



zenon
by COPA-DATA



Simply the BESS

The role of software technology
in BESS integration.

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Abstract

This white paper explains how Battery Energy Storage Systems (BESS) can help stakeholders in a dynamic grid ecosystem.

It considers how software can improve BESS at utility scale. We examine the fundamentals of BESS, including grid and utility-related considerations. There will be a discussion of existing standards, norms, regulations, and real-world examples, featuring use-cases where the zenon software platform has been deployed.

About this document

This document focuses on BESS and highlights how it can be improved by integrating software automation solutions. It profiles key subjects that will actualize sustainability through energy demand and distribution management.

Our research led us to conclude the information provided here should be directed toward energy-intensive sectors, including typical hybrid-batch sectors such as power generation.

However, the applicability of BESS extends to the infrastructure, refining, utilities, food and beverage, iron and steel, chemicals and pharmaceuticals, metals and mining, and pulp and paper sectors.

This white paper makes no assumptions about the reader's knowledge or experience. Hence, at the end of the document, we include a list of references for anyone who wants to learn more about the topic.

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1. How is energy storage used?

To understand how BESS can be used, you need to have a basic understanding of Energy Storage System (ESS) technology.

Location-independent provision of **system-level applications** is one of the numerous services that an ESS may offer to the electrical power system. The majority of them involve electricity market participation, ancillary services, or power balancing.

These activities include:

- energy arbitrage,
- power system adequacy,
- power grid balancing,
- balancing responsibility,
- demand turn-up-footroom,
- flexiramp, and
- the provision of virtual inertia.

At the **network level**, applications deliver services that are specific to the geographic location of an ESS grid connection. Energy storage systems (ESS) may be connected to either the transmission or distribution networks.

This type of application can:

- manage transmission system congestion,
- put off investments in network infrastructure,
- help meet system stability criteria,
- compensate for voltage and reactive power,
- handle “black starts”, and
- reduce network losses.

The objective of **end-user applications** is to aid various economic sectors, including conventional power plants and renewable energy sources. The primary objective is to realize benefits in the form of either a reduction in costs or an improvement in the quality and dependability of the power supply.

These services include:

- monitoring energy consumption and production,
- peak shaving and load shifting,
- retail arbitrage,
- voltage quality,
- backup power, and

Industry uses software to manage these requirements. COPA-DATA's zenon software platform is an example of one such solution.

The following table provides an overview of the various energy storage technologies applicable to generation applications: (1)

 APPLICATION	 TOP THREE CHOICES
▶ Regulation ▶ Renewable Energy Smoothing	▶ Flywheel ▶ Lithium Ion (P) Battery ▶ NaS Battery
	
▶ Renewable Capacity Firming ▶ Load Following ▶ Energy Time Shift ▶ Service Reliability (Utility Backup) ▶ Supply Capacity ▶ Renewable Energy Time Shift ▶ Supply Spinning Reserve ▶ Black Start	▶ Pumped Hydro ▶ Compressed Air (cavern) ▶ NaS Battery

The following table provides an overview of the various energy storage technologies applicable to transmission applications: (1)

 APPLICATION	 TOP THREE CHOICES
▶ Transmission Upgrade Deferral ▶ Transmission Congestion Relief	▶ NaS Battery ▶ NaNiCl Battery ▶ Hybrid Lead Acid Battery and Super-Capacitor
	
▶ Transmission Support ▶ Voltage Support	▶ Flywheel ▶ Lithium Ion (P) Battery ▶ NaS Battery

The following table provides an overview of the various energy storage technologies applicable to distribution applications: (1)

 APPLICATION	 TOP THREE CHOICES
▶ Distribution Upgrade Deferral	▶ Hybrid Lead Acid Battery and Super-capacitor ▶ NaNiCl Battery ▶ Lithium Ion (E) Battery
	
▶ Power Quality Utility	▶ Lithium Ion (P) Battery ▶ NaNiCl Battery ▶ Valve Regulated Lead Acid Battery

The following table provides an overview of the various energy storage technologies applicable to user applications: (1)

 APPLICATION	 TOP THREE CHOICES
▶ Service Reliability (Customer Back Backup)	▶ Valve Regulated Lead Acid Battery ▶ Advanced Lead Acid Battery ▶ Lithium Ion (E) Battery
	
▶ Retail TOU Energy Charges ▶ Retail Demand Charges ▶ Power Quality (customer)	▶ Thermal Storage (Hot) ▶ Valve Regulated Lead Acid Battery ▶ Lithium Ion (E) Battery ▶ Valve Regulated Lead Acid Battery ▶ Advanced Lead Acid Battery ▶ Lithium Ion (P) Battery

2. What is a battery energy storage system (BESS)?

An effective and resilient energy supply is essential for modern societies to function and as a fundamental pillar to international, national and corporate growth. Secure storage has always been an important part of delivering this.

Today, the energy sector is facing some serious challenges which make secure storage facilities even more important.

The need to move towards low-carbon energy resources is forcing utility-scale energy providers reconsider the grid infrastructures which they operate. Recent geo-political tensions have raised the stakes in terms of securing reliable and secure energy supply – both for grid operators and the businesses which depend upon them.

Energy storage systems offer one solution to help answer some of these challenges.

Within the wider umbrella of energy storage, which at a utility scale includes pumped hydro-electric, compressed air, and thermal solutions, battery energy storage systems (BESS) offer a cost-effective and relatively easy-to-implement solution.

BESS depends on batteries – an electrochemical device – that charges (or collects energy) from the grid or a power plant and then discharges that energy at a later time to provide electricity or other grid services when they are required.

Several different kinds of batteries, including lithium-ion, lead-acid, redox flow, and molten salt (including chemistries based on sodium), are capable of being utilized on a large scale or are being investigated for such a possibility (4).

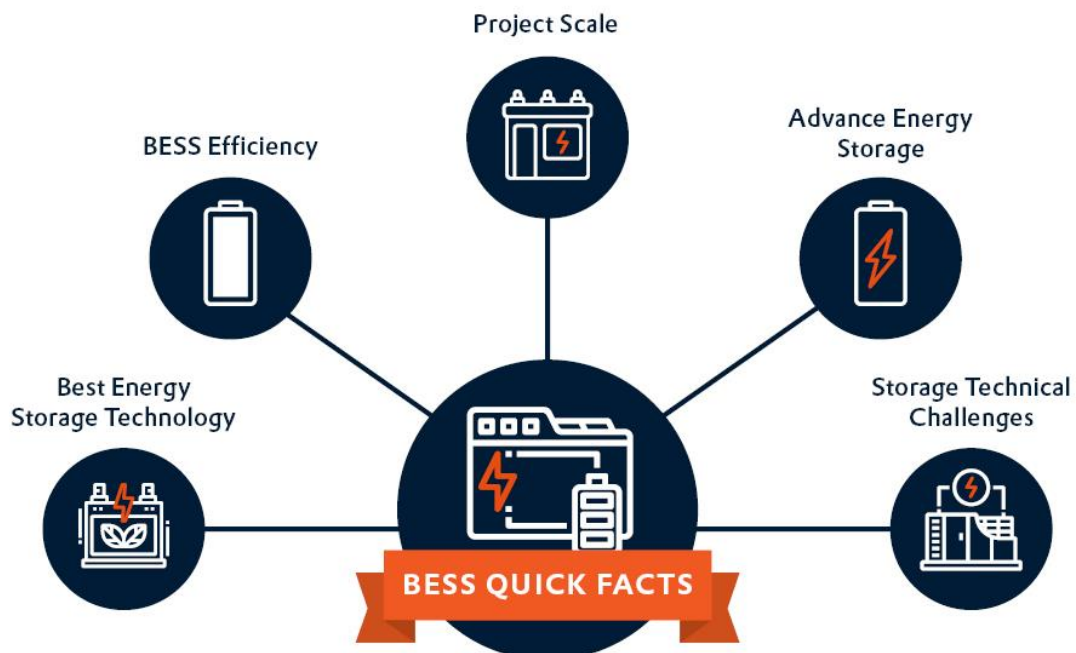
As well as battery modules, the typical components of a BESS include a storage enclosure with thermal management, a power conversion system, a battery management system, and an energy management system.

Software automation, control, and monitoring continue to make a big difference in the way countries, markets, industries, and institutions advance to world-class operations.

Although there is a good volume of research available on the topic of BESS as a solution to utility-scale transmission congestion (5), the role of software technology integration within the BESS ecosystem is an exciting area of research that has the potential to impact a wide variety of fields and industries.

In this white paper, we will consider the following questions:

- What is the market opportunity for BESS? What are the drivers for investing in BESS?
- Who could benefit from BESS? How does it assist actors facing challenges in a dynamic grid ecosystem? Why should power-intensive businesses pursue BESS adoption? For which other sectors and businesses is BESS appropriate?
- What best practices can we identify for BESS operation? How can a BESS be operated at the lowest possible cost? How does software help? And what are the current standards, protocols, and regulations?



TARGET	QUESTION	ANSWER
Project Scale	Which is the largest energy-storage site?	The largest BESS site is in California, USA called Vistra Moss Landing Energy Storage Facility with a capacity of 400MW/1,600MWh. (2)
BESS Efficiency	What is the most efficient battery storage?	The most efficient battery storage is the lithium-ion battery based BESS. (3)
Advance Energy Storage	What is advanced energy storage?	The term “advanced energy storage” refers to a battery that is typically equipped with an intelligent energy management system that allows it to charge and discharge itself as required. When a DC fast charger is in use, an AES is typically installed as part of a peak load shaving strategy. This type of installation has the potential to be especially useful in terms of lowering the amount of energy drawn from the grid.
Best Energy Storage Technology	What is the best energy storage technology?	Knowing what problems need to be fixed can help you choose the best storage technology. Batteries: thermal, mechanical, pumped hydro, and hydrogen are the five most common types.
Storage Technical Challenges	What are the technical challenges for storage?	There are no universally accepted methods for testing and commissioning. The difficulties inherent in the practical aspects of forecasting, measurement, and control present itself as obstacles. As the operations begin, there are also instances in which uncertainties in SoC measurement are most likely to occur. These instances can be found in a number of different places. There is also the conundrum of having to choose between optimizing the control system and increasing the speed of response. While a provider may have sustainability as one of their primary goals, how they handle energy losses may present a challenge, particularly from the perspective of the grid or the batteries.

We will attempt provide some answers in the following chapters.

We hope that by the time you've finished reading this white paper, you'll have a clear understanding of the many advantages offered by the BESS in terms of overall grid efficiency.

3. The drivers for investing in BESS

The market for BESS has enormous growth potential. Between 2022 and 2026, the BESS market is expected to grow at a compound annual growth rate (CAGR) of 26.1%.

This equates to the global market for BESS being forecast to expand from an estimated US \$4.7 billion in 2022 to a revised size of US \$12.9 billion by 2026 (6).

The growth forecast for the BESS market is based on several prevailing market conditions:

- The expanding renewable energy sector.
- Modernization initiatives and the transition to “smart grid” technologies.
- The changing pattern of demands on the grid as part of our energy transition, e.g. switching to electric power for heating and for vehicles.
- Global geo-political tensions which are creating more pressure on high consumers of electric power to make their own supplies more resilient.
- The changing pattern of feed into the grid as the lines blur between producers and consumers.

We'll consider each of these drivers in turn but, first, we will consider the role of energy storage systems in a typical grid.

3.1. Integrating renewable energy sources

BESS will play an important role in helping countries to meet their energy needs as they look toward a more secure and sustainable energy future for the world.

With BESS, renewable energy may be stored at a low cost to support peak demand events, and charging can take advantage of low spot-pricing and excess renewable energy sources. Using BESS, a business can connect to much more powerful technology that can adjust to changing needs in a matter of milliseconds. It allows for more

integration of intermittent power sources like wind and solar, which are effective yet unreliable due to the need for periodic smoothing of generation output.

A more sustainable future will be the result of many businesses making small, individual decisions. Even though a lot of countries have made progress integrating renewable energy sources into their electricity grids (7), the transition from an economic system that was built to run on fossil fuels remains a huge challenge.

Battery technology makes the storage and distribution of renewable energy more appealing. It helps to smooth out the highly variable patterns of generation and demand. With BESS, a crucial step is being taken by governments (8), universities (9), and corporations (10)(11) in their journey toward realizing a shared vision for a sustainable future in terms of the world's energy infrastructure.

According to studies and practical experience, interconnected power systems are capable of safely and reliably integrating high levels of renewable energy from variable renewable energy (VRE) sources without the addition of new energy storage resources. Previously, this was believed to be impossible. This was discovered by integrating large quantities of renewable energy. There is no general rule that can be applied to determine the amount of battery storage that is necessary in order to incorporate large amounts of renewable energy. Instead, the specifics of the system for which the deployment is intended will determine how many grid-scale batteries are needed (12).

The role of BESS in aiding the transition to clean energy is reflected in the enormous potential of the BESS market. Here at COPA-DATA, we recognize the potential of BESS to be an important feature in smart grids as well as in becoming a foundational pillar for a sustainable energy future.

3.2. KOMIPO, Korea

KOMIPO is one of Korea's five public power suppliers and a subsidiary of Korea Electric Power Corp. In 2015, it began construction of a new 21MW wind power plant with seven wind turbines on the Korean island of Jeju. As with any renewables project, the architects of the new Jeju Sangmyeong wind farm were aware that fluctuations in supply – which do not always correspond to fluctuations in demand – can pose challenges for the planning and delivery of a reliable electricity supply.

To address this issue, the new wind power plant was designed with an Energy Storage System (ESS). It featured a high-performance lithium-ion cell technology Battery Management System (BMS) developed by LG Chem to support power supply stabilization in renewables operations. Consequently, the project scope required a secure and dependable Electrical Equipment Control and Monitoring System (ECMS) and a Power Management System (PMS) capable of visualizing and controlling the electrical equipment and connecting to the Energy Storage System.

To ensure supply security, it was crucial that the new software system be flexible enough to meet the needs of all subsystems and provide highly reliable redundancy between the ECMS & PMS Primary Server and the ECMS & PMS Secondary Server. KOMIPO conducted a comprehensive solicitation process to identify a solution that would meet the requirements of the utilities.

The chosen system integrator NEOPIS, a COPA-DATA partner, utilized zenon to implement the Power Management System (PMS). zenon displays and controls the amount of energy stored in the batteries and the amount transferred directly to the grid. The system is programmable with rules dictating when energy is stored. This includes relative cost. Because energy is less expensive at night due to reduced demand, it is sold back when it can achieve the highest price. zenon provides the flexibility to automate or manually adapt these processes in the PMS to the current circumstances.

Project Manager Jun Seon Lee explains that by storing energy in this manner, the company can maximize revenue generation. He says, "We are ecstatic with the system's operation and performance. In zenon, we have a single solution for control and monitoring of both the wind farm and the energy storage operations, with built-in redundancy that would allow operation even in the event of a system blackout." (13)

3.3. Smart Grid

Creating a more sustainable energy supply isn't only about bringing in new sources of renewable energy into the grid, although that is important. It's also about minimizing waste and driving optimization of existing operations.

Demand for BESS has also been on the rise thanks to initiatives to modernize the grid, such as the transition to cutting-edge technologies like smart grids (14). "Smarting" the grid systems allows for increased security of supply (15)(16).

BESS software can help with data visualization, analytics, and strategy. Today, utilities providers operating in the energy sector are thinking about utilizing the automation of substations and feeders along with more intelligent monitoring systems. This advancement can bring about a number of improvements in power distribution networks for the primary purpose of analyzing operational data so it can strengthen the grid and enhance network security. Potential applications include predictive asset management and the planning and management of capital investments (17).

The modern electrical grid is a vertically integrated system made up of three parts: power generation, transmission, and distribution. Each of these parts is supported by different controls and devices that keep the system stable, reliable, and efficient. Utility-scale BESS helps to keep the grid running smoothly by making up for delays or interruptions in scheduled power transfers. As a result of the dramatic changes that are going to take place in the highly energy-intensive industries of the future, there will be opportunities for investment in new technologies that have the potential to both increase resilience and decrease carbon emissions.

With large and permanent installations, BESS systems can either be connected to pre-existing power grids or used to generate new sources of electrical power. Their services include adjusting the frequency of the grid on a minute-by-minute basis and creating time-shifting features that allow power to be bought and stored when prices are low and then used when prices and demand are high.

This enables a power company to reduce the strain that power lines have on the grid. BESS offers an alternative to other solutions to this problem that would require greater investment. If we could save money without having to renovate or modernize the entire power line network, that money could be diverted to purchase more BESS. That paves the way for the development of virtual powerlines, a novel form of technology.

Virtual powerlines are extremely helpful when two BESS are operating at opposite extremities of a grid. Both are involved in distribution, but one is on the supply side and the other on the demand side. Because of this, energy may be introduced to the system gradually.

3.4. RTE, France

The [RINGO project](#) for RTE features a virtual power line that is comprised of a BOLLORE battery grid.

When RTE's RINGO solar project began in February 2018, it was called a “virtual power line”. Thanks to the 72 MWh storage project, new power infrastructure wasn't needed.

The planned storage capacity was only for power transmission, not production. The first of three 12 MW/24 MWh storage systems for the €80 million project was installed after two years of planning. Nidec made the nickel-manganese-cobalt (NMC) battery system installed by RTE in Vingeanne, France.

Saft and Schneider Electric set up a storage system in Bellac, Haute-Vienne, France. Engie, Blue, and SCLE Inéo will install the same battery in Ventavon, Hautes-Alpes. The first system was planned to be operational by May 2022. (18)

In addition, there is an electrical control command made up of power electronics and inverters. A transformer HTA/BT and its equivalent distribution transformer are installed. There are several technologies that are being managed via software, and these include the control room, local HMI solution for the battery energy system, and monitoring of container auxiliary systems such as ventilation and climate control, as well as the link between the utility control room and the local storage plant.

3.5. Building resilience for end users & managing changing patterns of generation and demand

As our earlier questions revealed, there are a number of drivers which are changing the way heavy consumers of energy and other businesses and organizations think about their energy supply which make BESS an attractive investment.

This includes:

- The changing pattern of demands on the grid as part of our energy transition, e.g. switching to electric power for heating and for vehicles.
- Global geo-political tensions which are creating more pressure on high consumers of electric power to make their own supplies more resilient.
- The changing pattern of feed into the grid as the lines blur between producers and consumers.

As we enter an era when limitations on energy supplies once again becomes a likelihood, businesses that implement BESS technology have the ability to eliminate seasonal downtime, reduce risk, and maintain operations. BESS is a safe bet for meeting increased

demand beyond what the grid can supply, reducing transmission and distribution bottlenecks. At the same time, they can take steps toward a more sustainable energy future. This is a win-win situation for everyone involved.

For businesses that do invest in energy infrastructure onsite to secure more resilient operations, HMI/SCADA software can help to manage BESS. It makes it simpler to use data to make decisions regarding power generation, transmission, distribution, operational reliability, energy efficiency, and load shedding.

3.6. Potsdam Chamber of Crafts, Germany

Decentralized energy supplies based on renewable sources have long been the subject of research and development. Efforts to put these ideas into practice are gaining traction. This story showcases a true partnership between two countries and between the education and the technology sectors.

The education and training of qualified specialists is a critical component in making a sustainable energy future a reality: who will build, install, maintain, and network all of the plants required to make the energy revolution a success? Who will be in charge of keeping the plants running?

[The Potsdam Chamber of Crafts \(HWK\)](#) identified this need. In response, it launched a project in 2013 at the Education and Innovation Craft Campus in Groß Kreutz. A new Competence Center for Energy Storage and Energy System Management facility followed in April 2022. Its primary goal is to provide tradespeople with practice-focused qualifications. These credentials will cover all aspects of the implementation of sustainable, decentralized energy systems, as well as their installation in industry, trade, and residential settings.

As a result, the campus's energy supply has been divided into two halves, with one half cut off from the public grid so that it can operate independently as an island grid. The other half of the campus is still connected to the public power grid. It boasts eleven photovoltaic plants totaling 144 kW, a wind turbine, several charging stations, and a variety of home storage systems on campus.

"In order to put the plants into operation, we needed a large 640 kW battery storage system and an intelligent energy management system," explains Christian Leest, Technical Manager of the Education and Innovation Craft Campus (BIH) at the Potsdam Chamber of

Crafts. HWK Potsdam sought a specialist supplier capable of supplying, developing, and installing both core components.

WEMAG, a utility company based in north-eastern Germany, and its partner SCADA-Automation were chosen to partner with HWK on the project. These companies provided HWK with extensive experience and expertise in large-scale storage system control, as well as the ideal software to develop an innovative control system: zenon from COPA-DATA. The implemented solutions work with the industrial automation software providing visualization, logging, and operation. (19)

4. Who could benefit from BESS?

As we can see from our examination of the drivers for BESS investment, many segments of industry might benefit from BESS.

Typically, BESS beneficiaries fall into five key categories or user groups:

- Power generation
- Energy trading
- Energy transmission and distribution
- Energy sales and marketing
- Energy consumers



Let's consider each of these groups in turn.

4.1. Power generation

Generation space: energy producers (power plant operator and end consumer) and virtual power plant aggregator.

In recent years, BESS has become an increasingly important component of the power system as a result of the growing significance of system flexibility and the rapidly falling cost of battery technology.

Investments in battery storage are rising throughout all sectors of the grid (transmission and distribution) and in all market segments (public, industrial, commercial, and residential). Transmission-level BESS installations are more common. Their primary function is to improve grid stability by facilitating the rapid release of power in emergency situations. Transmission and distribution firms rely heavily on grid stability to keep their infrastructure running smoothly. With the help of batteries, they can maintain the grid's frequency. They charge if the load is too high and push energy from the batteries if the load is too low. Further, a battery system can help to mitigate disruption to supply, e.g. after a blackout.

Policymakers, regulators, and utilities are increasingly looking to develop policies to kick-start the deployment of BESS as the price of BESS continues to fall and the demand for system flexibility increases due to the deployment of wind and solar energy.

By utilizing BESS, Independent Power Producers (IPP), utility operations, and monitoring service providers could provide support for the grid infrastructure. IPPs have the potential to sell to commercial companies which have a need for power supply. (26)

4.2. Energy trading

As well as production and operational stakeholders, it is critical to include indirect stakeholders in the key user chain. These stakeholders are primarily involved in trading and sales, e.g. energy trader and market maker, virtual marketplaces, and energy storage aggregators.

4.3. Energy transmission and distribution

Energy transmission and distribution stakeholders include: (T&D) network operators; T&D grid equipment manufacturers; distributed energy providers; distributed energy resources

network owners and operators; smart energy solutions providers; energy suppliers; utilities businesses; grid operators; energy storage systems integrators; energy storage project developers; wind project developers; solar project developers; independent power producers; T&D technology providers; engineering, procurement, and construction (EPC) firms; energy regulatory agencies; solar and storage developers; energy storage OEMs; solar PV OEMs.

4.4. Energy sales and marketing

Stakeholders operating in energy sales and marketing include: commodity sales, energy solutions, and smart services providers.

Some organizations have the option to rent BESS by utilizing a prosumer model instead of buying it through an aggregator.

4.5. Energy consumers

Customers who operate in high-energy-use industries, utilities, and public service organizations stand to benefit the most from the incorporation of BESS into their business operations.

However, with the shift to micro-generation and the need to secure energy independence, the profile of organizations which could benefit from BESS is widening to include very many commercial, industrial, and institutional energy consumers.

4.6. Additional stakeholders

Another important part of the value chain for the BESS industry is comprised of battery technology producers and second-life battery refurbishers and restorers, whereby batteries that were initially used as batteries for electric vehicles can be given a second lease of life.

	 ENTITY	 CHALLENGES	 PAINS	 SOLUTION FEATURES REQUIRED
Segment	Who are these?	What are these?	What are these?	What are these?
Utilities	- Transmission Service Operators (TSO) - Distribution Service Operators (DSO) - Regional Utility - Mixed Utility	- Power quality - Economic asset utilization - Struggles with the DER integration	- Long asset lifecycle - Grid congestion - Aging workforce - CAPEX/OPEX	- Strong installation base - Robust connectivity and interfaces - Platform solution based - Leading edge ergonomics - Low-code platform - Consciousness regarding high-level security
Independent Power Producers	- Single or multiple geo distributed plants (generation/storage) - Privately owned/funded companies	- Compliance to grid codes - Amortization of investment - Fleet management - Supply of grid services	- CAPEX/OPEX - Consolidated views - Identification of underperformance - Utility interface	- Scalability/ interoperability - Integrated analytics/ reporting - Control center integration
Commercial and Public	- Industrial sites - Commercial and public entities	- Reduction of energy cost - ISO 50001 / EDMS - Subsidies, uninterruptible power supply - Seamless system landscape (IT/OT) - e-mobility	- Amortization of investment - Operational transparency - Non-interruption	- Monitoring/redundancy - Open integration (3rd party) optimization through analytics - Horizontal integration
System Integrator	- Hardware System Integrators - Engineering System Integrators - EPCs	- Complementing technology - efficient engineering - compliance to grid codes - added value service	- Engineering time - Employer qualification - Adapting to varying needs - Know-how gap	- Automatic engineering - Template-able solution - Simplicity - Out of the box functions - Independence - Application sets
OEM	BESS technology / equipment manufacturers	- Asset lifecycle - HMI / local control - add-on services - innovation	- Solution integration - Supplier flexibility - Rapid prototyping - Time to market	- Openness / connectivity - Independence - Platform solution - Scalability - Proven utility-scale experience

Another important group of stakeholders are the system integrators who play an essential role in the construction of the BESS facilities.

5. What best practices can we identify for BESS operation?

How can a BESS be operated at the lowest possible cost? How does software help? And what are the current standards, protocols, and regulations?

5.1. Components of BESS

For energy storage systems that rely on batteries, the Power Conversion System provides input and output power regulation via a bidirectional inverter (PCS).

By charging or discharging in response to a dispatch signal in milliseconds, a PCS allows a BESS to go from standby to full nameplate capacity in under two seconds (not counting communication latencies). It only takes a few milliseconds for a PCS to respond to an electrical signal and change its charge state. This near-instantaneous transition between charging and discharging (and vice versa) allows for the delivery of high-performance ancillary services, such as frequency regulation (27) (28).

Battery modules, a storage enclosure with thermal management, a power conversion system, a battery management system, and an energy management system are the typical components of a BESS.

5.2. Battery types

A number of battery types are available for use in BESS (29). Some of the most important are shown in the table below.

VANADIUM-REDOX FLOW These batteries have demonstrated their ability to meet the challenge of integrating renewable energy sources such as solar and wind farms. For many years, the sensitivity to high temperatures, high cost, and smaller storage capacity of these batteries limited their widespread use.	ZINC-POLYIODIDE FLOW The zinc-polyiodide redox flow battery, which was developed in 2015, is used to store renewable energy. It employs an electrolyte with more than twice the energy density, or stored energy, of the next-best flow battery, and is getting close to the energy density of the type of lithium-ion battery used to power portable electronic devices and some small electric vehicles.	ORGANIC AQUEOUS FLOW This battery, like the vanadium-redox flow battery, generates power by pumping liquids from external tanks into a central stack. It is also used for renewable integration. When fully developed, the new version is expected to cost as little as \$180 per kilowatt-hour, which is 60% less than today's standard flow batteries.
SODIUM-ION Although sodium-ion batteries are highly efficient and relatively inexpensive, developing such batteries with high energy density and long life has proven difficult. In the future it is aimed that sodium-ion will be a good alternative to lithium for storing energy on the grid.	MAGNESIUM-ION Magnesium batteries are a potentially promising energy storage option because they have more capacity and fewer safety issues than lithium batteries, but the electrodes are difficult to produce and fail quickly.	LITHIUM-ION Portable electronics and electric vehicles frequently use Li-ion batteries. These rechargeable batteries have two electrodes: one that is positively charged and contains lithium, and the other that is negatively charged and typically made of graphite. When electrons flow through a wire that connects the two, electricity is produced. This however is the widely use battery type among BESS projects.

Lithium-ion

Rapid technological advancements have made Li-ion batteries the industry standard for energy storage in batteries. For this reason, we will focus on lithium-ion in BESS in this white paper.

The global demand for mobile technology has had an impact on li-ion investment. It has captured a sizable portion of the industrial energy storage market due to the fact that it is mass-produced and available in a variety of chemical compositions. Today, the majority of lithium-ion BESS are less than 10 megawatts (MW). Hornsdale Power Reserve in South Australia is home to the one of the world's largest BESS, a 100MW (129MWh) lithium-ion system.

Over the last two years, a number of Li-ion BESS projects have been in progress and their combined capacity will exceed 100 MW (30).

5.3. Battery specification

The type of battery, e.g. lithium-ion, is not the most important decision when it comes to specification. Aspects such as the recommended power rate must be taken into account.

This relates to the C-rate concept. This is defined in battery manufacturing terminology as “the capacity of any battery is given in Ah at a specific rate” (usually 1 hour, 10 hours, or 20 hours). When the capacity is expressed in terms of a rate of 10 hours, the abbreviation “C10” is used. This means that a 100 Ah₁₀ battery can be discharged at 10 A for 10 hours, at which point the end-of-discharge voltage will be approaching. (31) From a system standpoint, it is critical to understand the purpose for which the battery is designed. For example, if a battery is commissioned for a BESS that is not designed for frequency regulation, it will create a safety hazard and may even cause an incident.

In terms of battery selection sizing, optimum C rate against oversizing, efficiency, and maintenance to lifetime, it is essential to have an understanding of cost in terms of the components of the battery. The price is established at terms with the expectation that the customer will want to purchase a particular usable battery at EOL. However, in practice, the customer pays for the installed capacity at the beginning of life (BOL).

5.4. The role of software

The energy and infrastructure industries benefit greatly from highly automated digital software. In industry, today's rising retail electricity prices has increased the importance of monitoring the energy consumed by various processes.

The information made available by a reliable and efficient energy production and transmission solution has rarely been more crucial. In this way, BESS software automation (32) can aid in the reduction of costs, the enhancement of efficiency, and the promotion of sustainability in the energy sector.

An HVAC software solution is required since precise temperature control is an important factor in terms of battery efficiency and longevity. Battery packs are grouped together as a

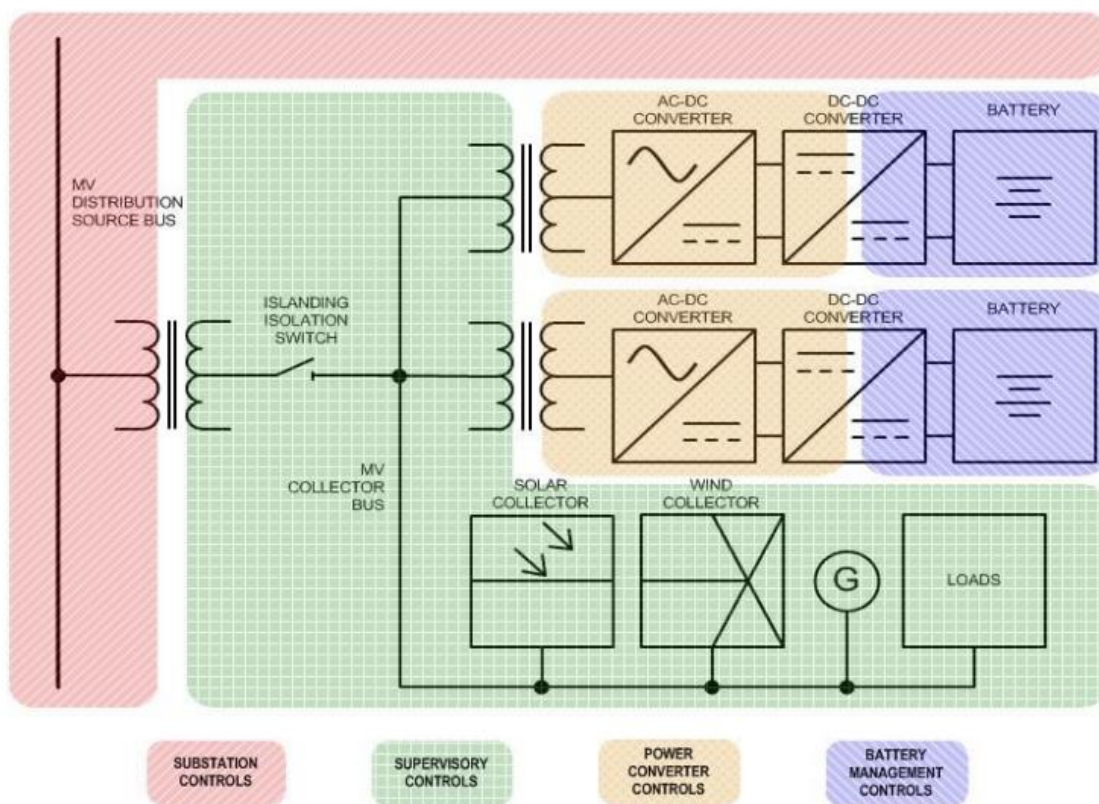
rack and are enclosed using containers. Other key auxiliaries exist, such as switches, safety, and fire detection systems. These form part of the BESS hardware package.

An existing energy management system (EMS) can monitor and control the flow of power into the grids using BESS components (battery modules, battery management system, and power conversion system).

For a software to be appropriate for use with BESS, it must support the use of the key communication standards and protocols and other key standards used in the sector.

5.5. Automation & communication

The following schema explains the components of a typical energy storage solution, with reference to CIGRE's BESS generic architecture and controls (33):



Source: CIGRE WG C6-30 brochure

The CIGRE model (33) can guide us to the typical cost elements. Note that it is critical to evaluate the initial capital cost of BESS when investment made is being linked to energy efficiency targets.

It also offers insight into the controls required within BESS.

Substation controls

- **MV Distribution Source BUS**

Supervisory controls

- Islanding Isolation Switch
- MV Collector BUS
- Solar Collector
- Wind Collector
- Loads

Power converter controls (PCC)

- AC-DC Converter

Battery Management controls (BMC)

- Battery
- DC-DC Converter

The technology infrastructure requires different communication technologies to be available to use:

- Some that are used have emerged from other industries, such as the auto sector. CAN, which is an important communication standard, is one such example.
- Modbus, a protocol that is tied to the battery management system, is also important.
- Other protocols include KNX and BACnet, which could be tied to auxiliaries.
- Higher level components, such as those of energy management systems or plant control systems, make use of DNP3, IEC 61850 and IEC 60870-5.
- The IEC 60870-5 comes into play when a utility provider wants to connect a local battery plant to a utility control room or a Distributed Energy Resource Management System (DERMS).

- IIoT protocols such as MQTT and OPC UA play a role in the areas of remote access and cloud computing.

Because of the wide gamut of these communication protocols, the industry values software solutions that can serve all these communication technology requirements.

5.6. A standard for BESS performance evaluation: The SNL/PNNL protocol

The SNL/PNNL protocol (34) demonstrates how BESS can be implemented in numerous ways. Several case studies detailing BESS implementation will be discussed in the section below.

The SNL/PNNL protocol applicability use case consists of seven distinct sections:

- Peak shaving
- Frequency regulation
- Islanded microgrids
- PV firming
- Volt/Var
- Power quality
- Frequency control

The SNL/PNNL protocol (34) addresses the various applications that BESS can have, as well as the ways in which it can be of assistance to the energy and power industries in a variety of different ways.

- **System Control:** In order to keep the generation and load balanced, advanced planning of transactions and generation, as well as real-time control of some generation, is required.
- **Reactive Supply & Voltage Control:** The production or consumption of reactive power from generators for the purpose of keeping voltage levels on transmission systems within acceptable ranges.
- **Regulation:** Generation and load balancing within a control area on a minute-by-minute basis in order to conform to NERC standards.
- **Spinning Reserve:** A generation capacity that is online but unloaded and that can respond within ten minutes to compensate for outages in either generation or transmission is said to be online but unloaded. The 'frequency-responsive' spinning

reserve reacts to changes in the system frequency within ten seconds to keep it stable.

- Supplemental Reserve: Generation capacity that may be offline or load that is capable of being curtailed and can respond within ten minutes to compensate for outages in either generation or transmission.
- Energy Imbalance: On an hourly basis, correcting any inconsistencies that have arisen between the actual transactions and the ones that have been scheduled.
- Load Following: Adjusting to the shifting demands imposed both hourly and daily.
- Backup Supply: Generation that is available within an hour, either to supplement already existing reserves or for use in commercial transactions.
- Real Power Loss Replacement: Generation that makes up for losses in the transmission and distribution system.
- Dynamic Scheduling: Control in real time that allows for the electronic transfer of either the output of a generator or the load of a customer from one control area to another.
- Black Start: After a power outage, the capability to reenergize a portion of the grid without assistance from outside sources.
- Network Stability: Immediate action taken in response to system disturbances in order to preserve system security or stability.

5.7. Other standards and protocols for BESS

The provision of standards that are applicable to BESS projects is relatively contingent on a wide variety of aspects of the project, including the legal requirements of the country. There are also specific project criteria, such as the components of the BESS, the full infrastructure of the BESS, the installation of the BESS, the aspect of the BESS that deals with safety, and the processes that involve interconnectivity. (35)(36)

The following table considers some of the most important standards relating to BESS installations.

Energy and Infrastructure protocols

MODBUS	"The Modbus protocol is a way to communicate that is based on a client/server architecture. Gould-Modicon made it in 1979 so that its programmable logic controllers could talk to it." (37)	"Modbus can connect a client (like a PC) to more than one server (e.g., measurement and control systems). There are two types: one for serial (EIA-232 and EIA-485) and one for Ethernet." (37)
CAN	"The CAN protocol is a standard that was created so that microcontrollers and other devices can talk to each other without needing a host computer. The CAN protocol is different from other communication protocols because it has a bus that works like a broadcast. This is one of the things that makes it stand out. The CAN protocol is a standard that was created so that microcontrollers and other devices can talk to each other without needing a host computer. The CAN protocol is different from other communication protocols because it has a bus that works like a broadcast. This is one of the things that makes it stand out. The process of sending information to all of the	"Initially, the CAN protocol was designed to solve the problem of how to talk to each other inside cars. Later, though, it was used in a wide range of other fields because of the features it offered." (38)

	nodes is called broadcasting." (38)	
KNX	"The KNX open standard (see EN 50090 and ISO/IEC 14543) is the gold standard for both commercial and residential building automation. KNX devices can control a wide range of functions, such as lighting, heating, ventilation, and air conditioning (HVAC), security systems, energy management, audio/video, white goods, displays, and remote control." (39)	"KNX grew out of three older standards: the European Home Systems Protocol (EHS), BatiBUS, and the European Installation Bus (EIB or Instabus). Powerline, RF, or IP links can be used. Twisted pairs can also be used in a tree, line, or star topology. Devices on this network make up distributed applications, which makes it possible for them to work together closely. Logical device channels are modeled using interworking models with standard datapoint types and objects." (39)
BACnet	"BACnet is a protocol for building automation networks. It stands for Building Automation and Control Networks. It has been agreed upon by ASHRAE, ANSI, and ISO 16484-5. There are gateways that connect BACnet-side communication participants with other fieldbus systems and protocols (like DALI, KNX, or LON) so that they can communicate with each other and with systems from other industries." (40)	"BACnet makes sure that devices from different manufacturers can work together if all project partners agree on certain BIBBs that are set by the standard. A BIBB (BACnet Interoperability Building Block) tells the server and client what services and procedures they need to support to meet a certain system requirement. The Protocol Implementation Conformance Statement (PICS) document for a device lists all the BIBBs, object types, character sets, and communication options that it can use." (40)
OPC-UA	"The OPC Unified Architecture (OPC UA) is a	"The OPC UA architecture is a service-oriented architecture

	standard for exchanging data. It is a service-oriented architecture (SOA) that works on any platform. OPC UA is the latest generation of open platform communications (OPC) specifications from the OPC Foundation. It is very different from its predecessors. It can transport machine data (control variables, measured values, parameters, etc.) and also describe them in a way that machines can understand." (41)	(SOA), and its structure is made up of a few different layers." (41)
MQTT	"MQTT, which used to be called MQ Telemetry Transport, is an open network protocol for machine-to-machine (M2M) communication. It lets devices send telemetry data in the form of messages to each other even when networks are slow or have limited bandwidth. Sensors and actuators, mobile phones, embedded systems in cars or laptops, and full-fledged computers are all examples of this type of device." (42)	"An MQTT server (also called a broker) holds all the information about its communication partners. It can be used as a state database because of this. So, it's possible to connect small MQTT devices that don't work well to an MQTT broker. The devices can then collect data and/or receive commands while an MQTT broker creates a complex picture of the situation that can be evaluated there or by a powerful communication partner." (42)
IEC 61850 Client/Server and GOOSE	The IEC 61850 Standards are predicated on the concept of defining models and modeling	"IEC 61850 is a standard for electrical substation automation design. IEC 61850 is a part of the reference architecture for

	methods for typical information found in real-world substation applications. In accordance with the GOOSE principle, a device transmits data via multicasting. Only subscribed devices will receive this message.	electric power systems developed by Technical Committee 57 (TC57) of the International Electrotechnical Commission (IEC). The IEC 61850 abstract data models are mappable to numerous protocols. The standard currently includes mappings to MMS (Manufacturing Message Specification), GOOSE, SMV, and (soon) Web Services. These protocols can operate over TCP/IP networks or substation LANs using high-speed switched Ethernet to meet protective relaying response times below four milliseconds.” (43)
IEC 61850 Edition 2 (certified by DNV GL)	Guarantee the interoperability of smart grid systems (44)(45)	The objective of IEC 61850 Edition 2 is to simplify the engineering process of IEC 61850 Edition 1. It also clarifies how future versions of the standard will continue to be interoperable while expanding the application space of the base standard. In addition to supporting maintenance, commissioning, and testing, the second edition introduces redundant communication at the communication-port level. (46)
IEC 60870-5 (101/103/104)	101: refers to the accompanying standards, particularly for fundamental telecontrol tasks.	The definition of telecontrol systems, which are utilized in the fields of electrical engineering and power system automation, can be found in this standard (part of IEC

	103: refers to the companion standard for the protective equipment's informative interface. 104: refers to network access using standard transport profiles for IEC 60870-5-101	60870). Part 5 provides a communication profile for the transmission of fundamental telecontrol messages between two systems using permanent, directly connected data circuits. (47)
ICCP - TASE.2	This is the Inter-Control Centre Communications Protocol, or ICCP. The IEC 60870-6-503 standard specifies TASE.2 at the application layer.	This standard defines the protocol of the application layer so that it meets the functional cooperation requirements. In addition, it specifies the requirements for TASE.2's presentation and relation layers. TASE.2 protocol derives from MMS (Manufacturing Message Specification). The fundamental ICCP functions are specified as a collection of "Conformance Blocks." (48)
DNP3 Master and Outstation	This is ideal for remote communications with limited bandwidth and frequent interruptions, such as power outages in remote areas.	DNP3, also known as IEEE Std 1815, is a comprehensive protocol standard that specifies the rules for computer-to-computer communication. DNP3 identifies two types of communicating endpoints: the master and the outstation. These are explained and defined below: • The master

		A computer or network used in a control center is the master. This computer is powerful and capable of storing and displaying all incoming data from remote sources. • The outstation The outstation, also known as the slave, is a computer used in the field. These outstation computers collect data from numerous field devices, including current sensors and voltage transducers, and transmit it to the master station. (49)
IEC 62056-21 (Energy Meter)	IEC adopted and maintains this standard for energy meter communication. (50)	This is an international protocol standard for reading utility meters. It is intended to function over any medium, including the Internet. Using a serial port, a meter transmits ASCII (in modes A to D) or HDLC (mode E) data to a nearby hand-held unit (HHU). (51)

Any software used in a BESS installation should be capable of supporting these standards and protocols.

6. Conclusion

The market potential for BESS is highly dependent on a variety of factors, including its applications. BESS has a number of applications that are linked to specific beneficiaries along the value chain. In the value chain, BESS's job is to always try to maximize value, no matter who it helps or where it can be used.

Every new technology has its own essential features and limitations, even when its primary purpose is to reimagine or regenerate an existing system. A reliable and efficient BESS designed for utility-scale applications (52) could be an important new technology solution in our answer to the energy crisis.

BESS will play an important role in how countries meet their energy needs as they look toward a more secure and sustainable energy future for the world. Sustainability should be at the heart of the solution. To meet these needs, the software automation at the core of BESS technology sets the wheels in motion for a cleaner and fairer global energy transition based on renewables.

Several parameters are critical in understanding BESS investments within the industry (53). This includes storage capacity as well as power output range. Energy storage capacity is the amount of charge or energy that an energy storage device can deliver in a single discharge. Furthermore, lifetime is an important factor, as is energy efficiency, which can be defined in a variety of ways depending on the storage technique.

Payback time, dependability, and asset life span remain important metrics which investors must consider (54). There is a lot at stake and, as yet, a scarcity of data. Within the next decade, software technology like that used for monitoring and reporting in the asset performance management sector will allow for more confidence in investments – as more data is produced.

Sustainability should be at the heart of the solution. To meet these needs, the software automation at the core of BESS technology sets the wheels in motion for a cleaner and fairer global energy transition based on renewables. BESS software automation (55), the result of some creative thinking, can aid in the reduction of costs, the enhancement of efficiency, and the promotion of sustainability in the energy sector.

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