ELECTRICITY LAWYER

SUB-SAHARAN AFRICA (SSA) BATTERY ENERGY STORAGE SYSTEMS (BESS) TOOLKIT

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Content

Table of Abbreviations

AC	Alternating Current
ARAI	Automotive Research Association of India
BaaS	Battery as a Service
BCS	Battery Charging Stations
BESS	Battery Energy Storage System
BEVs	Battery Electric Vehicles
BIS	Bureau of Indian Standards
BSS	Battery Swapping Stations
CalGreen	California Green Building Standards
CEA	Central Electricity Authority
CIT	Corporate Income Tax
CNG	Compressed Natural Gas
DC	Direct Current
DoD	Depth of Discharge
DRC	Democratic Republic of Congo
E2Ws	Electric Two Wheelers
EPRA	Energy and Regulatory Authority
ESS	Energy Storage System
EU	European Union
EV	Electric Vehicle

EVSE	Electric Vehicle Supply Equipment
FCEVs	Fuel Cells Electric Vehicles
FMVSS	Federal Motor Vehicle Safety Standards
FOB	Free on Board
IFC	International Finance Cooperation
IoT	Internet of Things
ISO	International Organisation of Standardization
LPG	Liquefied
MINIFRA	Ministry of Infrastructure
MoP	Ministry of Power
NABL	National Accreditation Board for Testing and Calibration Laboratories
O&M	Operations and Maintenance
OCPI	Open Charge Point Interface
OEM	Original equipment Manufacturer
PCS	Public Charging Stations
PHEVs	plug-in hybrid electric vehicles
PV	Photovoltaics
SAE	Society of Automotive Engineers
SSA	Sub Saharan Africa
TNERC	Tamil Nadu Electricity Regulatory Commission
USD	United States Dollars
VAT	Value Added Tax

1. An Introduction to Energy Storage

Energy storage refers to the capacity to gather energy all at once for usage at a future time or period. It is the process of storing energy produced at one moment for use at a later period, in order to balance out the imbalance between energy production and demand. Storage devices have the ability to capture energy in a variety of forms (such as chemical, kinetic, thermal etc.) and transform the stored energy back into a usable form, like electricity. Almost all current energy storage capacity is in the form of pumped hydro, which illustrates the need for a diverse range of energy storage systems. There are five major technological categories that can be used to classify the many forms of energy storage. These include batteries, thermal, mechanical, hydrogen and pumped hydro energy storage system. The adoption of battery systems is expanding rapidly, and several storage technologies are currently being deployed.

Thermal storage entails the holding and releasing of heat or cold as solid, liquid, or air. It also involves possible changes in the state of the storage medium, such as from gas to liquid or from solid to liquid and vice versa. Examples of technology used include the use of liquid air and molten salt for energy storage. Mechanical energy is the most basic energy storage devices which use the rotational or gravitational kinetic forces to store energy. Hydrogen energy storage is a form of energy that is still being developed for energy storage, and it would be electrolyzed from electricity and stored in tanks. Pumped hydro involves the cycling of water between two reservoirs at different levels, the upper reservoir acting as "energy storage" that is released when water is released into the lower reservoir.

In the era of climate change and clean energy, energy storage is becoming increasingly necessary, and as a result, a wider variety of solutions are becoming available, as they provide a viable solution to the intermittency of renewable energy. Battery Energy Storage System (BESS) has become prominent. Batteries are the oldest, most popular, and most generally available type of storage. Batteries are an electrochemical technology made up of one or more cells having a positive terminal called a cathode and a negative terminal or anode. There are various chemistries used in batteries, the two most well-known and frequently used in portable electronics and automobiles are lithium-ion and lead acid. Nickel-cadmium, sodium-sulphur, and zinc-air are further solid kinds of battery. The flow batteries with liquid electrolyte solutions fall under another group. These include vanadium redox, iron-chromium, and zinc-bromine chemistries.

2.

Battery Energy Storage Systems (BESS) across Sub-Saharan Africa (SSA)

Sub-Saharan Africa (SSA) remains one of the world's least developed regions despite the significant potential offered by a wealth of natural resources. Access to affordable and dependable power, a requirement for social and economic growth, is only available to a cumulative of 35–40% of SSA's population. Replacing generators and smoothing energy supply in areas where the national grid is unreliable or non-existent presents a significant market opportunity for BESS. About 12-17 billion USD is spent on back-up generators yearly in Nigeria alone and 9% of electricity consumed across SSA is supplied by generators.

Energy storage in the industry is becoming increasingly necessary, and as a result, a wider variety of solutions are becoming available as the demand surges and new innovations employing cutting-edge materials and technologies are created. To increase productivity and cut costs, innovation is being applied to all storage methods. The rapidly falling costs of battery storage technology and supporting equipment such as photovoltaics (PV) panels make the business case for their deployment more attractive each year. Per capita energy consumption is anticipated to more than double by 2040 and demand from industrial and service sector actors are anticipated to more than triple. This constitutes a significant opportunity for private sector providers of equipment locally and internationally.

According to the International Finance Corporation (IFC), replacing 25 million diesel and gasoline generators in developing nations (aside from China) with energy storage technology could reduce annual CO_2 emissions by up to 100 million tonnes. Carbon dioxide emissions from using fossil fuels significantly worsen the effects of global warming, which disproportionately affects the world's poorest people, the majority of whom live in countries across SSA. Battery storage technology can maintain the vital services provided by hospitals, schools, and factories, in addition to the productive activity of economies. Additionally, battery storage can make it possible for off-grid energy delivery methods like mini-grids, which are the most cost-effective approach to supply 111 million of the 238 million unconnected households in sub-Saharan Africa with electricity allowing for the integration of utility-scale renewables and delivering electricity and opportunity to the continent's least developed regions.

Novel energy storage technologies may be competitive and practical in SSA, providing different options for grid independence and resilience.

The market for battery energy storage in SSA is characterized by several factors some of which include:

- As domestically made batteries cannot compete with imported batteries in terms of quality, variety, and cost, most batteries are imported from China.
- Most African markets have limited options for several variations of BESS.
- Lead-acid BESS account for much of the installed energy storage.
- Deep-cycle batteries are also produced by automotive battery producers in numerous African nations. Lead-acid battery lifespans for mini grid operators fall short of expectations.
- Lithium-ion (Li-ion) batteries are beginning to be used for specialized high-value instances and in more developed African markets (South Africa, Kenya, and Nigeria).
- The expected payback periods for many of these direct diesel substitution initiatives range from three to six years.
- Smaller ventures have trouble being financially viable. In response, some start-ups are providing more compact lithium-ion systems with creative funding plans.
- Compared to lead-acid batteries, Li-ion batteries are the preferred technology for solar household systems.
- New pay-as-you-go business models for small-scale energy storage are emerging.

- Li-ion BESS integration with renewable energy has been requested in recent international competitions for utility-scale projects in nations including South Africa, Mozambique, and the Democratic Republic of the Congo (DRC).
- Significant mini-grid deployments in West Africa are beginning to choose Li-ion as the preferred storage option.
- Stand-alone storage projects are being put into place in South Africa and Nigeria to provide ancillary services. These projects will save money on transmission and distribution extension expenses and provide backup power in the event of a supply disruption.

Some of the advantages of BESS include:

- Reduction of fuel consumption.
- Increased integration of renewable energy sources.
- Less dependence on the grid.
- Reduction of carbon footprint
- Long term cost savings
- Reduced operations and maintenance (O&M) costs associated with using generators by minimizing load fluctuations and unit starts.
- Replacing backup generators used for brief periods of time each day (such as rolling blackouts).

3.

BESS End Users and Market

BESS has for some time been dominated by the commercial, industrial and transport sectors with a rapid spike in the usage of energy storage systems in the residential sector in recent years. This section explores the use of BESS in the residential, commercial and transport sectors.

3.1 BESS in the Residential sector

BESS has begun to gain traction in the residential sector in recent times. Within four years (2014- 2018) annual installations of residential energy storage in the United States were recorded to reach 185 MWh in 2018 from 2.25 MWh in 2014. This utilisation of battery energy storage system by residential consumers has been recognised as providing an added opportunity for utilities to balance electricity supply and demand; thereby providing a potential value to the power grid. This is as a result of electricity consumers desiring to have an added control plus the reliability that emanates from having a battery at home. It has been observed that this could potentially lead to communities having a network of "home-based" batteries financed by residential customers largely driven by the family/unit scale demand, but with minimal usage. Therefore, there are considerations around linking residential batteries together and dispatching the stored energy to deliver grid support services, in the same way as utilities use demand–response programs and ancillary services resources.

3.2 BESS in Commercial & Industrial (C&I) sectors

BESS offers numerous benefits for the commercial and industrial sectors. It enables control of energy supply and cost. It also enables organizations to store electricity during off peak periods and when prices are low to be used at peak hours where electricity prices are higher. C&I energy storage acts as a reliable backup power source during such instances, ensuring minimal disruption to operations and safeguarding businesses from the detrimental effects of power outages. BESS also incorporates the use of an inverter and rectifier to convert power back and forth between the DC battery and the AC grid. As an inverter-based resource, it is capable of several grid support features such as volt-var and frequency-watt. Finally, by storing renewable energy and replacing conventional backup power sources, BESS aids in creating a greener and more sustainable energy landscape for businesses which can add to their corporate social responsibilities.

3.3 BESS in the Transport sector

The transport sector is the only sector in which greenhouse gas emissions have risen since 1990 in Europe. It is possible to reduce emissions from the sector. The European Union is focusing on accelerating decarbonisation of the transport sector, based on renewable energy sources, through Battery Electric Vehicles (BEVs) and Fuel Cell Electric Vehicles (FCEVs). Energy storage can greatly foster this effort. BEVs and FCEVs can both have a role to play in both automotive and heavy-duty transport sectors. Energy storage technologies allow the storage of excess energy (typically renewables) and for discharge when there is limited electricity generation or excess demand. With the anticipated uprise of electric vehicles (EVs), millions of vehicles can be anticipated to be connected to the grid for recharging, resulting in an increase in energy demand. If all electric vehicle owners recharge their batteries in the evening after the day's activities, a high peak demand can be expected compared to where there are no electric vehicles in the picture. In these situations, energy storage systems connected to e.g., the charging points, will discharge the energy previously stored, such as when there is an excess of sun or wind power.

There are also other ways to reduce costs and stress on the energy system, e.g., vehicle-to-grid integration. Electric vehicle batteries can actively work as storage systems; they can store surplus electricity to be fed back when necessary; provide services to the grid such as the bi-directional charging technology; and also participate in the electricity market, by alleviating power grid stress during peak periods; in addition to the provision of ancillary services (where feasible).

Another consideration is that the electric vehicle market will grow exponentially in the coming years – worldwide, an estimated 100-200 million vehicles by 2030, according to the International Energy Agency. Battery costs are going down and consumers are increasingly willing to switch from fossil fuels to new forms of mobility. Therefore, there will be a proliferation of used electric vehicles' batteries. How then can environmental sustainability be ensured? the vehicles' batteries can be recycled – they often have rare materials, and this might make it economically viable. But there is another possibility, which is to repurpose the battery for another use, giving it a “second life”. Old electric vehicle batteries maintain 70-80% of their initial capacity; they could be repurposed for energy storage applications in a wide array of contexts. This is great for consumers, who can reclaim a part of the initial investment in the electric vehicles' battery. It is also great for storage developers, who can access batteries at lower prices.

BESS is a key element in decarbonising the transport sector; and it reduces costs for many of the actors across the energy value chain. Nevertheless, most of the solutions are becoming mainstream at a slow pace owing to various factors. Currently, fiscal rules, energy taxes create a lack of revenue certainty for storage facilities, coupled with charging infrastructures; considering that appropriate taxes, grid fees, and levies placed on energy storage facilities are key to allow for a robust business case. Charging standards and protocols are inadequate, based on the current state of EV charging protocols which are fragmented, with different manufacturers using proprietary protocols that are incompatible with each other. Second-life batteries face regulatory barriers, as the EU Battery Directive categorises electric vehicles batteries at the end of their first life as waste. These are only a few examples. In-depth research proposes that the EU regulatory framework should be revised to allow commercial business models to thrive, and there are indications that policymakers agree with the position.

3.3.1 Policies and Regulations

Standards and regulations for electric vehicles are still under development and are regulated by various organisations. An example of electric vehicle standards is the Society of Automotive Engineers (SAE) International standards, put in place to advance the engineering involved with vehicular mobility. SAE standards are voluntary practices and are often considered recommended guidelines. One example would be SAE J2990/2_202011, titled "Hybrid and Electric Vehicle Safety Systems Information Report." This overlaps with the isolation requirements in the United States Federal Motor Vehicle Safety Standards (FMVSS) No. 305, but this SAE report further addresses enclosures, labels, and identifications. In addition, the International Organization for Standardization (ISO) is a global organization that develops standards in collaboration with several countries. A predominantly known standard, ISO 26262, focuses on the safety of vehicles, including EVs. Some ISO standards apply to electrical safety, like ISO 17409, developed to help minimalize shock hazards within high-voltage testing. The current situation of the myriad of and often contradictory directives, standards and regulations makes harmonisation of regulations and standards however necessary.

3.3.2 Charging Infrastructure

Consumers and fleets considering electric vehicles (EVs)—which include all-electric vehicles and plug-in hybrid electric vehicles (PHEVs)—need access to charging stations. For most drivers, this starts with charging at home or at fleet facilities. Charging stations at workplaces and public destinations may help bolster market acceptance, by offering more flexible charging opportunities at commonly visited locations. In the United States, community leaders can find out more through electric vehicles readiness planning prepared by the government to help communities evaluate their readiness for electric vehicles, including case studies of ongoing successes. The EVI-Pro Lite tool by the United States government is also available to estimate the quantity and type of charging infrastructure necessary to support regional adoption of EVs by state or city/urban area and to determine how EV charging will impact electricity demand.

Charging the growing number of EVs in use requires a robust network of stations for both consumers and fleets. The Alternative Fuelling Station Locator in U.S allows users to search for public and private charging stations. Quarterly reports on electric vehicle charging station trends show the growth of public and private charging and assess the current state of charging infrastructure in the United States.

The charging infrastructure industry has aligned with a common standard called the Open Charge Point Interface (OCPI) protocol with this hierarchy for charging stations:

location, electric vehicle supply equipment (EVSE) port, and connector. The Alternative Fuels Data Center and the Station Locator use the following charging infrastructure definitions:

- **Station Location:** A station location is a site with one or more EVSE ports at the same address. Examples include a parking garage or a mall parking lot.
- **EVSE Port:** An EVSE port provides power to charge only one vehicle at a time even though it may have multiple connectors. The unit that houses EVSE ports is sometimes called a charging post, which can have one or more EVSE ports.
- **Connector:** A connector is what is plugged into a vehicle to charge it. Multiple connectors and connector types (such as CHAdeMO and CCS) can be available on one EVSE port, but only one vehicle will charge at a time. Connectors are sometimes called plugs.

3.3.3 Permitting

Like any other business, a car charging station company requires permits and licenses to operate. These can include building permits, electrical permits, and business licenses. It is essential to consult with local authorities to ensure that all necessary permits and licenses are obtained. For instance, in California, law AB 1236 (2015) provides streamlined permit approval for the installation of EV charging stations. The law requires a city, county, or city and county to administratively and ministerially approve applications for EV charging stations which meet all health and safety requirements of local, state, and federal law. There is no limit on the size or type of EV charging station that qualifies for AB 1236 except that it be built in compliance with the California Electrical Code and similar applicable safety and performance standards. Local agencies may deny an application for an EV charging station only if they find in writing, based on substantial evidence, that the installation of the EV charging station would cause a specific, adverse impact upon the public health or safety; that cannot be mitigated or avoided. The California Green Building Standards Code ("CALGreen") imposes specific mandatory requirements for EV charging technology for new development projects. Depending on the type and size of the project, CALGreen requires that new multi-family residential projects, hotels, and motels include a certain percentage of EV Ready and EV Capable parking spaces. In addition, for larger developments, a certain percentage of spaces must be equipped with EV charging stations. These laws are intended to remove barriers to EV charging projects that can help developers and governments permit EV charging infrastructure at a quicker pace.

3.3.4 Safety and Operation Standards

In urban traffic, due to their beneficial effect on environment, electric vehicles are an important factor for improvement of traffic and more particularly for a healthier living environment. The electric vehicle represents a "new" technology, introducing electric power components on board road vehicles. The different risks associated with this technology must be carefully assessed. The risk levels however should not be overestimated by fear of the unknown.

Different aspects of electric safety can be considered for electric vehicles:

A. Electric system safety which involves protection against electric shocks, protection against direct contact and indirect contact;

B. Functional system safety which involves system activation warning, power on procedures, prevention of fierce reverse braking, and the likes;

C. Battery charging safety taking into consideration mechanical, electrical and chemical explosion hazard; and

D. Vehicle maintenance, operation and training, etc.

3.3.5 Considerations for the Integration of Electric Vehicles across Sub Saharan Africa

Globally, at least 17 countries have announced target dates to phase out the sale of internal combustion engine vehicles. Electric vehicles remain rare in most of Africa. In South Africa, thought to be the largest EV market on the continent, only 1,000 EVs had been purchased by 2019 – out of more than 12 million vehicles on South Africa's roads. Even fewer electric cars are in operation in most other African countries. Governments and investors can scale up, and accelerate planning for Africa's EV future by taking the following into consideration:

1. **Taxes:** there has been recent push for electric vehicles by introducing tax cuts and other incentives to boost the e-mobility industry and drive the demand for eco-friendly vehicles. As governments throughout Africa gamble on tax exemptions and other incentives to encourage the roll-out of electric vehicles, Tunisia has become the most recent nation to implement e-mobility incentives. The value-added tax (VAT) has been decreased to 7%, and customs taxes on electric car charging equipment have been reduced to 10%, according to the country's Finance Act 2023, which came into effect on January 1 2023.

   Rwanda unveiled a comprehensive package of tax benefits in April 2022 to encourage the use of electric vehicles. The country in East Africa waived import, excise, and VAT taxes on electric vehicles, accessories, batteries, and equipment for charging stations.

   To promote the importation and usage of electric vehicles, Egypt began offering a 10% discount on the free on board (FOB; the value at the point of export) price for old passenger cars with electric or dual motors in March 2021.

   By lowering the import tax on fully electric vehicles (from 20% to 10%) in 2019, the Kenyan government has previously surpassed its contemporaries. State-owned businesses in Kenya, including the energy distributor Kenya Power and the power generator KenGen, have started phasing out fossil fuel-powered vehicles from their own fleets.

2. **Tariff for Charging Stations:** tariffs will go a long way in determining the viability of the EV industry. For instance, recently, Tamil Nadu Electricity Regulatory Commission (TNERC) of India furnished a new tariff order for public charging stations in the State. It has placed charging stations one step above commercial tariffs, which is the most expensive structure in the State. Hence, the operators of EV charging stations have asked the India State Government to amend fixed rates to $70 per kw and lower the tariffs for public charging stations to $7 per kWh. Additionally, the operators asked that the tariff be kept in place through 2025, otherwise, a public charging station would not be financially sustainable to operate at the early stage, and infrastructure development will be halted.

3. **Scrapping/End of Use**: The lithium-ion battery is one of the major obstacles when it comes to scrapping an EV, which may be a very risky process. All current EVs use lithium-ion batteries, while some hybrids (especially Toyotas) may employ nickel metal hydride batteries. Because the compounds found inside lithium-ion batteries, they have the potential to be damaging to the environment and those handling them, recycling these types of batteries is not an easy task that calls for specialized training for workers involved. A battery that has been improperly handled or kept is susceptible to a fire outbreak or an explosion.

   There is also the potential for electrocution even after the battery has been detached, electric cars can still have up to 800 volts flowing through them, which again emphasizes the necessity to go to a qualified mechanic with the necessary accreditation to work on electric cars. In fact, there are several sizable magnets inside electric motors that are so strong they can yank tools out of mechanics' pockets. In addition to posing a risk to the mechanics already working on them, magnets have the potential to interfere with medical devices like pacemakers.

   On a brighter side, up to 80% of the storage capacity of the lithium-ion battery is retained when it is no longer able to power the driving range and acceleration needed to power a vehicle. Therefore, these used power packs are reused for a variety of less power-intensive purposes rather than ending up in landfills or being recycled.

4. **Financing Instruments:** The major reason for the financial difficulties for EVs is risk. Compared to cars with internal combustion engines, electric vehicles are thought to be riskier to finance because of asset risks and business model risks that apply to EVs. Additionally, there are not many specialist finance options for electric vehicles, and insurance premiums can be higher in particular markets and use cases. However, given the enormity of the market, Sub-Saharan African lenders are becoming increasingly interested in funding e-mobility, particularly electric two wheelers (E2Ws). However, it will require cooperation between various financial institutions, including commercial banks, DFIs, venture and equity funders, and grant sources.

5. **Consumer Awareness**: Taking steps to raise customer awareness is essential to fostering the early electric vehicle market's expansion. Consumers in many areas

are generally uneducated about electric car technology, unaware of the incentives that are available, and unaware of the variety of advantages that electric vehicles offer. According to research, consumers who are familiar with the technology and have used it to some degree, are more inclined to think about buying an electric vehicle in the future.

To enhance consumer awareness, stakeholders should work together to build on their individual strengths and make the most of their limited funding for electric vehicle awareness efforts. Many different levels of government, non-profit groups, businesses, academic institutions, local communities, and people have all taken action to raise education and awareness. Collaboration offers many chances to boost the effectiveness of outreach, particularly as the programs and technology that support it continue to advance.

6. **Environment (emissions):** Most experts concur that over the course of their lifetime, electric vehicles leave a smaller carbon footprint than automobiles and trucks powered by conventional internal combustion engines.

   According to a Massachusetts Institute of Technology Energy Initiative study, producing an EV's battery and gasoline produces more emissions than creating an automobile. But over time, EVs' improved energy efficiency more than makes up for the higher environmental costs. However, Before EVs start nearing the end of their useful lives over the course of the next ten years, the majority of automakers are already striving to guarantee they have considerable recycling capacity in place.

7. **Interoperability of Batteries**: As of 2022, EV battery packs are not standardized, making them incompatible with a variety of car types, makes, and models. A crucial part will be played by ensuring battery compatibility with various vehicle types and standardizing battery packs and connectors in the future.

8. **Technical Standards:** Technical specifications for electric vehicle chargers vary across charging stations across different countries. In India, the BIS, CEA, and ARAI are regulatory bodies responsible for developing reference standards to ensure interoperability and minimize trade barriers for electric vehicles and their components, make technical standards and regulations in the power sector of the country, and develop standards for vehicles and its components.

9. **Road usage Policies:** Due to the added weight of the batteries, electric and hybrid vehicles often weigh more than their gasoline-powered counterparts. Thus, it is believed that EVs should pay more taxes, and road usage charges to governments for the road upkeep. However, all passenger cars, from sub-compact sedans to full-size pickups, have equal effects on the road network because most road surfaces are made for the heaviest of vehicles—big trucks and buses. Regardless of their fuel source, all cars have the potential to harm the roads and increase traffic. Additionally, everyone suffers from terrible roads, including EV drivers.

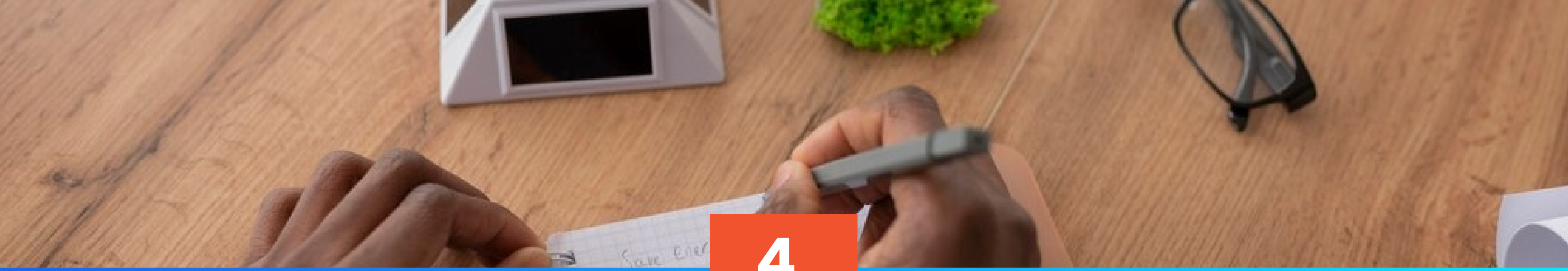
3.3.5.1 A New Alternative: Sodium Ion Batteries

The best performing battery technology now offered by businesses is lithium-ion. However, the cost of the raw materials needed to make these batteries is costly and the demand is growing rapidly; between late 2020 and 2022, the price of lithium carbonate alone surged tenfold. Since China, Australia, Chile, Argentina, and Chile account for over 84% of the world's known lithium resources, it can be costly and challenging for manufacturers to obtain the raw materials needed to produce lithium-ion batteries.

Electric vehicles often use lithium-ion batteries; however, these batteries might have unstable supply chains and expensive raw ingredients. A solution that might ease some of these issues is the use of sodium-ion batteries. These new sodium ion batteries are more affordable, because sodium is more abundant than lithium as a resource. The key material for making sodium-ion batteries, sodium carbonate (or soda ash), can either be found in rocks and Salt Lake brines or it can be made in factories from limestone and salt. Both minerals are widely accessible and practically inexhaustible. With this breakthrough technology, shifting from lithium to sodium-ion batteries could reduce dependence on critical minerals and yield cheaper battery packs. Cheaper batteries may also result in cheaper energy storage on the electrical grid. The newest lithium-ion batteries can run an electric vehicle (EV) for approximately 300–400 miles on a single full charge.

Unfortunately, compared to lithium ions, sodium ions are three times heavier and one-third larger. This implies that for sodium-ion batteries to store the same amount of energy, their electrodes need to be thicker and heavier. The energy density of sodium-ion batteries are yet to be greatly increased. The cathode is a major bottleneck. Because the best layered oxide cathode materials can only store roughly half as much sodium ion as the anode, the battery must weigh more, because twice as much cathode material is needed to balance both sides of the sandwich.

In order to increase the range of electric vehicles (EVs), research is being undertaken to create novel cathode materials that can store more sodium ions in their structure and produce higher voltage output.



4. BESS Projects across Sub-Saharan Africa (SSA)

BESS have been deployed in a select few Sub-Saharan African countries. This section explores some of these projects in the applicable reference countries.

4.1 Mozambique

The African Development Bank has provided financing to the government of Mozambique as of 3rd January 2023, for the cost of the Mozambique Renewable Energy Integration Program. The government of Mozambique intends to use a portion of the grant money allocated for this purpose to pay for consulting services for feasibility studies for BESS and evaluations for pump storage hydropower plants. The consultancy services to be offered include site identification, full feasibility studies for BESS in 10 sites, and assessment for a pumped storage hydropower plant, which must at a minimum consider the following factors: technical viability, financial viability, environmental impact assessment of plant infrastructure and interconnection lines, adaptation and climate resilience, and socio-economic aspects of the proposed technologies.

The introduction of Energy Storage System (ESS) in Mozambique is intended to address the requirement to resolve several issues pertaining to the extensive grid integration of renewable energy sources. Technically speaking, batteries are more suitable for frequency management than the conventional spinning reserve from a power plant. In addition, batteries offer a less expensive option than network expansion for lowering the curtailment of wind and solar power generation. Third, excess power should either be restricted or exported, because renewable energy supply frequently does not match electricity demand. Instead, excess energy can be stored in batteries for use later, when renewable energy production is low and electricity demand is high. Fourthly, storage devices can strengthen the grid's ability to withstand climate change and assist with recovery from climate-related catastrophes like Cyclone Idai.

4.2 South Africa

Eskom, the primary utility, and grid operator in South Africa, has announced that construction on the country's first battery energy storage system (BESS) with Hyosung Heavy Industries has begun. It will be constructed in 7 to 12 months, have an 8 MW power capacity and 32 MWh of energy storage, and be connected to Eskom's Elandskop substation. According to a press release, its primary function will be to boost the network during peak times to reduce grid stress, which is akin to peak shaving. The project is part of phase one of a 343MW/1,440MWh BESS procurement that Eskom concluded in August 2022. The first phase would involve the construction of 199MW/833MWh at eight substations around the nation, coupled with 2MW of solar PV, and the second phase will involve the deployment of 144MW/616MWh at five more Eskom locations with 58MW of solar PV. A total of 11 billion Rand (US$630 million) is being invested in the projects which will be completed by June 2023 and December 2024 in phases one and two respectively.

5.

Battery Swapping

Despite the fact that electric vehicles are becoming more and more popular around the world, distance anxiety and charging times continue to be barriers to widespread EV adoption given that electric vehicles in general are still novel and individuals who frequently travel long distances may find them a little daunting. Numerous solutions are being created in response to the problem in an effort to improve the charging process and reduce the amount of time needed to recharge the battery before getting back on the road, one of which is battery swapping.

Battery swapping is a variation of replacing a drained battery with a fully charged one without waiting for the charging procedure to finish. Rather than plugging an electric car battery in to charge, battery swapping entails replacing a depleted battery with a fully charged battery When compared to the regular 30-minute or longer wait time at a typical recharging station, the process typically takes less than five minutes, which is a win for the EV (electric vehicle) community. An individual is expected to drive the electric vehicle (EV) to a battery switching station, where the station will take care of most of the remaining labor, including lifting the car, removing the chassis and battery bolts, and subsequently swapping out the empty battery.

Battery switching was previously simply a daring theory and not truly firmly in use. Nio, a Chinese startup, was able to bring the notion to life on a big scale, nevertheless. By introducing the battery switch stations on such a large scale, Nio has generated a lot of attention. Earlier in 2022, the Chinese startup producing electric cars announced the completion of the 1000th battery swap station in Shanghai, China. The swap station resembles an automatic vehicle wash in appearance. The automobile pulls up directly onto the platform. The battery pack is automatically unbolted and swapped out for a fresh one. There are three different battery capacities available for this: 75kW, 100kW, and 150kW. The batteries work with all Nio models and the transaction can last up to six minutes.

Recharging batteries takes longer than switching out batteries. In slower situations, the process of replacing the battery and reassembling all components can be concluded in less than five minutes. The process might be concluded in one minute, in quicker facilities; while charging stations can take anywhere from 15 to 40 minutes to fully charge on a rapid or ultra-rapid charge. Furthermore, less ownership is required in battery swapping. Due to the high cost of electric car batteries, the public who may not have the resources to purchase an electric car battery outrightly may have easier access to newer electric cars if they can lease the battery for a relatively modest cost. However, building battery swapping stations is expensive. The cost of constructing one of these stations is approximately £600,000, not including the cost of the land or ongoing operating expenses. Also, to function, a battery swapping facility needs a huge area in terms of land mass. Overall, it would be faster for cars to recharge rather than switch batteries, because a Tesla charging station with ten stalls could be installed in the same space as one battery changing station.

The universality of such stations might be the largest challenge. Despite how well Nio is doing in the Chinese market, it is important to keep in mind that their stations only function with their own line of automobiles. Given that more companies are releasing their own brand and models of electric vehicles, the variety of models offered expands, making it more challenging to compete. This essentially leaves three possibilities for changing the batteries; (i) Each automaker begins creating their own swap stations, which would require a significant financial commitment and may likely not have enough physical space or expanse of land; (ii). Battery changing stations are designed to accommodate different models, which, if practicable, would result in actual costs being significantly higher; (iii) Automakers agree to a universal battery installation, which in many cases would necessitate major adjustments to the entire production process.

Regarding their widespread adoption, all the possibilities highlighted are incredibly difficult for developers considering the financial costs demanded. Some battery-swapping initiatives have previously been carried out in the past. For instance, Tesla proposed the notion when it was looking for investors. The concept was, however, presumably abandoned more quickly than it was initiated in favour of supporting its global network of super chargers rather than battery swapping. However, in the beginning of 2021, a Tesla spokesman confirmed the firm's stance on battery swapping, stating that "the company feels electric vehicle charging is the best way to power its vehicles and that battery swapping is fraught with difficulties and not fit for wide-scale deployment." Battery swapping however, has the potential to mitigate the obstacles impeding the widespread adoption of electric vehicles. Swapping technology allows the EV owner to lease the battery and thus avoid paying the high upfront cost of the battery. Customers have the option to choose between a monthly or yearly subscription for battery-swapping services or can opt for a pay-per-use model based on their requirements.

Furthermore, battery-swapping stations provide a promising resolution to the issue of range anxiety among EV users during long journeys and better still, battery-swapping stations have the facility to monitor battery health through the smart battery management system (BMS). The battery stations mount a smart BMS over the battery and monitor the temperature of battery packs, reducing battery degradation and improving battery age for application in the first and second life, contributing to sustainability.

5.1 SSA Countries with Battery Swapping Policies

5.1.1 Rwanda

The Rwandan government has declared that it will issue national policy guidelines to ban two-wheelers powered by fossil fuels from the roads. It was confirmed by Patrick Nyirishema, the head of the Utilities Regulatory Authority, that plans for the electrification of two-wheelers were a part of a larger national electric mobility plan. The aim of the government appears to start with public transportation providers like moto-taxis before moving on to buses and autos. The president's announcement in 2019, reflects the course of government policy accurately, which concerns switching to electric motorcycles. The policy was ready; and only needs to be approved as it is currently undergoing the approval procedure. Once the policy is out, Rwanda government will no longer permit any motorcycle that is not electric to be added to a fleet.

Although the government of Rwanda has not specifically indicated which organizations and projects will be a part of its overall transport change, one participant is already obvious. Ampersand, a Kigali-based company that develops EV charging infrastructure, has been working on a feasibility study for introducing EVs throughout Rwanda and has already received funding from the Rwandan government. Relevantly, the start-up has created a technique for swapping batteries by allowing motorcycle taxi riders to easily replace dead batteries with fully charged ones at one of the swap stations, using hydroelectric power from the national grid(s).

Although, Rwanda do not currently have any law on battery swapping but the country hasprovided both fiscal and non-fiscal incentives for EVs. In his presentation titled "Status of E- Mobility in Rwanda," Janvier Twagirimana, Transport External link & Donor Coordinator at the Ministry of Infrastructure (MININFRA) in 2022, provided a summary of these incentives. The fiscal incentives include:

- Electricity tariffs for charging stations to be capped at the industrial tariff. This means that charge point operators will be billed at close to USD 10 cents/kWh instead of close to 20 cents/kWh.
- Electric vehicles will also benefit from reduced tariffs during off peak periods.
- Electric vehicles, spare parts, batteries, and charging station equipment will all be exempted from import and excise duties. All of these would also be treated as zero rated VAT products and will also be exempt from withholding tax.
- Companies manufacturing and assembling electric vehicles in Rwanda are given other incentives in the investment code, such as 15% Corporate Income Tax (CIT) and tax holiday (irrespective of the investment value).
- Other non-fiscal incentives are:
- Rent free land for charging stations on land owned by the government.
- Provisions for EV charging stations in the building code and city planning rules.
- Green license plate to allow preferential parking for EVs and free entry into any future congestion zones.
- Access to dedicated bus lanes, etc.

5.1.2 Kenya

Presently, there are no laws, regulations, or taxing structures in Kenya that address battery swapping technologies. However, this could soon change, as the State Department of Transportation recently put out a call for consultants to help it design an e-mobility policy that was targeted to be ready by the end of 2022 but is yet to be undertaking as of the time of publication of this toolkit in the last quarter of 2023. However, The Energy and Regulatory Authority (EPRA) has launched the Electric Vehicle (EV) Charging and Battery Swapping Infrastructure Guidelines, 2023, which are positioned to improve the penetration and uptake of electric mobility in Kenya. The guidelines go beyond providing a framework for charging ports and battery swapping stations, to giving investors the confidence and knowledge of the stipulated requirements during instalment. It also provides guidance on the quality of infrastructure that is installed, ensuring that consumers safety and ease of access is provided.

There are currently two battery swapping stations in Kenya. The WeTu Hub Homabay town battery swapping station is equipped with battery swapping systems for Opibus and Bodawerk. It is a manually operated battery swap facility. The batteries are removed from an e-bike and connected to a charging port. The charging ports for these two companies were noted to be different, but a solar PV system powers the off-grid charging station. Kiri EV is the other battery swapping station is in Nairobi and has also designed a manual battery change station that can accommodate up to 8 battery units for its e-2Ws and is at an advanced stage of implementation.

5.2 General, Legal, Regulatory and Policy Considerations for BESS and Battery Swapping

5.2.1 GHG/Carbon Emissions

Due to its capacity to lower emissions and energy consumption, electric vehicles have generated a lot of interest. Governments and manufacturers keep pledging new sales targets for electric vehicles, and as the price of producing electric vehicles continues to drop, they become increasingly competitive with internal combustion cars. The increasing success of electric vehicles has been largely attributed to advancements in lithium-ion battery technologies. Now that internal combustion engines are being replaced by battery electric vehicles, or B.E.V.s, some doubters are pointing out that these vehicles really have a bigger carbon footprint than the nonelectric counterparts. This is because the production and disposal of B.E.V.s, notably their batteries, and a reliance on coal to provide the electricity that drives them, both contribute to global warming.

Although it is true that the production of a BEV produces more pollution than its gasoline-powered counterpart, studies have shown that this disparity in greenhouse gas emissions is eliminated as the vehicle is driven. Erasing the difference does not appear to take very long,depending on how many greenhouse gases are produced in order to produce the electricity required to charge a battery. The amount of emissions will reduce, however, with the amount of renewable energy used, such as wind, solar, nuclear, and hydropower. One of the main criticisms of BEVs has focused on their dependence on coal for the electricity needed to power them, and the emissions produced during the manufacture of the batteries and the short battery life. But future BEV emissions will decline as a result of the closure of coal facilities and the expansion of renewable energy sources.

Having these limitations, it will be sustainable for countries to pursue renewable energy sources for the charging of battery electric vehicles, to avoid having the same performance output with non-electric vehicles.

5.2.2 Policies and Incentives

In a country like India, the goods and services tax on lithium-ion batteries would be reduced from 18% to 5%, and incentives for electric vehicles (EVs) with swappable batteries have been proposed in its policy draft. Rwanda, also have proposed both fiscal and non-fiscal incentives for the EVs. A policy draft and incentives like that of India will go a long way in providing clarity on the regulatory environment for batteries and its utilization vis-à-vis its eco-friendliness to a nation's environment.

The following are some of the policy's standout features: (i) batteries will come with cutting-edge features like Internet of Things-based monitoring systems; (ii) batteries and battery swapping stations will be given unique identification numbers; (iii) existing incentives for buying EVs will be extended to batteries covered by this policy; (iv) the policy will provide the technical guidelines, standards, and principles necessary to establish a battery as a service model (or "BaaS"); (v) relevant ministries and state governments to offer power to swapping stations at discounted rates; and (vi) Land needed to set up swapping stations to be provided by both government and public entities on a revenue-sharing basis.

Further, increased purchase incentives, policies and awareness about the benefits of battery swapping will attract more consumers, leading to large scale switch to Evs.

5.2.3 Technical Standards

Using Kenya as a case study, in its preparation for adoption of BEVs and battery swapping, the country has outlined technical standardization of battery swap systems such as:

- **IEC TS 62840-1:2016 (Electric vehicle battery swap system Part 1:** General and Guidance) gives the general overview for battery swap systems, for the purposes of swapping batteries of EVs when the vehicle powertrain is turned off. It is applicable for battery swap systems for EVs equipped with one or more swappable battery systems.
- **GB/T 40032-2021 (Safety requirements of battery swap for electric vehicles):** This is a Chinese standard that specifies the specific safety requirements, test methods and inspection rules for battery swappable EVs. This Standard applies to pure electric vehicles that can be battery swapped.
- **IEC 62840-2:2016 (Electric vehicle battery swap system Part 2: Safety Requirements)** provides the safety requirements for a battery swap system, for the purposes of swapping swappable battery system of EVs. The battery swap system is intended to be connected to the supply network.

The Philippines also have similar technical standards such as:

1. PNS IEC/TS 62840-1:2016 - gives the general overview for battery swap systems, for the purposes of swapping batteries of electric road vehicles.
2. PNS IEC 62840-2:2016 - provides the safety requirements for a battery swap system.
3. PNS ISO 12405-4:2021 – specifies test procedures for the basic characteristics of performance, reliability and electrical functionality for lithium-ion battery packs and systems.

5.2.4 Data Protection

The battery swapping policy of India provides that swappable batteries will come with cutting-edge features like Internet of things (IoT) -based battery monitoring systems, monitoring systems and immobilization capabilities, and other necessary control features to guarantee battery security and asset safety. Also, battery suppliers are required to make information on availability, battery type, compatibility, and performance for batteries at all battery swapping stations (BSS), freely and in a standardized manner in order to facilitate customer access to and usage of battery swapping services. This will of course be an avenue for data sharing of customers in the long run; by virtue of the loan system for battery swapping. This loan mechanism for the exchange batteries can be made simple and will demand rigorous adherence to information security and data protection. Generally, countries will have to rely on their data protection laws or adopt the European Union General Data Protection Regulation of 2018 while interfacing with battery swapping stations and its stakeholders.

5.2.5 Technical and Performance Standards

Technical and performance criteria aid in ensuring the cost-effectiveness, safety, and asset security of BaaS models. For better and more effective solutions to develop, battery technology heterogeneity and room for innovation must be preserved. The policy draft of India makes a provision for the necessary agencies to adopt or approve standards to enable the safe operation of certified battery packs in various cars and for Battery Charging Station (BCS) and Battery Swapping Station (BSS) compatibility with various battery types.

5.2.6 Approval and Certification Requirements

Another laudable provision of the India policy draft is the requirement standards for BCS and BSS to be developed or authorized by BIS/Ministry of Power (MoP) or other competent bodies to provide safe and affordable infrastructure for EV battery charging and swapping. Also, the National Accreditation Board for Testing and Calibration Laboratories (NABL) or another organization chosen by the central nodal agency for battery swapping must test and accredit the Electric Vehicle Supply Equipment (EVSE) used at the swapping station. For instance, Nio received TÜV certifications to sell and operate its battery exchange stations and chargers in all EU member states. The first deliveries to Nio's first European market in Norway have been launched in June 2023 The German certification agency TÜV Rheinland issued the European Conformity Certificate and TÜV MARK Approval Certificate to the 'Power Swap Station', the DC 'Power Charger' and the AC wallbox 'Power Home' to Nio. This means that the devices may be sold and operated in all EU member states.

5.2.7 Battery Theft

Theft of motorcycle and car parts, and complete cars, is not a new phenomenon There may be the same occurrence with BEVs because of its valuable components. Although there are fewer components to steal—the internal combustion engine, exhaust, and intake systems are not present in an electric vehicles but electric two-wheeler contains something very valuable: batteries. In Milan, Italy, where 12 people in 2022 were detained for stealing the batteries off electric scooters,. The most impacted vehicles are shared vehicles like electric bicycles and scooters. Majority of the time, unaware purchasers seeking replacement batteries for their own vehicles purchase the cells after they have been disassembled and sold on the illicit market or on the reconditioned second-hand market. Given the rapid rise in popularity of electric vehicles, and the integration of battery-swapping technology into the mix, chances are additional steps will need to be taken to safeguard the safety and security of the battery packs in electric vehicles.

5.2.8 Tariffs for Electricity Consumed by Swapping Stations to Reduce Operating Expenditure

A significant portion of the cost of running a battery charging station (BCS) is the energy bill from the electricity used to charge swappable batteries. This is acknowledged in the India policy draft which made provision for the tariff for supply of electricity to Public Battery Charging Stations. The provisions outlined in Section 7 of the unified Guidelines and Standards for Charging Infrastructure for Electric Vehicles released on January 14, 2022, or any subsequent changes, were reiterated in the policy draft which specifically states that: *"the tariff for supply of electricity to EV public charging stations shall be a single part tariff and shall not exceed 'Average Cost Supply' till 31st March 2025. The same tariff shall be applicable for Battery Charging Stations".* This allows the State Government to fix the ceiling of tariffs to be charged by such charging stations, as electricity is being provided at concessional rates and because subsidy is provided by the government in many cases for setting up charging stations,

5.2.9 Land Acquisition or Usage

Access to affordable land is necessary to scale up rollout of public charging infrastructure for EVs and BEVs, although battery swapping stations require less space than public charging stations for a given number of vehicles served, due to a quicker turnaround time per vehicle. With many countries' land allocation being vested in the government of the country, India on a revenue-sharing basis, has asked Government/Public bodies to make land parcels readily available to battery stations for the purpose of creating public charging and swapping infrastructure in the Guidelines and Standards for Charging Infrastructure for Electric Vehicles issued on 14th January 2022. However, the cost of land acquisition/usage will be factored in service delivery, increasing the amount charged for battery charging and swapping services.

5.2.10 Grievance Redressal

As the recipient of the subsidy on behalf of a battery swapping ecosystem, Battery Providers have been named as the Point of Contact with EV owners and oversee registering, handling, coordinating, and resolving any type of complaint from EV users regarding EVs, swappable batteries, charging stations, and/or the contracts/subscriptions in the India policy draft. This responsibility is to be undertaken in coordination with other ecosystem players. The Battery Provider will oversee providing the EV owners with financial reimbursement within a set time frame on behalf of the ecosystem. Depending on the specifics of the situation, the Battery Provider may not have to pay for such compensation; instead, they may be recouped from other ecosystem participants.

5.2.11 Reuse and Recycling of Batteries

Depending on the manufacturer and how the battery is used, an EV battery will still have roughly 70% of its initial capacity after 7–10 years. At this point, it would no longer be suitable for powering an EV, but the battery would still be suitable for recycling into a variety of "secondary" uses, such as being used for energy storage or to power fixed infrastructure like street lights or elevators, or the materials within the batteries could be recycled. The secondary uses of EV batteries will increase as batteries are produced to become more durable and are likely to include grid control, household power storage, and other use cases. However, many companies in China are concentrating more on the material recycling opportunity rather than the re-use opportunity.

The Batteries Directive 2006/66/EC is also an EU directive that lays forth rules for member states to follow when it comes to the production and disposal of batteries inside the EU. Its goal is to make batteries and accumulators more environmentally friendly. It also states that every battery producer has a take-back obligation/extended producer responsibility; making the producer responsible for the management of waste generated by batteries until they are scrapped.

5.2.12 Environmental Standards

By 2030, it is anticipated that at least 30 million electric vehicles will be zero-emission vehicles on EU roads. Although it is anticipated that electric vehicles will greatly reduce greenhouse gas emissions, their batteries have a negative impact on the environment. Imports of vital raw materials, like as cobalt, lithium, nickel, and manganese, which have a negative influence on the environment and society, are a major component of battery production. It is suggested that in order to make the environmental impact of batteries more clear, they will need to bear a label that shows their carbon footprint.

Additionally, environmental standards will ensure that new batteries contain minimum quantities of specific raw materials throughout their entire lifespan. It is expected that the EU will impose a due diligence requirement on battery makers in order to combat violations of human rights and ensure that batteries are supplied more responsibly. And in order to trade in raw materials and secondary raw materials, battery producers will need to abide by regulations that address social and environmental hazards.

5.2.13 Regulatory Standards and Specifications

The Indian policy draft for battery system provides for regulatory standards of battery components, to be regulated by the Bureau of Indian Standards. It provides that for the electric vehicle, battery safety requirements, degrees of protection of electrical equipment against foreign objects, technical specification of cables and connectors, and traction battery safety requirements, standards approved or defined by Bureau of Indian Standards (BIS) shall be put into practice. Also, there is a provision that batteries shall be tested and certified as per AIS 156 (2020) and AIS 038 Rev 2 (2020) standards for safety of traction battery packs. For EVs with swappable battery functionality, vehicle (Original Equipment Manufacturer) OEMs shall be required to get Automotive Research Approval of India (ARAI) approval for their vehicles to accept interoperable swappable batteries.

It is expected that SSA countries take a cue from the Indian policy draft as they formulate laws and regulations for the adoption of battery swapping.

6.

Benefits of BESS for SSA

6.1 Reduction of Fossil Fuel Usage

Energy is at the heart of the climate challenge and a key to the solution of addressing the impacts of climate change. A large chunk of the greenhouse gases that blanket the Earth and trap the sun's heat are generated through energy production, by burning fossil fuels to generate electricity and heat. To avoid the worst impacts of climate change, emissions need to be reduced. BESS can use renewable sources which are replenished by nature and emit little to no greenhouse gases or pollutants into the air.This is because BESS devices can enable energy from solar or wind to be stored and subsequently released when power is needed the most. The opportunities for BESS to displace Fossil fuel is driven by:

a. High cost of fuel

b. Weak, unreliable, or non-existent main power grids

c. High opportunity cost due to unreliable electricity supply

d. The availability of BESS in the local market at competitive costs.

e. Government support for implementing BESS and other renewable projects.

6.2 Steady Supply of Energy

BESS solutions are an enabler to supply backup power to consumers who want to make greater use of renewable energy but have found that, due to certain constraints such as, intermittency, weather conditions, power grid limitations, renewables have their own limitations. . BESS improves power quality by smoothing out voltage fluctuations that may otherwise disrupt equipment operations. Many types of BESS are easy to install making them a popular choice for businesses and homeowners looking for reliable energy storage systems.

6.3 Large Storage Capacity

BESS allows generation to be stored when demand is low and used later, rather than electricity being wasted. BESS can also be used by developing countries that are capacity short from an electricity generation perspective, as they opt for more renewable energy power sources in the energy mix. Batteries are green technology and produce no emissions or pollution during normal operation. BESS is a cost-effective way to store excess electricity generated by renewable energy sources such as solar or wind farms, allowing it to be used later when these sources are not available. Also, electricity demand fluctuates during the day. During times that demand is high, utilities may charge a higher peak-demand rate. During periods of low demand, the utility will charge at the normal rate for the energy used. If BESS is installed, the batteries can be charged during off-peak hours. Then the stored energy can be used to power loads during times of peak demand, decreasing power delivered from the utility, thereby allowing end-users avoid higher tariff charges, given the reduced grid dependency by end-users

6.4 Transmission Congestion Relief

BESS can provide backup power during outages or extreme weather events, reducing the need for costly distribution upgrades or emergency generators. It also assists in load levelling and grid support, helping to balance fluctuations in electricity demand throughout the day and reduce congestion on the grid.

Therefore, BESS plays an even greater and more sustainable role in three sectors of a country which are decarbonisation of the transport sector via electrification, allows transitions from traditional fuel to renewables for power generation, and provides off-grid communities access to electricity.

7.

Challenges to the Adoption of BESS across SSA

This toolkit has portrayed both the prospects and challenges of using hydrogen, specifically green hydrogen as an energy source in SSA countries. It is on this premise that the following recommendations are proffered:

As the need for power system flexibility and sustainability has surged, the interest in grid-scale battery energy storage systems has over time gained much prominence globally; except in developing countries across Africa. This is due to specific challenges faced by the continent, some of which are discussed below.

7.1 Cost Intensive Considerations

Cost is one of the most critical factors associated with deploying BESS. The cost of BESS is dependent on multiple factors such as the type of BESS (technology), applications, geographical locations, investment costs, and maintenance requirements. In addition, the BESS costs may also be directly impacted by additional factors including battery degradation and power losses via continuous use and charging. In Africa, high capital cost of batteries is still one of the primary barriers to the deployment of renewable energy systems and energy storage. For example, in a typical solar project in Nigeria, battery costs account for over half of the project's capital expenditure.

7.2 Battery Degradation

Batteries are the essential component of BESS, and with continued usage battery degradation is bound to occur. Nonetheless, several factors can fast track this degradation such as:

i. **Battery charge cycle:** one battery charge cycle entails draining the battery to 0% and then recharging it up to 100%, however charging the battery when it is just at 50% to 100% also completes one charge cycle; thus, the more charge cycles the battery completes the faster it will degrade.

ii. **Overcharging and Trickle Charging:** leaving the batteries on charge after 100% amounts to overcharging which can lead to battery damage and increase its risk of being susceptible to fire, and lead to its degradation.

7.3 Environmental and Health Threats

The production and disposal of batteries can have negative environmental impacts, including the use of hazardous materials and the generation of greenhouse gases. Additionally, upon disposal of battery, if not recycled properly, it can negatively impact on the environment and consequently the health of the people; as batteries contain harmful toxic chemicals. End-of-life management and battery recycling in Africa is still a major logistical and environmental challenge. The need for end-of-life battery management cannot be overemphasized. Policies on end-of-life management must be developed and implemented in order to prevent environmental problems in the future and to ensure the proper disposal of used batteries.

7.4 Regulatory and Policy Barriers

Absence of regulatory measures to define the function BESS is a major problem. In Africa, there is a lack of clear technical guidelines for the safe interconnection of batteries to national distribution and transmission infrastructure. While BESS can offer a variety of grid auxiliary services, where there are no clear rules, laws, or policies specifically directing or incentivising the utilization of BESS, network providers and market operators might be hesitant to deploy it. Additionally, storage owners and system operators might be reluctant to make the required financial investments if there are no guarantees that BESS projects for ancillary services would be compensated.

8.

1.Recommendations for Deploying BESS across SSA

While there is an increasing need for BESS in Africa, there is currently very little capability on the continent to deploy BESS due to constraints earlier discussed. Some proposed solutions to boost the adoption of BESS across SSA s are :

8.1 BESS Incentives and Subsidies

It is difficult to create an effective BESS that factors economic considerations, since many different elements must be considered. BESS costs depend on multiple factors, which include the type of BESS (technology), applications, geographical locations, investment costs, and maintenance requirements. To reduce the costs associated with BESS investment and operation, these factors can be optimized by taking BESS into account in the optimization models. Several countries are providing subsidies and incentives to encourage higher BESS installations, while others are yet to introduce ESS policies. Governments must create laws that offer incentives for BESS installations and deployment.

8.2 Smart BESS Algorithms

It is crucial to consider the manufacturer's advised requirements, notably optimum Depth of Discharge (DoD) throughout the design and operating stages, in order to maximize the battery's efficiency and slow the degradation process. In essence, intelligent control algorithms are needed to maintain the ideal ambient temperature in order to enhance the battery's health. Furthermore, policies on end-of-life management must be developed and implemented in order to prevent environmental problems in the future and to ensure the proper disposal/recycling of used batteries in Africa.

8.3 Battery Recycling Strategies

Battery manufacturers must be aware of the health dangers connected with battery disposal and should offer suitable recycling services. Determining methods for reusing or recycling the deteriorated BESS is vital because recycling batteries is a continual process. Governments must enact stringent regulations and enforce them strictly, to promote battery recycling. The governments can also fund research and development to enable scientists collaborate and create ecologically friendly storage methods and useful recycling tools. A coalition could be formed with foreign R&D companies and agencies for technology transfer and licensing, potentially leading to the deployment of the solutions in solving Africa's energy problems.

8.4 Policies and Guidelines for BESS and its market

There are several countries that still need to introduce the regulations and policies to promote high installation of BESS. Regulations governing BESS participation in the markets for energy, capacity, and related services must be established by the governments and energy ministries. Considering the operational and technical peculiarities of BESS, the regulations and guidelines must, among other things, guarantee that BESS has open and equitable access to the market. Specifically, in Africa, providing clear technical guidelines for the safe interconnection of batteries to national distribution and transmission infrastructure and ensuring batteries are remunerated for the grid flexibility services they can provide will help advance the investment case for behind-the-meter, mini-grid, and grid storage.

8.5 Increasing Consumer Financing to purchase Batteries

Studies demonstrate that batteries can offer substantial savings compared to alternatives such as fossil-fuel backup generators in a range of energy access applications. However, concessional finance is often required to help consumers overcome the higher upfront costs of batteries. Governments can put in place appropriate enablers, incentives and mechanisms to spur financial institutions to offer low-cost consumer financing options for the different consumer categories, from large scale commercial and industrial customers to residential end-users. Education and awareness should also complement government led and private sector implemented measures to scale energy access from grass root to a nation-wide spread.

Disclaimer

The devised method of data representation and the mode of populating the information in this Toolkit document is not premised on and does not in any way imply the opinion of International Organizations, Ministries, Governmental Bodies and Regulatory Entities of SSA countries, relating to the legal status of the country, the territory, boundary, or delimitation of the country's frontiers.

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