values

(a) Input Parameters and Assumptions

The input parameters applied in the LCOE and PPA calculations are summarised in Tables 13 and 14. Values were derived from desktop research and feedback from Indonesian stakeholders, complemented by feedback from an international company with experience in VRE/BESS project development in the region. Alternative values are documented in Table 13, to provide an indication of potential ranges that could be tested in the tools.

Key assumptions:

- Java-Bali and Sulawesi were selected as reference locations for the PV-battery and wind-battery HPP cases, respectively, impacting the expected VRE energy yield.
- CapEx values represent utility-scale projects and exclude taxes.
- The BESS is assumed to charge only from co-located VRE (no grid charging).
- Two services are evaluated: energy shifting and VRE smoothing. The BESS-to-VRE power ratio, BESS duration and average daily cycles used to represent each service are provided in Table 14. These parameters are typically defined by local power system needs and/or established requirements (e.g. in grid codes, PPAs). As there are no requirements for VRE smoothing (e.g. VRE ramp-rate limits) defined in Indonesia and this ceiling analysis is not tied to a single power system context, the service assumptions should be treated as indicative. Sensitivity analyses are therefore recommended and were conducted in this study.

Table 13: Techno- economic input parameters for the calculations of HPPs LCOE and PPA price in Indonesia.

Technology	Parameter	Value	Unit	Sources
Li-ion BESS	CapEx	213 (2h) 174 (4h)	USD/kWh	Installed kWh cost based on global 2023 weighted average turnkey usable kWh cost in (IRENA, 2025). Alternative: 208 (4h) and 260 (1h) USD/kWh (partner assumption).[62]
	OpEx (fixed, yearly)	2.5	% of CapEx	(NREL, 2025)
	Lifetime	12	years	Stakeholders input. Alternative: 15 (NREL, 2025).
	Roundtrip efficiency	0.85	-	(NREL, 2025)
	Usable SoC range	0.80	-	(PNNL, 2022)
	CapEx replacement	165 (2h) 128 (4h)	USD/kWh	Derived using reduction on kWh and kW cost factors after 12 years from (NREL, 2025) for utility scale BESS, moderate scenario.
Ground-mounted PV	CapEx	750	USD/kWp	750-900 range indicated by stakeholders. Alternatives: 798 (2023 total installed cost for Indonesia in (IRENA, 2024)) and 650 (partner assumption).[63]
	OpEx (fixed, yearly)	15	USD/kW, year	Partner input (2% of CapEx).
	Energy yield (Java-Bali as reference)	1511	kWh/kWp, year	Indonesia large-scale PV average in (GSA, 2025). Java-Bali values 1200-1600 kWh/kWp,year.
	Lifetime	25	years	(IRENA, 2025)
	Degradation rate	1.2 (Y1) 0.8 (Yn)	%/year	Partner input. Alternative: 0.8% (year 1); 0.5% (other years) from (GSA, 2019).

[62] Cost includes equipment, balance of plant, logistics, CIF, installation and commissioning. Assumes use of Chinese equipment.
[63] For single axis tracking, bifacial modules, string inverters. Costs include equipment, balance of plant, logistics, CIF, installation and commissioning. Assumes use of Chinese equipment.

Technology	Parameter	Value	Unit	Sources
Onshore wind	CapEx	1800	USD/kW	1600-2200 range indicated by stakeholders. Alternatives: 1912 (2024 Asia average excl. China, India, Eurasia, (IRENA, 2025) and 1500-1700 (partner input).[64]
	OpEx (fixed, yearly)	60	USD/kW, year	(IRENA, 2025), 2024 international range average.
	Energy yield (Sulawesi as reference)	2400	kWh/kW, year	Highly depends on location and turbine configuration. Developer input for Sulawesi to GIZ. Alternative: 30% capacity factor (average for Indonesia in (IRENA, 2025)).
	Lifetime	25	years	(Fraunhofer, 2024)
	Degradation rate	0.36	%/year	(3E, 2025), fleet-wide.
Economic/ Project	Discount rate	0.06	-	EBTKE benchmark WACC.
	Project time	25	years	Selected to match VRE lifetime.

Table 14: Service-specific input parameters for the calculations of HPPs LCOE and PPA price in Indonesia.

Service	Parameter	Value	Unit	Comments
VRE smoothing	BESS and VRE power ratio	0.3	-	Value will depend on the smoothing application requirements (e.g. defined in grid code or PPA). 0.3 is an indicative value. To strictly meet ramp rate limit requirements, a higher value would be used.
	BESS duration	1	hour	-
	Average daily cycles for service provision	1	-	Depends on VRE resource characteristics. Typically less than 1 cycle/day for VRE smoothing. 1 cycle used as a conservative value for this ceiling analysis purpose (i.e. yielding larger BESS and costs).
VRE energy shifting	CapEx	1	-	Very power system specific. Sizing usually defined based on an optimization considering service benefits vs. BESS costs. Values assumed are indicative only.
	OpEx (fixed, yearly)	4	hours	
	Energy yield (Java-Bali as reference)	1	-	

[64] Costs include wind equipment, balance of plant, logistics, CIF, installation and commissioning. Assumes use of Chinese equipment. Cost depends on site selection and logistics challenges might increase costs.

Further considerations and modelling choices:

- Additional BESS CapEx values for other durations were derived from the Table 13 reference values by assuming that the kW and kWh cost factors are the same for 2025, aligned with the 2025 moderate scenario utility-scale BESS costs in (NREL, 2025). This yields installed costs of 284 USD/kWh (1h), 163 USD/kWh (6h) and 157 USD/kWh (8h).
- VRE replacement costs are only incurred when the project lifetime exceeds the vRE asset lifetime. As the project lifetime in this report is aligned with the vRE lifetime, vRE replacement is not applied in the results; however, the functionality is included in the Excel tool for future analysis.
- PV inverter replacement is assumed at 60 USD/kW (NREL, 2025; 2035 cost, utility-scale PV, moderate scenario), occurring at half the VRE lifetime. As a simplification, the same assumption is applied to wind power-conversion equipment. Where more detailed assumptions are available, these can be substituted in future analysis. A sensitivity done on this parameter, varying to 0% and 200% of the reference value, resulted in changes to the LCOE of only 1%–3%.

(b) LCOE Calculations

The LCOE was calculated using an annuity method, in which the capital expenditures are converted into an equivalent annual cost using a capital recovery factor and other parameters are also on an annual basis (e.g. the VRE energy yield used is the average yearly value considering degradation throughout the VRE's lifetime). The equations are described in the Annex.

A reference scenario was defined to represent the most appropriate set of inputs for this analysis, based on desktop research and stakeholder discussions. The reference scenario inputs are summarised in Tables 13 and 14. Sensitivity analyses were conducted on the parameters considered most critical, while all other parameters remain unchanged from the reference scenario. The parameters varied in each sensitivity case are listed in Figure 15. The optimistic and pessimistic cases represent combined variations in CapEx, energy yield, and discount rate. The larger-BESS and smaller-BESS cases represent variations in the BESS sizing assumptions per service. Additional sensitivity cases are encouraged to be explored by stakeholders using the provided Excel tools.

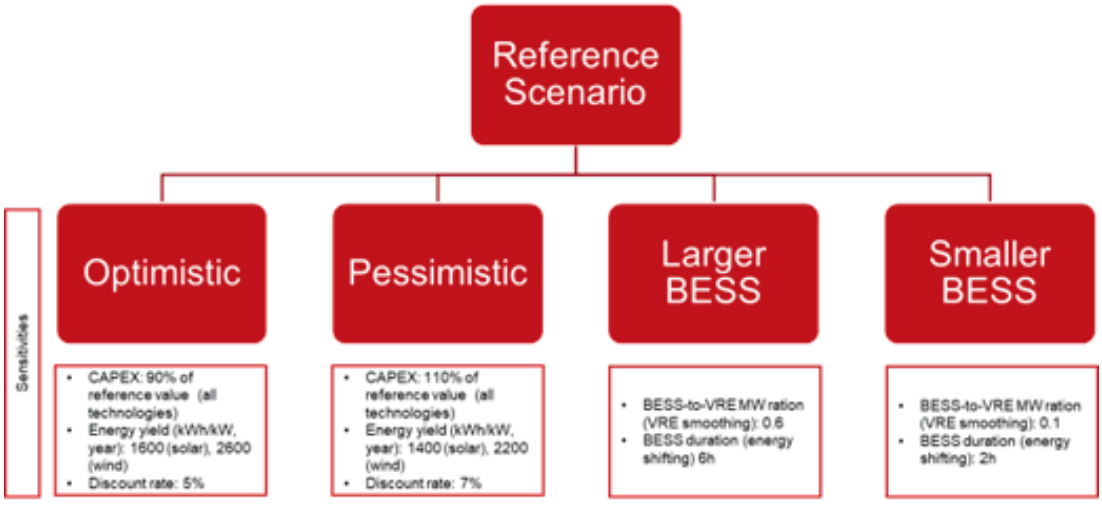


Figure 15: Sensitivity analysis overview and parameters changed.

The BESS was assumed to charge exclusively from the co-located VRE plant. Depending on the selected BESS sizing and service requirements, the available VRE generation may be insufficient to supply the required BESS charging energy (i.e. the service becomes energy constrained). This occurred for the energy shifting service in the larger-BESS sensitivity (6h duration). To ensure feasibility under the "charge-from-VRE-only" constraint, the BESS-to-VRE power ratio was reduced to 0.75, such that the specified average cycles per day could be met without requiring grid charging.

The LCOE results by service for the PV-battery and wind-battery HPP cases are presented in Figures 16 and 17, respectively. For reference, the LCOE of the VRE plant without a battery is also shown.

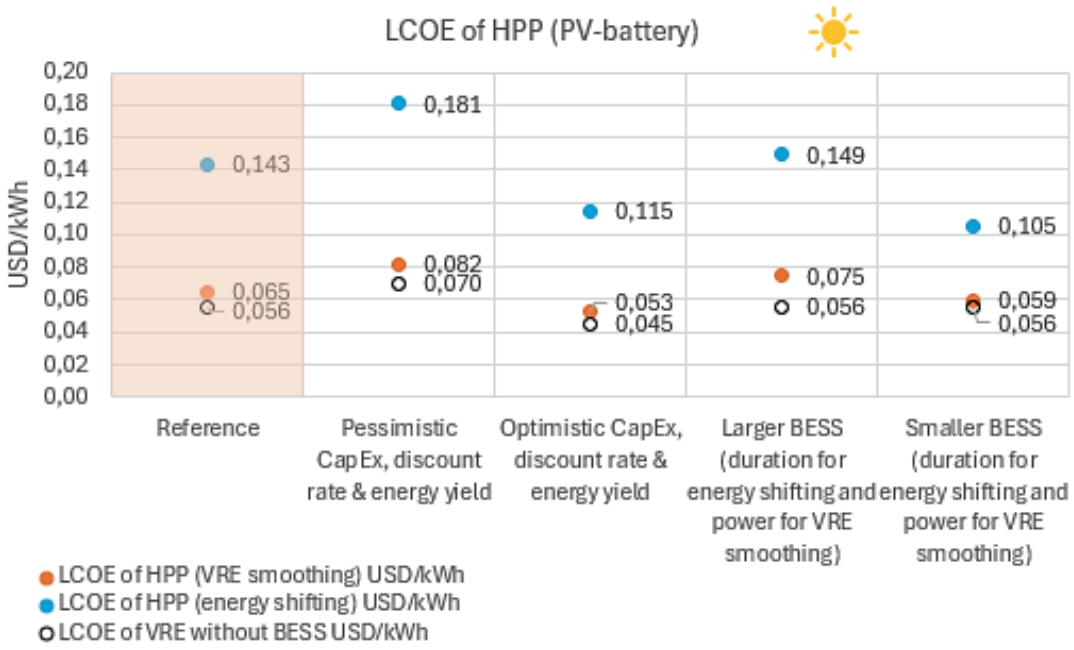


Figure 16: LCOE of HPP (PV-battery) for reference scenario and sensitivities.

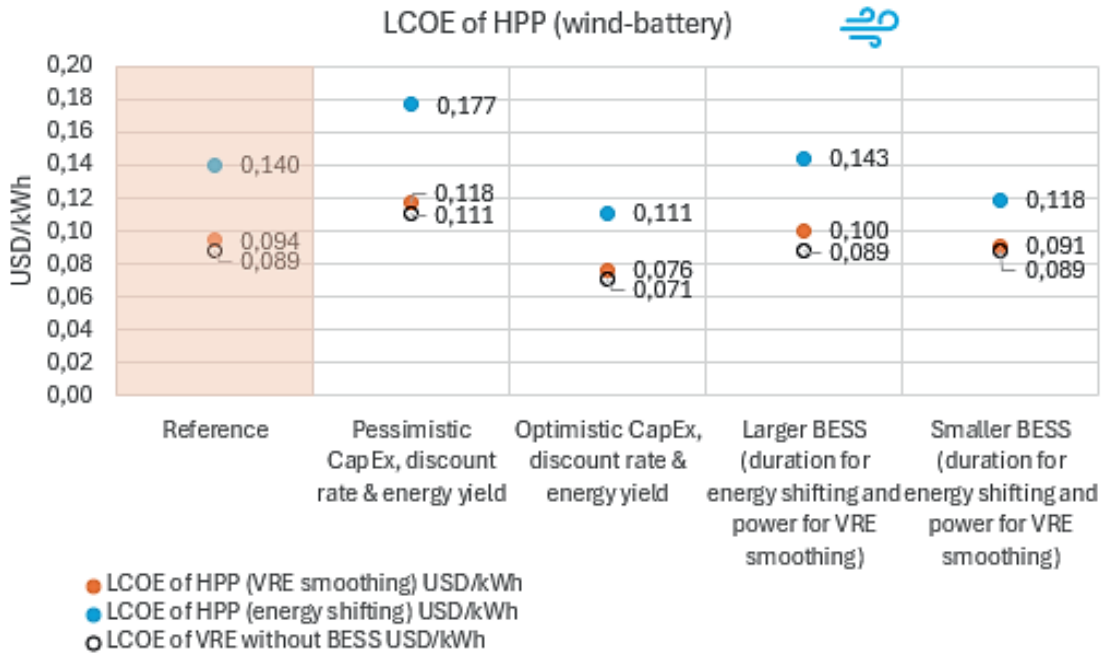


Figure 17: LCOE of HPP (wind-battery) for reference scenario and sensitivities.

The LCOE represents the average cost per unit of electricity delivered over the HPP lifetime. Comparing the calculated LCOE ranges to the applicable regulatory LCOE ceilings provides an initial indication of whether the ceilings are high enough to allow recovery of total CapEx and OpEx under the study assumptions, assuming the PPA is the sole project revenue stream.

Table 15 compares the reference scenario LCOE (bold) and sensitivity ranges to the current LCOE ceiling ranges, which vary by VRE plant size (see Figure 14).

Table 15: LCOE in reference scenario (bold) and sensitivity ranges compared to current LCOE ceiling ranges.

	LCOE ranges [USD/kWh] (optimistic – reference – pessimistic)		LCOE regulatory ceiling ranges [USD/kWh]
	VRE smoothing	Energy shifting	
Solar-battery HPP	0.053 - 0.065- 0.082	0.105 - 0.143 - 0.181	0.093 – 0.156
Wind-battery HPP	0.076 - 0.094 - 0.118	0.111 – 0.140 - 0.177	0.128 – 0.150

From Table 15, the VRE smoothing service yields LCOE values below the lowest price ceiling even under pessimistic assumptions, indicating that HPP costs can be recovered within current LCOE ceilings for a battery sized for smoothing (subject to the assumptions of this study). On the other hand, the energy shifting service requires a larger BESS and therefore results in higher LCOE values. In the reference scenario, the LCOE of the energy shifting case is below the price ceiling only for the smallest project size band (≤ 1 MW for solar and or ≤ 5 MW for wind), which correspond to the highest regulatory ceilings. Under optimistic assumptions, the LCOE remains at or above the ceiling in most size bands (except for solar projects > 20 MW). Under pessimistic assumptions, the LCOE exceeds the ceiling across all VRE size bands in the regulation.

Considering the reference scenario as the main indicator, and within the assumptions applied, adding a smaller battery in the HPP for VRE smoothing appears compatible with cost recovery under current LCOE ranges in PR 112/2022. For energy shifting, cost recovery under the ceilings is only possible for small VRE projects (≤ 1 MW solar or ≤ 5 MW wind), due to the larger battery required and associated larger costs.

The next section translates the LCOE assumptions into required PPA prices under different financing terms and target internal rate of return.

(c) PPA Calculations

Using the same input parameters and assumptions used to calculate the LCOE, PPA prices, based on desired IRR and loan arrangement, can also be calculated. Examples of PPA prices calculated for PV with BESS and wind with BESS are outlined in Table 16 and Table 17, respectively. Interest rates 4.2857% and 7.3009% have been chosen to obtain WACC value of 6% and 8% respectively, given 70/30 equity/debt ratio and cost of equity of 10%. Debt tenors of 5 and 7 years are based on local banks' lending duration while 15 years represents common lending duration of development banks. Finally target IRR of 9% and 12% are based on values for government or regulated projects.

(c) PPA Calculations

Using the same input parameters and assumptions used to calculate the LCOE, PPA prices, based on desired IRR and loan arrangement, can also be calculated. Examples of PPA prices calculated for PV with BESS and wind with BESS are outlined in Table 16 and Table 17, respectively. Interest rates 4.2857% and 7.3009% have been chosen to obtain WACC value of 6% and 8% respectively, given 70/30 equity/debt ratio and cost of equity of 10%. Debt tenors of 5 and 7 years are based on local banks' lending duration while 15 years represents common lending duration of development banks. Finally target IRR of 9% and 12% are based on values for government or regulated projects.

Although Table 16 and Table 17 have outlined the PPA prices for predetermined parameters, in the given excel tool, both the technical and financial inputs can be modified to automatically calculate the PPA prices based on the modified inputs. Therefore, the tool will remain useful even after substantial changes in technologies and market conditions. Using the PPA prices calculated for a range of different scenarios and input parameters, MEMR can make more informed decisions when updating the PPA prices listed in the Presidential Regulation No.112/2022.

Table 16: PPA prices for PV with BESS for a range of interest rates, debt tenors and target IRR.

	PPA price for BESS 1h (VRE smoothing) [USD cent/kWh]		PPA price for BESS 4h (VRE energy shifting) [USD cent/kWh]	
	Target IRR 9%	Target IRR 12%	Target IRR 9%	Target IRR 12%
Scenario 1: Interest rate 4.2857%, Tenor 5 years	9.844	10.824	14.513	15.775
Scenario 2: Interest rate 4.2857%, Tenor 7 years	9.675	10.520	14.276	15.351
Scenario 3: Interest rate 4.2857%, Tenor 15 years	9.126	9.609	13.509	14.076
Scenario 4: Interest rate 7.3009%, Tenor 5 years	10.188	11.219	14.993	16.328
Scenario 5: Interest rate 7.3009%, Tenor 7 years	10.133	11.036	14.916	16.071
Scenario 6: Interest rate 7.3009%, Tenor 15 years	9.950	10.472	14.661	15.283

Table 17: PPA prices for wind with BESS for a range of interest rates, debt tenors and target IRR.

	PPA price for BESS 1h (VRE smoothing) [USD cent/kWh]		PPA price for BESS 4h (VRE energy shifting) [USD cent/kWh]	
	Target IRR 9%	Target IRR 12%	Target IRR 9%	Target IRR 12%
Scenario 1: Interest rate 4.2857%, Tenor 5 years	12.583	13.901	15.393	16.897
Scenario 2: Interest rate 4.2857%, Tenor 7 years	12.377	13.531	15.147	16.454
Scenario 3: Interest rate 4.2857%, Tenor 15 years	11.712	12.419	14.351	15.122
Scenario 4: Interest rate 7.3009%, Tenor 5 years	13.000	14.383	15.893	17.474
Scenario 5: Interest rate 7.3009%, Tenor 7 years	12.933	14.159	15.813	17.206
Scenario 6: Interest rate 7.3009%, Tenor 15 years	12.711	13.472	15.547	16.383

6.7. Suggested Regulatory Improvement for BESS paired with VRE and Stand-Alone BESS in Indonesia

6.7.1. BESS Paired with VRE (Hybrid BESS)

The majority of the recommendations for Hybrid BESS elaborated in Section 6 is related to the technical performance and pricing aspect of the Hybrid BESS. In relation to the pricing, if the recommendations in Section 6 for Hybrid BESS are adopted, an amendment to PR 112/2022 will be needed. One recommendation for Hybrid BESS under Section 6 that is worth exploring from the Indonesian law perspective is the possibility of Hybrid BESS to provide a separate ancillary service to PLN.

The developer of the Hybrid BESS providing ancillary services will be Generation IUPTLU holders. We have prepared a study regarding ancillary services provisions as well for MEMR which can complement this section **(AS Study)**. Our legal recommendations in the AS Study are based on comparative legal study against ancillary services provision in Philippines and Singapore Law. Essentially, benchmarking from Singapore and Philippines Law, Generation IUPTLU holders developing Hybrid BESS can provide ancillary services (separate from the PPA) to PLN via a separate procurement process. The Hybrid BESS developers will enter into an Ancillary Services Provision Agreement **(ASPA)** with PLN. To separate Generation IUPTLU holders that only sell electricity to PLN under PPA with Generation IUPTLU holders that sell electricity to PLN under PPA and provide ancillary services to PLN under ASPA, the Generation IUPTLU holders providing ancillary services to PLN using its Hybrid BESS may register with MEMR to obtain a registration letter or obtain an ancillary service certificate from an accredited agency.

Please see the AS Study for the complete elaboration on this. Essentially, amendment to GR 14/2012 and a minister regulation specifically of ancillary services will be necessary to accommodate the above arrangements. Amendment to Law 30/2009 may not be necessary because Generation IUPTLU holders providing ancillary services can still be argued as producing electricity, which aligns with the definition of electricity generation activity under Law 30/2009.

6.7.2. Stand-Alone BESS

Based on Section 6.4, there are two business models recommended for BESS: (i) PLN-owned BESS for locations where PLN identifies clear BESS use cases and if PLN is willing to make the capital investment on the BESS; and (ii) third party-owned BESS which could provide dispatch flexibility without incurring the upfront capital investment or operational risks. This section will assess the regulatory improvement or legal reform necessary for these two BESS business models.

(a) PLN-Owned BESS (Scheme 1)

<u>i. Implementation of Scheme 1</u>

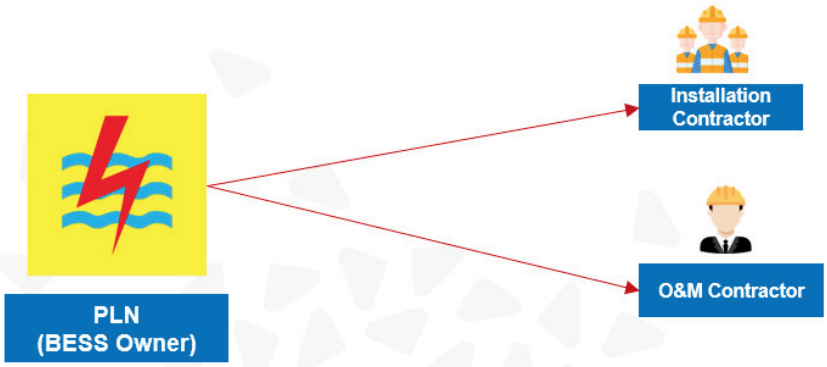
Scheme 1 can be carried out through the following mechanism:

1. Option A (PLN owns the BESS and operates the installation and O&M for its BESS)



- PLN acts as the owner of the Stand-Alone BESS.
- PLN operates the installation and operation and maintenance **(O&M)** of the Stand-Alone BESS without engaging the contractors.

2. Option B (PLN owns the BESS and engages with an installation and O&M contractor)



- PLN acts as the owner of the Stand-Alone BESS.
- PLN may enter into contracts with contractors for (i) the installation of the Stand-Alone BESS, and (ii) the O&M of the Stand-Alone BESS.

ii. Types of Business Activities

For both Option A and Option B, the Stand-Alone BESS developed by PLN may be categorized as an electricity transmission activity. Based on Article 1(5) of Electricity Law and Article 1(3) of GR 14/2012, electricity transmission is defined as the delivery of electricity from generation to the distribution system or to consumers, or the delivery of electricity between systems.

Although not expressly regulated, we understand from discussion with several technical consultants regarding the Study that PLN currently has been conducting transmission activity for the purpose of grid stabilization by way of purchasing and distributing electricity from IPP. Construction of Stand-Alone BESS projects owned by PLN is also planned in New PLN's RUPTL. One of the projects is 4x50 MW BESS development in Sumatera where the purpose of its project is to stabilize the grid. Therefore, if PLN operates the Stand-Alone BESS for the purpose of grid stabilization, this could arguably be considered as part of electricity transmission activity as well. The Stand-Alone BESS is used to store electricity from the grid which will then be distributed when needed. Given that in practice, PLN has been conducting transmission activity for the purpose of grid stabilization, arguments can be made that such grid stabilization activities using Stand-Alone BESS within the current electricity regulatory framework is legally possible. Nevertheless, for legal clarity and prudent purposes, MEMR may consider amending GR 14/2012 to clarify that transmission activity also includes transmission of electricity from the power plant to a Stand-Alone BESS for storage, before it is delivered to the distribution system for consumers or used for inter-system transmission.

The amendment should clearly distinguish transmission activity conducted by transmission owners and transmission activity conducted by PLN or other integrated IUPTLU holders as Stand-Alone BESS owners. This aims to ensure that the inclusion of Stand-Alone BESS in the electricity transmission activity does not mean elimination of the transmission activity conducted using transmission grid. Amendment to Electricity Law is also arguably not needed because the Stand-Alone BESS development does not change the definition of transmission activity nor changes provisions relating to transmission activity under Electricity Law.

Furthermore, MEMR Reg 5/2021 defines the scope of KBLI 35112 (Electricity Transmission) as operation of transmission system or electricity distribution from power plants to distribution grid through high voltage (35 – 150 kilovolt) and/or extra high voltage (150 – 500 kilovolt) and/or ultra high voltage (above 500 kilovolt) electricity grid, including substation, either from its own production or other party's production. Although KBLI 35112 is not relevant for both Option A and Option B (as further elaborated in Section 6.7.2(a)(iii) of this report), this scope indicates that the voltage range for transmission system is above 35 kilovolt. Based on discussions with GIZ's technical consultant, it is understood that the output produced from the transformer as part of BESS can be higher than 35 kilovolt, which aligns with the voltage range for transmission system as set out under MEMR Reg 5/2021.

iii. Applicable KBLI

Each business activity in Indonesia must be classified under certain KBLI codes, each of which carries specific legal implications such as the types of licenses, permits, and/or certificates required, as well as the associated risk levels.

For both Option A and Option B, the relevant KBLIs are as follows:

KBLI Code[65]	Description[66]	Business License[67]
KBLI 35115 – Generation, Transmission, Distribution, and Sale of Electricity as an Integrated Business Undertaking	The activities consisting of the generation of electricity, the transmission and distribution of electricity through transmission and distribution networks, and the sale of electricity to end consumers, which are carried out as an integrated business undertaking.	Integrated IUPTLU
KBLI 35116 – Generation, Transmission, and Sale of Electricity as an Integrated Business Undertaking Note: We also propose amendment to KBLI 35116 to accommodate Stand-Alone BESS development by Wilus holders other than PLN who hold KBLI 35116.	The activity of generating electricity, transmitting electricity through a transmission network, and selling electricity to end consumers, carried out as an integrated business undertaking	Integrated IUPTLU

Under both Option A and Option B, PLN can still use its existing KBLI and Integrated IUPTLU since Stand-Alone BESS development is considered part of transmission activity. For legal certainty and prudent purposes, KBLI 35115 and KBLI 35116 can be amended to clarify that the development of Stand-Alone BESS constitutes part of transmission activities. Such clarification should be implemented through amendments to the following regulations: (i) GR 28/2025; (ii) MEMR Reg 5/2021; and (iii) BPS Reg 2/2020.

iv. Licenses

Given that integrated electricity supply business is classified as high-risk business activities, the licensing requirements for PLN for both Option A and Option B consist of a NIB and integrated IUPTLU.[68]

PLN can still use its existing Integrated IUPTLU. However, if additional requirements are needed relating to the Stand-Alone BESS development, such additional requirements will require an amendment to GR 14/2012, GR 28/2025, and MEMR Reg 5/2021.

v. Cooperation with Contractors

Under Option B, PLN may engage with contractors for the installation and O&M of Stand-Alone BESS. There are several important notes in relation to such cooperation:

Type of Electricity Business Conducted by Contractors

Under Option B, if the installation and O&M of Stand-Alone BESS will be conducted by contractors, this may be considered as electricity supporting business or UJPTL. Law 30/2009 and GR 25/2021 set out a list of electricity supporting businesses, including: (i) electricity construction and installation; and (ii) electricity operation. Both UJPTL are classified into 4 sectors:

- electricity generation;
- electricity transmission;
- electricity distribution;
- electricity utilization installation; and
- other installations directly related to electricity installation.

[65] Appendix of BPS Reg 2/2020 and Appendix of GR 28/2025.
[66] Appendix of BPS Reg 2/2020.
[67] Article 10 of GR 14/2012.
[68] Article 10(1) of GR 14/2012.

As elaborated in Section 5.1.1(b) of this report, the prevailing regulations stipulate certain activities considered as UJPTL and installation and O&M of Stand-Alone BESS is not expressly regulated as UJPTL. We note that BESS is considered as part of UJPTL for electricity generation construction and installation as well as operation.

However, if Stand-Alone BESS development is considered as transmission activity, the UJPTL relating to installation and O&M BESS should fall into electricity transmission sector of electricity construction and installation and electricity operation.

Therefore, in enabling the Option B, an amendment to GR 25/2021, MEMR Reg 11/2021 and MEMR Reg 12/2021 will be required to add BESS as part of electricity transmission sector of electricity construction and installation and electricity operation.

KBLI

Below is the KBLI typically used by construction and O&M contractors for power plants:

KBLI Code[69]	Description[70]	Business License[71]
KBLI 35121 – Operation of Electricity Supply Installations	The activities involving the operation by a third party of facilities for electricity generation, electricity transmission systems, and electricity distribution systems.	• Electricity Support Services Business License/Izin Usaha Jasa Penunjang Tenaga Listrik (IUJPTL) • Certificate of Electricity Support Services Business Entity/Sertifikat Badan Usaha Jasa Penunjang Tenaga Listrik (SBUJPTL) • Competency Certificate/Sertifikat Kompetensi Tenaga Teknik Ketenagalistrikan (SKTTK)
KBLI 43211 – Electrical Installation	The activities cover construction, installation, maintenance, and reconstruction of electrical installations in power plants, transmission systems, substations, electricity distribution, power supply systems, and building electrical installations, whether residential or non-residential, including the installation of low-voltage electrical networks.	

KBLI 35121 and KBLI 43211 can still be used for contractors engaged by PLN, but it will need to be amended to specifically include the installation and O&M of Stand-Alone BESS. Such amendment is conducted through the amendment to GR 28/2025, BPS Reg 2/2020, and MEMR Reg 5/2021.

If Stand-Alone BESS construction involves civil construction, an amendment to KBLI and licenses related to civil construction for power plants and Stand-Alone BESS may also be needed.

Licenses

Specifically for the operation of installation and O&M of Stand-Alone BESS, both KBLI 35121 and KBLI 43211 are classified as high-risk business activities, hence requiring NIB and operational licenses.[72] Specifically, for operational purposes, the contractor must obtain the following:

- IUJPTL;[73]
- SBUJPTL, which will be issued through a certification process held by the Agency Certification of Business Entity/Lembaga Sertifikasi Badan Usaha (LSBU);[74] and
- SKTTK.[75]

[69] Appendix of BPS Reg 2/2020 and Appendix of GR 28/2025.
[70] Appendix of BPS Reg 2/2020.
[71] GR 62/2012.
[72] Article 133 of GR 28/2025.
[73] Article 3(2) of GR 62/2012.
[74] Article 45(2) of GR 25/2021
[75] Article 19(1) of GR 62/2012.

Hence, the contractors installing and conducting O&M of Stand-Alone BESS for PLN will need to obtain IUJPTL, SBUJPTL, and SKKTK for its technicians. However, MEMR Reg 12/2021 may need to be amended to include the qualifications and accreditation for the contractors and its technician, as well as the certification for the SBUJPTL and SKTTK, for the construction and O&M of the Stand-Alone BESS.

Procurement

Given that the contractors will provide services in the form of construction and O&M of Stand-Alone BESS, PLN may conduct its typical goods/services procurement to engage with such contractors. Such procurement is subject to MSOE Reg 2/2023 and its internal regulations on goods and services procurement. Please refer to Section 5.1.4(a) of this report for further elaboration.

Pricing

The fee paid by PLN to the contractors for the construction and O&M of Stand-Alone BESS can be considered as service fee that can be agreed by the parties.

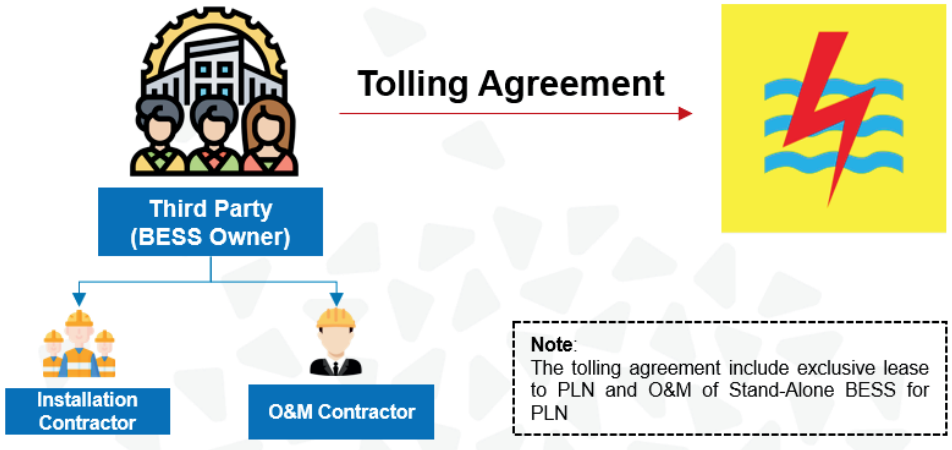
(b) Third-Party Owned (Scheme 2)

<u>i. Implementation of Scheme 2</u>

Scheme 2 can be carried out where a third-party acts as the owner of a Stand-Alone BESS and may enter into a contract with PLN or another relevant party for the operation of the Stand-Alone BESS. Based on Section 6.5.1, the recommended contract type for Scheme 2 is either: (i) capacity agreement where the Stand-Alone BESS developers retain operational control while PLN dictates the dispatch in contracted periods or (ii) tolling agreement where PLN has direct dispatch control over the full Stand-Alone BESS capacity.

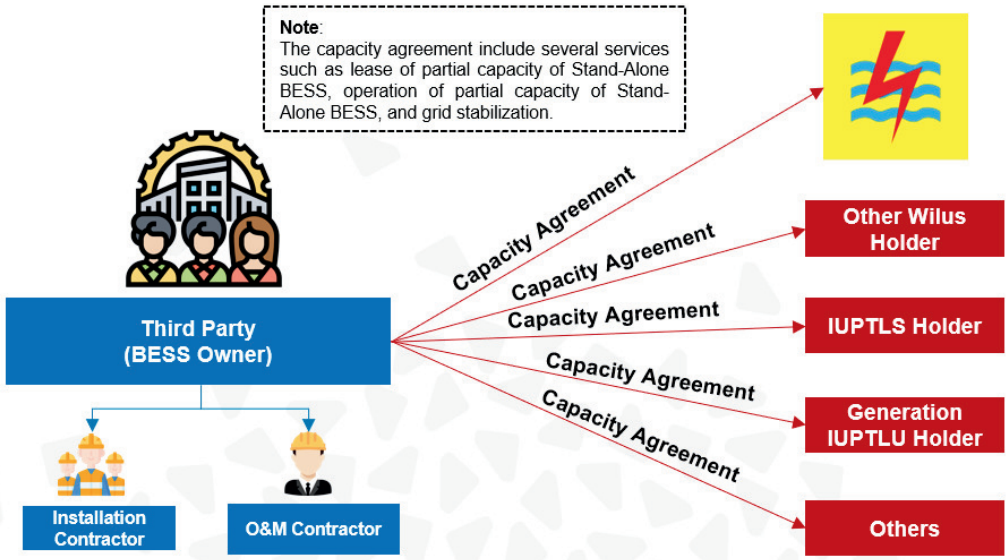
In the context of Indonesian law, tolling agreement is equivalent to a lease agreement whereby the Stand-Alone BESS is exclusively leased to PLN. Meanwhile, capacity agreement can be implemented in Indonesia if the Stand-Alone BESS owners enter into a contract with multiple parties (e.g.: PLN, other Wilus holders, IUPTLS holders, and Generation IUPTLU holders) for the Stand-Alone BESS operation and ultimately electricity grid stabilization. The capacity agreement is not a concept previously known in Indonesia's electricity regulatory framework, and therefore, will require certain legal reform. Please see below the 2 proposed schemes based on the tolling agreement and capacity agreement schemes:

1. Option 1 (Tolling Agreement Scheme)



- Third party will act as the owner of the Stand-Alone BESS.
- Third party will provide the services only to PLN through tolling agreement, i.e.: exclusive lease to PLN and O&M Of Stand-Alone BESS for PLN.
- Third party may engage with third party contractors to perform the installation and O&M of the Stand-Alone BESS (optional).

2. Option 2 (Capacity Agreement Scheme)



- Third party will act as the owner of the Stand-Alone BESS.
- Third party will provide services to many parties (e.g., PLN, other Wilus holder, IUPTLS holder, generation IUPTLU holder) through capacity agreement to each of those parties, i.e.: lease of partial capacity of Stand-Alone BESS, operation of partial capacity of Stand-Alone BESS, and grid stabilization.
- The Stand-Alone BESS owner may engage with third party contractors to perform the installation and O&M of the Stand-Alone BESS (optional).

<u>ii. Types of Electricity Business Activities</u>

There are three types of business activities that can be carried out for Scheme 2, namely:

1. Option 1

   In practice, currently leasing power plants may be conducted by the power plant's owner having KBLI 77395 (Rental and Leasing Activities Without Option Rights of Mining and Energy Machinery and Equipment) and NIB (since KBLI 77395 is low risk). If Option 1 is implemented for Scheme 2, Stand-Alone BESS's owners may own Stand-Alone BESS and lease it exclusively to PLN so long as they own KBLI 77395 and NIB.

   If PLN wishes for the Stand-Alone BESS's owners to also provide O&M services, the Stand-Alone BESS's owner will be considered providing UJPTL or the Stand-Alone BESS's owner can engage with a separate O&M contractor. Please see Section 6.7.2(a)(v) of this report for further elaboration on contractors providing O&M of Stand-Alone BESS as UJPTL.

2. Option 2

Capacity agreement can be implemented in Indonesia if the Stand-Alone BESS owners enter into a contract with multiple parties (e.g.: PLN, other Wilus holders, IUPTLS holders, and Generation IUPTLU holders) for the Stand-Alone BESS operation and ultimately electricity grid stabilization. This is not a concept previously known in Indonesia's electricity regulatory framework. This scheme is analogously similar to joint utilization of transmission and distribution electricity grid whereby the grid can be utilized by several parties. Based on this concept, this scheme is not suitable with the current electricity generation business activities regulated in Law 30/2009, i.e.: generation, transmission, distribution, and sale. Therefore, if Option 2 is implemented in Indonesia, a new type of electricity generation business activity will need to be introduced in Law 30/2009. For example, electricity storage and grid stabilization business activity.

Accordingly, amendment to Law 30/2009 and its implementing regulations is necessary to add the electricity storage and grid stabilization business activity as an additional type of electricity generation business activity. If Option 2 is implemented, the development of Stand-Alone BESS by PLN can also fall under this new type of business activity which is conducted in an integrated manner with other types of electricity generation business activities.

To ensure that the capacity agreement scheme is not considered as electricity sale, Law 30/2009 amendment needs to expressly state that the services being provided by the parties conducting electricity storage and grid stabilization business activity is storage of electricity in the Stand-Alone BESS and electricity grid stabilization, not electricity sale.

Furthermore, we note that under the 2022 Issue Inventory List (DIM) of New and Renewable Energy Bill **(NRE DIM),** a concept of new and renewable energy storage is introduced. The following are some of the relevant provisions:

a. Definition of New and Renewable Energy Storage (Article 1)
"New and Renewable Energy Storage means a series of processes, methods, devices, and/or technologies used to store electrical, electrochemical, chemical, mechanical, thermal, or other forms of energy, which can be utilized at a specific time for various purposes."

b. Scope (Article 4(e) in conjunction with Article 28A(1)(d))
"One of the scopes of regulation for the implementation of New and Renewable Energy is:
(e) the provision, storage, and utilization of New and Renewable Energy, which also includes the storage of electrical energy."

c. New and/or Renewable Energy Storage Facilities (Articles 22(d) and 37(d))
"One form of New Energy business under Article 21 and/or Renewable Energy business under Article 36 may be carried out through the construction of New Energy and/or Renewable Energy storage facilities."

d. Renewable Energy Storage Facilities (Articles 41(4) and (5)(e))
"The Central Government and/or Regional Governments shall provide infrastructure and facilities in the form of Renewable Energy storage facilities to accelerate the development of Renewable Energy."

e. Implementing Regulations (Articles 28A(2) and 46A(2))
"New and/or Renewable Energy Storage shall be further regulated in Government Regulations."

If MEMR wishes to only regulate Stand-Alone BESS in the New and Renewable Energy Bill **(NRE Bill),** this may be conducted so long as: (i) the NRE Bill provides provisions specifically for the Stand-Alone BESS development in the context of electricity generation, including its licenses, its connection with other types of electricity generation business, and other requirements; and (ii) the Stand-Alone BESS is used exclusively for new and renewable grid because NRE Bill only applies for new and renewable energy development. If the Stand-Alone BESS will also be used to store electricity from conventional power plants, amendment to Law 30/2009 is required.

<u>iii. Applicable KBLI</u>

1. Option 1

Currently, there are no KBLI codes that explicitly govern the operating lease of BESS. However, the potential KBLI codes that may be suitable are:

- **KBLI 77395 – Rental and Leasing Activities Without Option Rights of Mining and Energy Machinery and Equipment,** which is described as the rental and operational leasing activities without option rights of mining and quarrying machinery and **equipment without operators,** which are generally used as capital goods by companies, **such as power generation machines**. This includes engines or steam turbines, mining and oil equipment, and professional radio and communication equipment.[76]
- **KBLI 77399 – Other Rental and Leasing Activities Without Option Rights for Machinery, Equipment, and Other Tangible Goods Not Elsewhere Classified,** which is described as Rental and leasing activities without option rights (operational leasing) for machinery, equipment, and other tangible goods not elsewhere classified under group 7730, which are generally used as capital goods, such as containers for residential or office use, pallets (container lifting devices), and similar items. This also includes the rental of baggage scanning equipment using ionizing radiation sources and the rental of livestock, racehorses, and similar.[77]

The applicability of these KBLI codes for Scheme 2 has been confirmed through a no-name basis consultation with officials from the OSS system.

KBLI 77395 provides for the operational lease of certain equipment which includes power plants. However, it does not explicitly mention BESS system. On the other hand, KBLI 77399 serves as a more general classification, intended to cover machinery or equipment not specifically accommodated under other relevant KBLI codes.

Both KBLI 77395 and KBLI 77399 are categorized as low-risk activities, hence require only NIB. These KBLI codes may arguably be used to facilitate operational leasing under Scheme 2. Nevertheless, for legal clarity and prudent purposes, MEMR may consider amending the scope of both KBLIs to specifically include the operational lease of Stand-Alone BESS. This can be conducted through the amendment of BPS Reg 20/2020.

Furthermore, if PLN wishes for the Stand-Alone BESS's owners to also provide O&M services, the Stand-Alone BESS's owner will be considered providing UJPTL and will need to obtain KBLI 35121 and KBLI 43211. However, if the Stand-Alone BESS' owner engages with an O&M contractor, KBLI 35121 and KBLI 43211 will need to be obtained by the O&M contractor. Please see Section 6.7.2(a)(v) of this report for further elaboration on contractors providing O&M of Stand-Alone BESS as UJPTL.

[76] Appendix of BPS Reg. 2/2020.
[77] Ibid.

2. Option 2

Since electricity storage and grid stabilization business activity will be a new type of electricity generation business activity, a new KBLI will be required. Consequently, amendments to GR 28/2025, MEMR Reg 5/2021, and BPS Reg 2/2020 would be necessary.

iv. Licenses

1. Option 1

Given that the activities described under KBLI 77395 and KBLI 77399 are classified as low business activities, the licensing requirement is only NIB.[78]

Furthermore, if PLN wishes for the Stand-Alone BESS's owners to also provide O&M services, the Stand-Alone BESS's owner will be considered providing UJPTL and will need to obtain IUJPTL. However, if the Stand-Alone BESS's owner engages with an O&M contractor, the O&M contractor will need to obtain IUJPTL. Please see Section 6.7.2(a)(v) of this report for further elaboration on contractors providing O&M of Stand-Alone BESS as UJPTL.

2. Option 2

Since electricity storage and grid stabilization business activity will be a new type of electricity generation business activity, a new business license will be required that corresponds with the new KBLI.Consequently, amendments to GR 28/2025, MEMR Reg 5/2021, and BPS Reg 2/2020 as well as amendment to Law 30/2009 and its implementing regulations would be necessary.

v. Procurement

1. Option 1

Procurement here refers to the procurement conducted by PLN to select a Stand-Alone BESS developer. As elaborated in Section 5.1.4(a) of this report, there are currently no procurement regulations specifically for selecting a Stand-Alone BESS developer. However, given that the Stand-Alone BESS developer could be consider as providing services, namely lease and O&M of Stand-Alone BESS, PLN may conduct its typical goods/services procurement to engage with such the developer for Options 1 and 2 (subject to MSOE Reg 2/2023 and PLN's internal regulations on goods and services procurement). Please refer to Section 5.1.4(a) of this report for further elaboration.

2. Option 2

Given that the electricity storage and grid stabilization business activity will be added as a new type of electricity generation business activity, it may be necessary to regulate a procurement process specifically for Stand-Alone BESS developed by third parties for Option 2, e.g.: direct selection and direct appointment (if certain criteria are met).

The procurement process can be regulated in the amendment to GR 14/2012 since the procurement for electricity purchase is firstly regulated in GR 14/2012 as well. Please note that the recommendations elaborated in Section 6.5.2 recommend PLN to procure Stand-Alone BESS via a competitive procurement process.

[78] Article 130 GR 28/2025.

vi. Pricing

1. Option 1

   Given that the procurement for Stand-Alone BESS can be conducted using goods/services procurement, the price can also be agreed by the PLN and the Stand-Alone BESS developers.

2. Option 2

   If MEMR wishes to supervise the BESS development given that the electricity storage and grid stabilization business activity will be added as a new type of electricity generation business activity, GR 14/2012 amendment may also require an approval from MEMR for the price agreed by PLN and the Stand-Alone BESS developers.

Please note that based on Section 6.6.1, the recommendation is to have a market-driven price formed through competitive procurement process, subject to regulatory approval.

As for the electricity price of charging the BESS, PLN can either set out a special tariff for such BESS charging or bear the charging cost. In South Africa, India, and Arizona, the party that ultimately pays for the electricity charged to the Stand-Alone BESS is the utility.[79]



[79] Department of Electricity and Energy, "The Battery Energy Storage IPP Power Programme Bid Window 3" https://www.ipp-storage.co.za/, accessed on 5 August 2025, Arizona Public Service Company . (2022). 2022 All Source Request for Proposals . Retrieved from https://www.aps.com/-/media/APS/APSCOM-PDFs/About/Our-Company/Doing-business-with-us/Resource-Planning-and-Management/051622APSAllSourceRFP.ashx?hash=98F3A2642714075FE11A0099649468C9&la=en, and TERI. (2023). Kilokari RFP. Retrieved from https://teriin.org/sites/default/files/files/Vol_1_Sow_and_technical_specs_updated.pdf.

Table 18 Summary of Proposed Regulatory Framework for Stand-Alone BESS

	Types of Electricity Business	KBLI and Business License	Cooperation with BESS developers	Cooperation with Contractors for the installation and O&M of BESS
Scheme 1 (PLN-Owned BESS)				
Stand-Alone BESS Development as Transmission Activity	• Part of transmission activity • GR 14/2012 amendment to clarify that Stand-Alone BESS development is considered as part of transmission activity	• KBLI related to integrated electricity business: KBLI 35115 and KBLI 35116 • Integrated IUPTLU • Amendment to the KBLIs will be needed to clarify that Stand-Alone BESS is part of transmission activity. Therefore, GR 28/2025, BPS Reg 2/2020, and MEMR Reg 5/2021 will need to be amended accordingly.	N/A because the BESS is owned by PLN	• Contractors engaged by PLN to install and O&M Stand-Alone BESS will be considered as providing UJPTL, namely (i) electricity construction and installation; and (ii) electricity operation. However, GR 25/2021 and MEMR Reg 12/2021 need to be amended to add Stand-Alone BESS as part of electricity transmission field under those two types of UJPTL. • The contractors can use existing KBLI 35121 and KBLI 43211, with amendment to the KBLIs to include installation and O&M of BESS. • Procurement: goods and services procurement conducted by PLN. • Pricing: agreed by PLN and the contractors.
Scheme 2 (Third Party-Owned)				
Option 1 (Tolling Agreement Scheme)	• Does not fall into generation, transmission, distribution, or sale. • Option 1 consists of lease of Stand-Alone BESS and O&M (if agreed contractually)	• KBLI 77395 (Rental and Leasing Activities Without Option Rights of Mining and Energy Machinery and Equipment) – which will need to be amended to expressly include lease of Stand-Alone BESS. • License: NIB. • Therefore, GR 28/2025, BPS Reg 2/2020, and MEMR Reg 5/2021 will need to be amended accordingly. • If the Stand-Alone BESS's owners wish to provide O&M services on its own, the analysis on UJPTL for O&M of Stand-Alone BESS will also apply.	• Procurement: goods and services procurement conducted by PLN. • Pricing: agreed by PLN and the contractors.	Similar with Scheme 2, but the contractors will be engaged by the third parties owning Stand-Alone BESS. Partner input (2% of CapEx).
Option 2 (Capacity Agreement Scheme)	New type of business activity, namely electricity storage and grid stabilization business activity	• New KBLI and business license • Therefore, GR 28/2025, BPS Reg 2/2020, and MEMR Reg 5/2021 as well as Law 30/2009 and its implementing regulations will need to be amended accordingly.	Amendment to GR 14/2012 to regulate: • Procurement process for Stand-Alone BESS developers • Pricing: agreed by PLN and the contractors, subject to MEMR's approval	

Based on the above, below is a pros and cons table of each proposed scheme:

Table 19 Summary of Pros and Cons of Each Proposed Business Model Scheme for Stand-Alone BESS

Proposed Schemes	Pros	Cons
Scheme 1 (Utility-Owned BESS)	• The structure is straight forward because the Stand-Alone BESS is controlled by PLN as the utility. • This scheme may arguably be implemented within the existing regulatory framework, although regulatory amendment is advisable for prudent purposes. However, if PLN engages with installation and O&M contractors, regulatory amendments are needed for the services provided by the contractors. • No new KBLI and business license are required for PLN as the Stand-Alone BESS owner.	• Limited private participation. • The implementation of Scheme 1 may be slow because it requires heavy upfront capital expenditures borne by PLN.
Scheme 2 – Option 1 (Tolling Agreement)	• More private participation compared to Scheme 1. • Option 1 scheme is similar with power plant leasing, which is a scheme commonly used in the market. This could help create a more seamless implementation of Scheme 2 – Option 1. • This scheme may arguably be implemented within the existing regulatory framework, although regulatory amendment is advisable for prudent purposes. However, if the Stand-Alone BESS owners engage with installation and O&M contractors, regulatory amendments are needed for the services provided by the contractors. • No new KBLI and business license are required for the Stand-Alone BESS owners	• If a special tariff is needed for the BESS charging fee, this will require amendment to MEMR Reg 7/2024 which will take time.
Scheme 2 – Option 2 (Capacity Agreement)	• More private participation compared to Scheme 1. • This scheme is more inclusive compared to Scheme 1 and Scheme 2 – Option 1 because it may involve other electricity stakeholders, such as IUPTLS holders, Generation IUPTLU holders, and Wilus holders other than PLN.	• If a special tariff is needed for the BESS charging fee, this will require amendment to MEMR Reg 7/2024 which will take time. • Longer and more complex process than Scheme 1 and Scheme 2 – Option 1 because amendment to Law 30/2009 will be required to introduce this scheme. • New KBLI and business license are required for the Stand-Alone BESS owners

6.8. Further Aspects to Consider

6.8.1. Pilot projects as a starting point

As Indonesia has limited experience with BESS and the valuation of services is not yet clear, it is recommended to start with demonstration projects either utility-owned or via capacity agreements (where the third party operates the BESS), to gain initial technical experience and to understand how the BESS can provide most value. In some cases, such projects manage to secure funding support. As per (World Bank, 2023), this practice has been the case for many developing countries, where commonly there are no markets for electricity or ancillary services.

6.8.2. Comparison to other flexibility options

Furthermore, batteries can provide a range of services and have fast ramping capabilities; however, investment costs are still high, despite significant cost decrease in the past decade. BESS should therefore be compared to alternative flexibility options (see Figure 11), to find the optimal solution for the system. The most techno-economically viable flexibility option depends on existing grid infrastructure, generator fleet, vRE penetration and vRE distribution, etc.

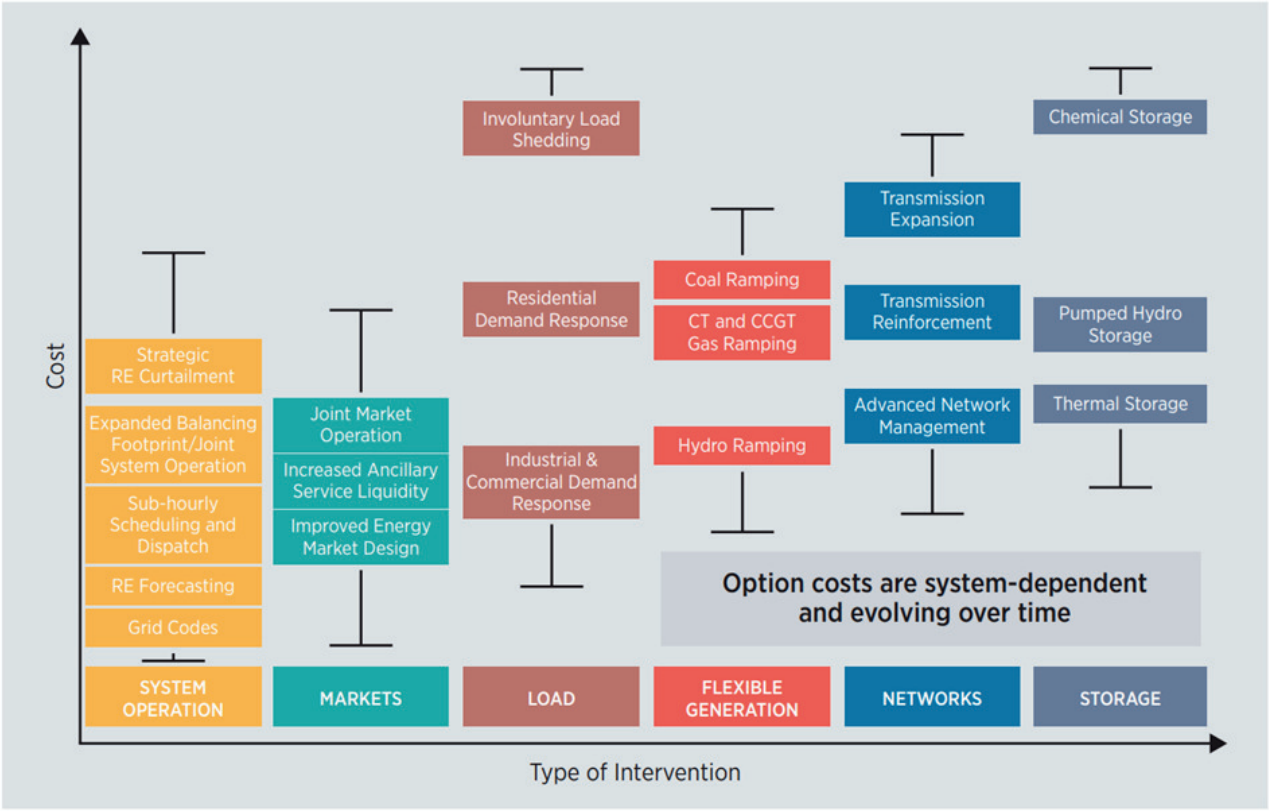


Figure 18: Flexibility sources. Source: (IRENA, 2017).

6.8.3. Safety aspects

Fire and other accidents can occur when BESS is not designed, installed, and/or maintained properly. Extreme heat can result from normal operations as well as from hot and humid weather conditions, like in Indonesia. The battery thermal management system (BTMS) needs to be designed properly to ensure proper monitoring, ventilation, and cooling of the BESS components, even during extreme heat events. In addition to the batteries, other equipment also need to be designed to withstand high temperatures.

Fire incidents have occurred before, such as in the US and in Australia (U.S. Department of Energy, 2024). Learnings from these incidents have reduced the number of catastrophic failures per GW BESS deployed. Most of the fires are now attributed to battery management system (BMS) or power conversion system (PCS) instead of battery cells' and modules' failure (U.S. Department of Energy, 2024). To prevent accidents and ensure the quality of BESS, there needs to be safety standards and regulations for BESS implementation.

Some of the materials contained in the different battery technologies are toxic to humans and the environment. Improper handling and disposal, including illegal dumping, may cause these toxic materials to pollute water and leach into the ground, among other adverse consequences. Proper recycling programmes and infrastructure are needed, which require investment. As different battery technologies require different recycling methods, investments in recycling facilities may not be profitable if there are only small quantities for each type of batteries to be recycled.

This report does not cover challenges and vulnerabilities arising from criminal activities (cybersecurity, physical, or otherwise) and natural disasters.

6.8.4. BESS' operational constraints

BESS has additional constraints compared with traditional generators, the major one being SOC. If the SOC of the BESS is already full (depleted), it can no longer charge (discharge). Ensuring that BESS can deliver the services that it is supposed to requires optimisation in its charging and discharging schedule. Moreover, depending on the battery technologies, maximum and minimum BESS power levels can change depending on the BESS' SOC (especially at the highest and lowest ends) and temperature, further complicating the BESS operation. A system operator that seeks to integrate BESS into its dispatch schedule must be able to model the BESS' constraints and capabilities accurately.

The capacity factor of BESS is inherently low because it needs to charge before it can discharge (maximum 50% capacity factor for a device with 100% RTE). Assuming an RTE of 85%, an 11-hour duration BESS requires 13 hours to charge when being charged and discharged at 100% of rated power (Denholm, Cole, Frazier, Podkaminer, & Blair, 2021).

Battery lifetime is generally shorter than those of other BESS components, as batteries are more sensitive to operational conditions, temperature, cycling, and depth of discharge (IEA, 2024). Therefore, it is important to optimise the design of BESS for the intended use. Non-optimal operation of BESS will reduce its lifetime, as is the case for generators and other grid infrastructure. Location of the BESS needs to be determined optimally to fully utilise BESS' capabilities.

6.8.5. Grid infrastructure

To utilise BESS' fast response time (within milliseconds) for grid services, appropriate control, telemetry, and reliable communication/coordination with the system or distribution operator are often required. BESS is able to inject and absorb power from the grid, acting as both generator and load. While transmission systems are generally designed for bidirectional power flows, distribution networks were historically designed for unidirectional power delivery (from generator to the load). Therefore, high penetrations of VRE and BESS especially in distribution systems or behind the meter can lead to reverse power flows which may require network upgrades. These upgrades, such as deployment of smart meters and SCADA (supervisory control and data acquisition) are likely necessary too to be able to utilise BESS for voltage regulation and congestion relief in the distribution system.



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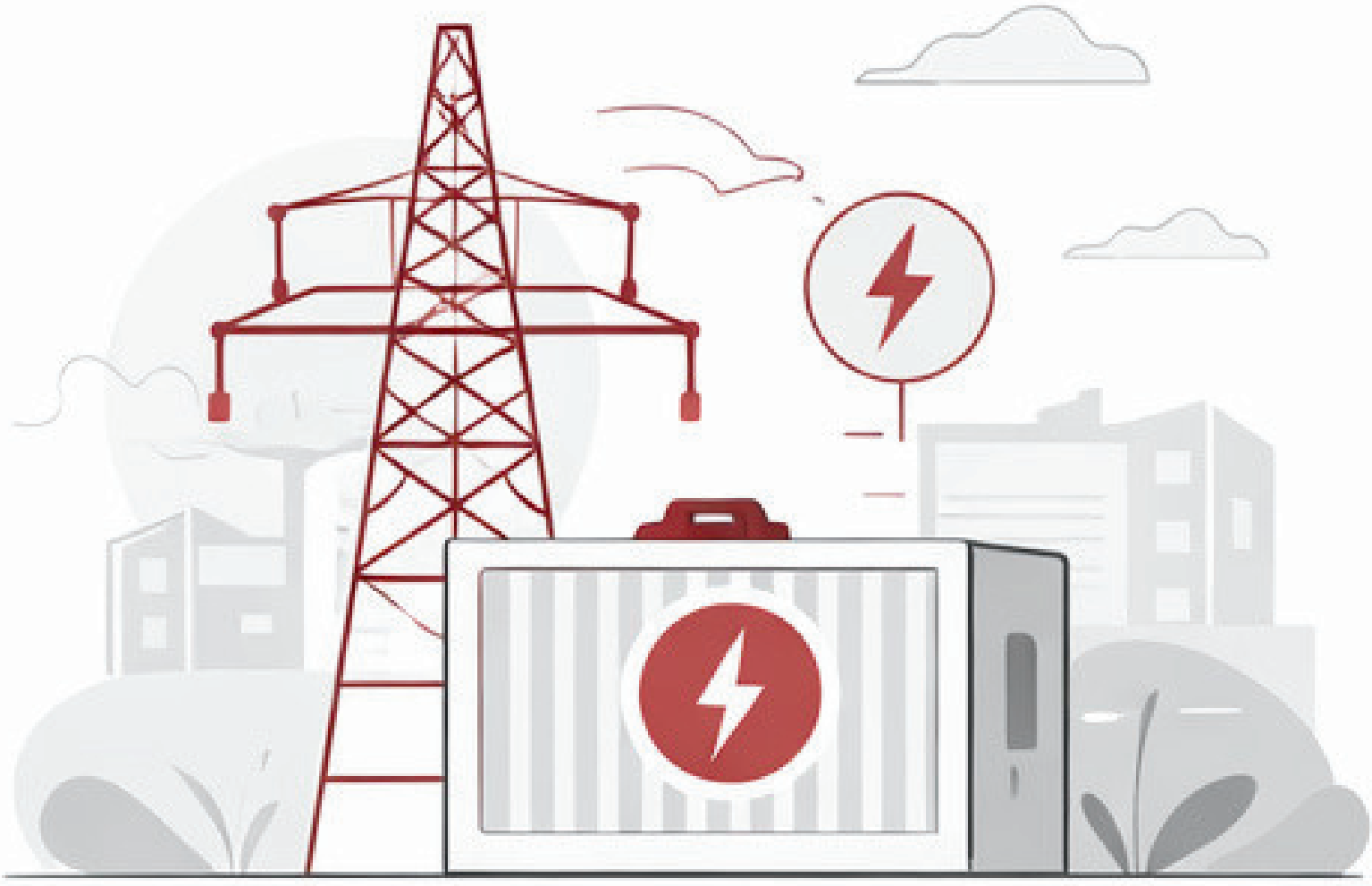
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Annex

LCOE calculation (annuity method):

$$LCOE = \frac{(CAPEX_{VRE} + CAPEX_{St} + REP_{VRE} + REP_{St} - RV_{VRE} - RV_{St}) * CRF + OPEX_{VRE,y} + OPEX_{St,y}}{(1 - A) * E_{VRE,y} + A * \eta * E_{VRE,y}}$$

Where:

- The LCOE is given in USD/kWh
- $CAPEX_{VRE}$, $CAPEX_{St}$: Capital costs of vRE and storage [USD]
- REP_{VRE}, REP_{St}: Present value of vRE or storage replacement cost at end of its lifetime [USD], $REP = \frac{CAPEX_{Replacement\ year}}{(1+DR)^{t_replacement}}$
- RV_{VRE}, RV_{St}: Present value of vRE or storage residual value at end of project time [USD]
- $OPEX_{VRE,y}$, $OPEX_{st,y}$: Fixed operational costs of vRE and storage [USD/year]
- CRF: Capital recovery factor, $CRF = \frac{DR}{1-(1+DR)^{-t}}$
- DR: Discount rate
- t: Project period [years]
- $E_{VRE,y}$: vRE average output per year [kWh/ year], considering degradation throughout lifetime.
- A: Share of vRE output that charges battery (considers battery size, usable state of charge range and average daily cycles for service provision)
- η : BESS roundtrip efficiency

The numerator represents the capital and operational costs of vRE and BESS and any replacement value, annualised. The denominator represents the vRE generation directly fed to the grid ($(1 - A) * E_{VRE,y}$) plus the vRE generation that passes via the BESS to the grid, per year, considering BESS losses ($A * \eta * E_{VRE,y}$). Losses of the PV or wind are already considering in the energy yield input.

The residual value for the vRE or storage is calculated for the final year of the analysis and discounted to present value as:

$$RV = \frac{CAPEX_{replacement} x \frac{Asset\ Lifetime - (Project_{duration} - Year_{replacement})}{Asset\ Lifetime}}{(1 + DR)^{end\ year}}$$

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