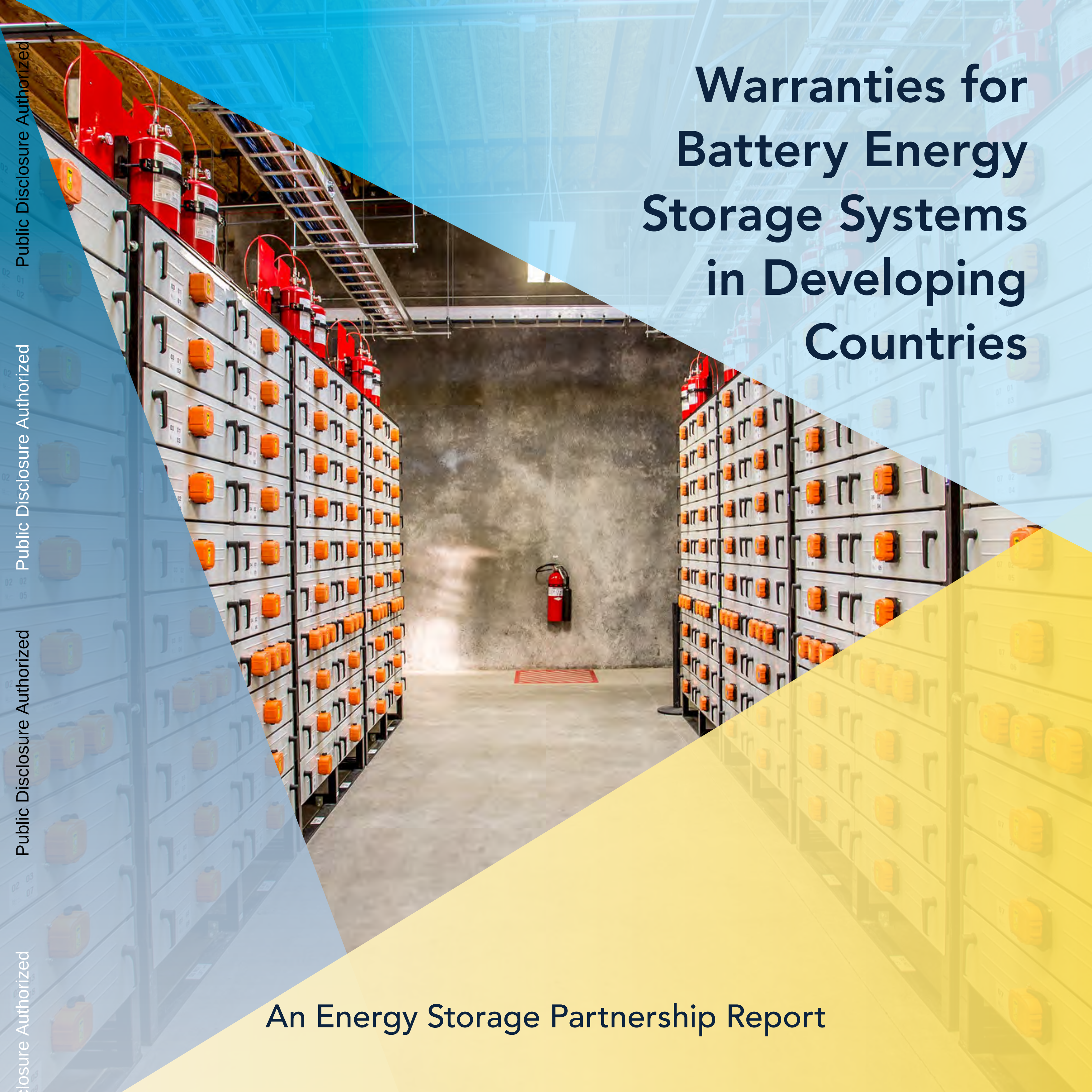

Warranties for Battery Energy Storage Systems in Developing Countries

An Energy Storage Partnership Report

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ABOUT ESMAP

The Energy Sector Management Assistance Program (ESMAP) is a partnership between the World Bank and 18 partners to help low and middle-income countries reduce poverty and boost growth through sustainable energy solutions. ESMAP's analytical and advisory services are fully integrated within the World Bank's country financing and policy dialogue in the energy sector. Through the World Bank Group (WBG), ESMAP works to accelerate the energy transition required to achieve Sustainable Development Goal 7 (SDG7) to ensure access to affordable, reliable, sustainable, and modern energy for all. It helps to shape WBG strategies and programs to achieve the WBG Climate Change Action Plan targets. Learn more at: https://esmap.org

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WHY ARE WARRANTIES IMPORTANT FOR BATTERY ENERGY STORAGE SYSTEMS?

In developing countries, battery storage is becoming a viable way to increase system flexibility and enable more integration of variable renewable energy. Battery energy storage systems (BESS) respond rapidly to control signals, are easy to deploy, and are benefiting from cost reduction trends.

By contrast, most mainstream technologies cannot provide long duration storage, often fail to withstand harsh climatic conditions, or require frequent operation and maintenance. The current battery market is driven by the electric vehicle industry, which is well aware of the additional challenges posed by end-of-life management of batteries.

New battery technologies have valuable attributes that are well suited to the needs of developing countries. However, they have a rather short track record in terms of deployment and operation, and this can hamper efforts to reassure buyers and investors that these new technologies will perform reliably over their project life. Conditions found in some developing countries may present extra challenges as energy storage systems need to operate in harsh climate conditions, often in remote locations with limited data access.

Warranties[1] for BESS provide mechanisms for buyers and investors to mitigate the technical and operational risks of battery projects,[2] by transferring the risk of a manufacturing defect or performance issues to the manufacturer or the battery vendor. Warranties are used in the same way for traditional generation technologies, such as solar photovoltaic (PV) and wind.

Warranties for BESS vary in coverage and duration. For their use in developing countries, key attributes include providing a level playing field for all battery technologies, with clear terms and conditions, taking into account specific conditions such as: high temperatures, poor accessibility in remote locations, limited internet access (and, therefore, limited remote monitoring options), and low availability of a sufficiently skilled local workforce. These conditions all render the underlying need for flexible operation even more acute.

WARRANTIES FOR BESS CAN:

1. **Guarantee** certain manufacturing quality and performance capabilities, subject to specifications in accordance with a predefined application or applications; related contracts may also mitigate risks associated with transportation, construction, and installation

2. **Reduce the risk** perceived by investors in BESS projects using new technologies or new manufacturers

WHAT DO BESS WARRANTIES COVER?

They typically warrant that the BESS components remain free from defects[3] and performance over the course of the warranty period (up to 15 years for long-term warranties), providing that certain operating conditions, usage patterns, and other warranty conditions are met.

- **Manufacturing defects:** guarantee the quality of BESS components and that the overall system will meet manufacturers' specifications. In the case of new manufacturers with a short track record, warranties can be backed by insurance companies or other creditworthy entities.
- **Performance:** guarantee systems ensure minimum performance levels for a predefined application(s), covering against declines in performance and excessive maintenance costs. Available energy capacity (MWh), which specifies up-time and response time, a common performance metric. Other less common performance metrics are: duration (minutes, hours), power (MW), availability (%) and efficiency (%).

For the policy to remain valid, certain environmental, operational, and maintenance[4] conditions must be met. These conditions may include: (i) staying within the operational boundaries defined for the application, and system limits on throughput (MWh/MW), temperature of cell, pack, and/or enclosure, charge/discharge rates, depth of discharge (DOD), and state of charge (SOC), among others; and (ii) ensuring that both planned and preventive maintenance are carried out correctly in a timely manner.[5]

Other important considerations that the warranty must clarify are: workmanship warranty requirements, responsibilities for diagnosis, replacement parts, on-site removal of equipment, installation of new hardware, and recommissioning. Warranties for other assets work in the same way: for example, those for solar PV plants guarantee material and workmanship for up to 10 years. The module manufacturers guarantee a certain output for the first year, and then reduce it linearly each year for up to 25 years by a proportion of the nominal output power.

BESS WARRANTIES IN DEVELOPING COUNTRIES

The conditions found in some developing countries may present extra operational challenges, obliging well-designed warranties to give special consideration to one or more of the following factors:

1. **High air temperature** (annual average and peaks), including the potential impact of extreme temperatures during outages, causing aggravated deterioration of key chemical processes (degradation). Installations without grid connection may need a backup generator. Consider other local environmental conditions such as humidity, dust, proximity to sea, among others.
2. **Limited internet access, data transfer** and/or **remote monitoring** can hinder access to sufficient operational data to prove warranty claims. It would need to be verified that data collection6 as necessitated by the warranty will proceed, uninterrupted, despite any adverse local conditions.
3. **Too few skilled local workers** available for BESS installation, maintenance, and repairs, as errors can influence the performance of the BESS. Workmanship warranty requirements need to be clear and realistic in view of local conditions in developing countries.
4. **Remote and difficult to access areas** will impact transportation and storage of the BESS, during which certain limits, such as temperature, or SOC, must be maintained. If they are exceeded, the warranty may become void. In developing countries, there might be very few available sites that could offer compliance with those strictures.
5. **Flexible operation:** BESS may be required to operate differently to the predefined application (when, for example, responding to a change in market rules). The circumstances must be discussed and agreed with the vendor, lest the warranty become void.
6. **Unreliable grid supply:** Poor power quality can stress the battery storage equipment, leading to damage typically not covered by the warranty (unless proper conditions for surge protection and switching frequencies are negotiated in contracts to guarantee reliability and durability).

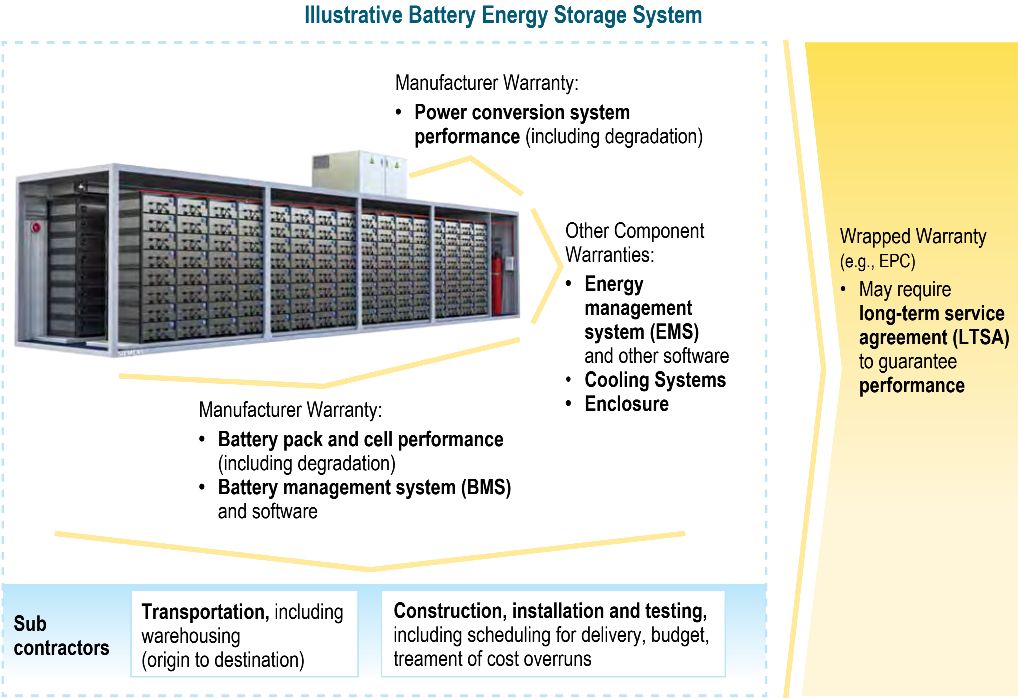
THE STRUCTURE AND COST OF BESS WARRANTIES

A BESS is composed of different components—battery pack, inverter, switch gear, energy management system, software—as shown in Figure 1. Warranties for individual components can vary in coverage and duration. For example, the warranty of some components could be shorter than the expected life of the project life (over 15 years).[7] It would therefore be highly advisable to demand minimum requirements for warranties (such as their duration and other elements) as an integral part of procurement processes for BESS. This would help to appropriately account for overall costs during comparison and evaluation of competing BESS designs or proposals.

A number of constituent warranties can be wrapped within a single “back-to-back” warranty to facilitate management by a single point of contact. This can reduce the perceived risks for buyers and investors.

The turnkey provider, who could be an engineering, procurement, and construction firm (EPC) or an energy storage system integrator, would maintain the manufacturer’s warranty and, in so doing, sometimes even offer more comprehensive warranties than those provided by the equipment vendor (Robson and Bonomi 2018).[8] Such a warranty, with a single point of contact, is typically of shorter duration than

FIGURE 1: BESS Warranty Aggregation Through a Single Point of Contact



Note: The physical layout is illustrative and would be significantly different, depending on the design of a given battery system. For example, alternative cooling exists such as HVAC systems or liquid cooling for battery packs. Flow batteries could include electrolyte tanks (in place of battery packs) and pumps.

Source: Figure adapted from various sources, including ACES (2019) and Lazard (2019).

the manufacturer's warranties. This could in time entail warranty gaps and mismatches for the BESS owner. Unfortunately, for newer technologies or smaller systems, these single point warranties might not be available or cost effective.

The cost of the warranty is typically included in the total installed capital expenditures (CAPEX) of the BESS, with the option to extend the coverage period or to add a service contract over the life of the warranty. According to industry estimates, the annual cost of the warranty of a BESS is approximately 0.8% of the equipment cost starting in year 3, and the augmentation[9] cost 2.5% of equipment cost (Lazard 2019).

For projects in developing countries, the costs associated with BESS warranties could be higher. These extra costs could be associated with access to remote locations (roads unsuitable for transporting sensitive battery storage equipment, thus, special trucks or helicopters are needed), limited remote monitoring and troubleshooting, and a lack of local skilled workers or testing equipment (experts able to send samples to test labs for verification).

Other considerations when designing BESS warranties include:

- **Financial strength behind the warranty.** Credit ratings offer a measure of the ability of an organization to meet its financial obligations. For newer manufacturers or technologies with a limited track record, third-party re-insurers can backstop warranties that cover performance and even business continuity risk. For example, Munich Re and the flow battery manufacturer ESS partnered to offer 10-year insurance coverage on specific components of its long-duration energy storage products (Munich Re, 2019).

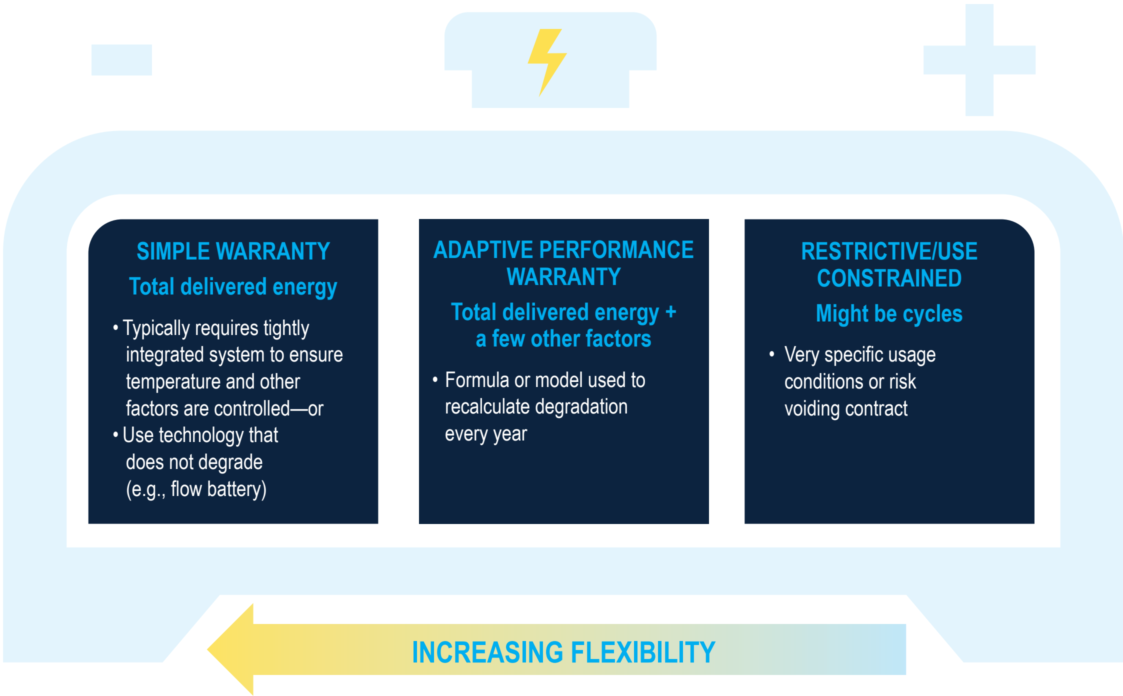
- **Balancing affordability against scope and length coverage.** Warranties of longer duration or those that allow for more than one application may be more expensive than those that provide more limited coverage—although this may vary significantly according to technology, chemistry, and application.[10] The cost of the warranty, to an extent, can be reined in when the user fully understands the fine details of the allowable operational boundaries of the BESS, and is able to limit warranty coverage to key parameters characteristic of the desired service.

BATTERY DEGRADATION

BESS degradation refers to the naturally occurring decline of available capacity caused by wear and tear, and irreversible chemical reactions resulting from the normal use of the battery. The rate of degradation may vary significantly by chemistry, environmental conditions and application involving different depths of discharge, and the number of cycles. Battery management systems can take into account some of the physical characteristics of the battery to reduce degradation and maintain adequate performance for longer.

BESS warranties specify the degradation rate provided by the battery manufacturer with reference to key operational parameters such as SOC, ambient temperature, and power ratings. In order to enable a more flexible operation of the BESS that maximizes the value of the asset, some manufacturers offer more flexible warranties that recalculate coverage, instead of voiding the warranty, if the operational limits are exceeded (Figure 2). Flexible warranties take into account various usage scenarios. This is of crucial relevance to future applications that may arise from regulatory changes or other opportunities.

FIGURE 2: Flexibility of BESS Warranties



Source: Authors.

Battery chemistries with degradation coefficients that are less dependent on operational factors may be better served by more flexible warranties. This possibility of managing degradation may bring significant economic benefits through avoided cost of degradation or need for augmentation. For example, flow batteries expect no degradation with use and allow for asset lifetimes of 20 years (and 10,000 cycles) or more, when the electrolyte is refreshed, and the stacks are replaced at specific intervals. The relative lower round trip efficiency of flow batteries needs to be considered when selecting viable applications.

For batteries with degradation coefficients that are more dependent on operational factors, the following two strategies can be used to manage degradation: (i) allow for expected degradation, and, perhaps, consider battery replacements in the future (depending on the battery chemistry selected and the intended project life); or (ii) opt for augmentation through a combination of planned additional batteries, or perhaps an oversized original build, to maintain a set minimum level of available energy over the life of the project. The planned addition of batteries seeks to take advantage of future falls in the prices of batteries and has the effect of transferring the degradation risk to the seller.

In developing countries where regular maintenance visits may be impractical, larger initial oversizing may be desirable as opposed to scheduling battery additions throughout the life of the project. When oversizing the system, it is recommended that the battery management system be set up in a way that reduces voltage stress during the initial years of system life (DNV GL, 2019). Augmentation is not always desirable because it may limit the flexibility to adopt alternative battery technology in the future. Furthermore, the initial cost of augmentation may be significant, although this depends markedly on the technology and chemistry.

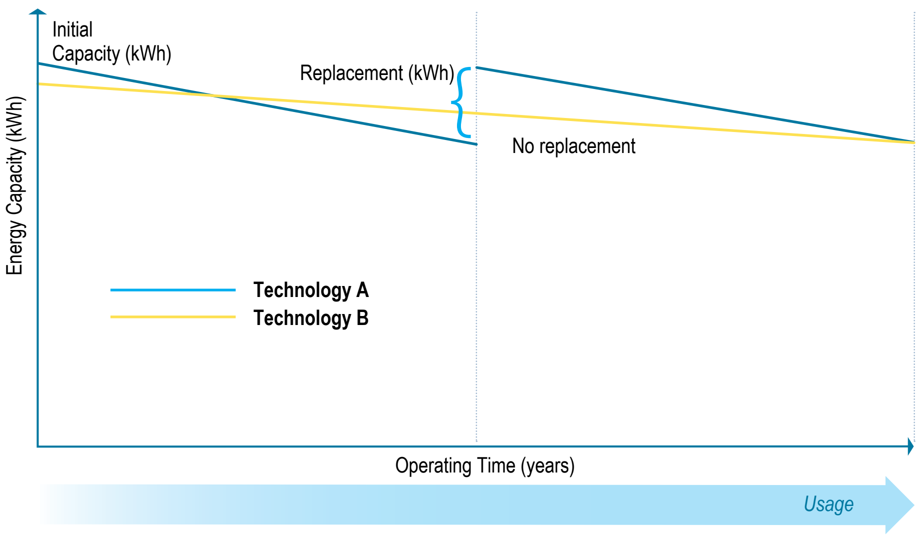
CHECKLIST FOR BESS WARRANTIES IN DEVELOPING COUNTRIES

BESS warranty documents need to be easy to understand and clearly state the terms and conditions of the policy. The checklist below presents a non-exhaustive list of elements that need to be clearly stated in the warranty. The World Bank Procurement Document and Energy Storage Integration Council (ESIC) guides[11], among others, include more details on BESS procurement and warranty design elements.

- **Power (kW) and energy (kWh),** including any limitations that would cause greater degradation than that formally permitted over the life of the contract.
- **System round trip efficiency and minimum efficiency** at the specified location where it will be measured.
- **Warranty lifecycle** and the warranted calendar life of the battery to include: (i) a clear and simple proration formula, for crediting the buyer for unused capacity of equipment replaced or repaired; and (ii) end of life definitions, including calendar age and number of complete charge-discharge cycles (throughput).
- **Intended application and allowed duty cycle**, such as number of cycles per day, or discharge rate (C-rate); avoid definitions that include broad terms such as typical, or average.
- **Start of warranty** (such as after delivery, after grid connection, or after proper commissioning) and simple terms and easy warranty extension; and extended performance warranty
- **Terms and conditions of the warranty,** including operating requirements, procedures that must be followed, and all maintenance requirements. These conditions must be respected for the policy to remain valid, including where and how the appropriate system variables will be measured.
- **Monitoring performance** and how non-performance is established. This will cover the procedures, distribution of responsibilities, any data collection requirements and handing of data gaps.

- **Cost of the warranty** and any required or related Long-Term Service Agreement (LTSA) contract. This must specify guaranteed battery replacement costs and the option to secure the guaranteed replacement cost at the time of the initial supply agreement. It must also specify all labor, materials, shipping charges, and other expenses not included in the warranty. Price management clauses can specify acceptable inflation rates or applicable currency exchange rates.
- **Scope of service** associated with software updates (to respond to changes in regulations, or additional applications) as well as replacement or repair of the equipment.
- **Clarify responsibility for cyber issues** resulting from any compromise of the battery management system (hacking).
- **Repair schedule:** estimated time to complete repairs or replacement required to restore the BESS to the warranted performance level.
- **Compensation** in case of breach of warranty by the user, typically replacement or pro-rated value, or more rarely economic damages.[12]
- **Serial loss clause** (e.g., recall for recurrent problems).

FIGURE 3: Comparison of Two Different Technologies with Different Degradation Rates



Source: Authors adapted from sources including ACES Energy Storage Best Practice Guide (2019).

If all warranties were required to support a common minimum performance level, this would greatly facilitate economic comparison of BESS based on different technologies, or similar technologies offered by different sellers and developers. However, performance information may be limited and the most the most reliable information may be the one from the predefined warranty levels, information tailored to new performance levels has the risk of being less reliable. Figure 3 shows two BESS with different degradation rates that have been illustratively chosen to provide the same minimum available energy after 20 years.

GOOD PRACTICES FOR BESS WARRANTY DESIGN IN DEVELOPING COUNTRIES

Warranties can help **create a level playing field for new battery chemistries,** beyond Li-ion, that have valuable attributes for grid applications in developing countries. Good practices of warranty design based on lessons learned include:

1. Order BESS performance insurance products from manufacturers of new technologies with a limited track record (such as the 10-year performance guarantee from ESS through Munich Re).
2. Specify the application and other minimum requirements (such as duration) that need to be covered by the warranty to enable comparison of different battery technologies. Add top-up insurance on warranty liability in case the warranty provider defaults.

Warranties for grid-connected BESS need to be **tailored to applications in developing countries,** offering flexibility of operation suited to projected duty cycles (i.e. number of cycles, charge rates, depth of discharge). Warranties should also verify that the environmental limits are realistic under local conditions of temperature and humidity, including:

3. Clearly specify the temperature limitations,[13] and how the temperature is measured, as BESS may need to operate under high ambient temperature or humidity in developing countries.
4. Allow for a flexible operation of the battery, including fair penalties when operated outside the predefined application(s), for example, modifying the length of coverage or degradation rate rather than voiding the warranty. Develop a cost structure that reflects the flexible operation of the BESS including the penalties for deviation from boundaries defined in the contract.

Terms and conditions of BESS warranties should be clear and easy to implement. They should clearly define the environmental and operational limits that can void the warranty, to prevent voiding the warranty through unintended misuse.

5. Clearly specify installation, maintenance, remote monitoring and other requirements.
6. Clearly specify degradation rate and curve applicable to relevant battery chemistry.
7. Specify the claims process for defects and repairs (such as response time). Where possible, use a single point of contact warranty to streamline claim processes and address problems promptly.

The **correct operation and maintenance** of the BESS is crucial to ensure that the warranty remains valid:

8. Support training to ensure qualified technicians are available for installation, maintenance and repairs as needed. Ensure only authorized personnel access the site.
9. Ensure that the BESS complies with the data collection requirements so as to prove a warranty claim (if needed). Consider the project location—remote locations might have poor internet connectivity—when setting up data collection and transfer.
10. Consider modest oversizing of the BESS to reduce visits necessitated by replacement operations in remote locations, even where degradation is incorporated into the business model.

ENDNOTES

1 A warranty refers to a written contract that specifies the manufacturing, performance or other guarantees in writing. While the term "guarantee" is sometimes used in place of "warranty," its usage is best avoided here in view of its broader meaning, that includes verbal promises.

2 Referring to stationary energy storage systems.

3 Including any attributable to or consequent upon manufacturing, storage, transport, or installation.

4 Sometimes manufacturers require a long-term maintenance contract to be in place with certified partners so as to activate the warranty.

5 A Long-term Service Agreement (LTSA) covers normal wear and tear of the BESS, whereas the warranty covers larger defects implicated in performance issues. An LTSA is sometimes a pre-requisite for the warranty.

6 System owner is responsible for the data to demonstrate proper operation, an absence of negative external impacts, as well as proper commissioning

7 For example, for PV systems the inverter warranty is typically 5 years and the cost of extending the warranty is equivalent to a maintenance contract with annual fees including preventive replacements.

8 Even in this case, not all the components will be guaranteed over the life of the project.

9 Periodic upgrades needed to maintain DC equipment capacity.

10 Some applications may be combined without significantly increasing the cost, as they might offer synergies contributing to a more efficient use of the battery (e.g., peak shaving and fast frequency response).

11 https://www.epri.com/#/pages/sa/epri-energy-storage-integration-council-esic?lang=en-US

12 Compensation of economic damages can be especially useful for remote locations where the cost of mobilizing a team for repairs outweighs the benefit of the small improvements needed to attain target performance.

13 Thermal management involves consideration of an increase in internal resistance of the cells, leading to higher heat output (loss of efficiency) over the long term.

ACRONYMS

BESS	battery energy storage system
kW	kilowatt
kWh	kilowatt hour
LTSA	long-term service agreement
MW	megawatt
MWh	megawatt hour
PV	solar photovoltaic
SOC	state of charge

All currency is United States dollar (US$ or USD), unless otherwise noted.

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