Enhancing Quality of Batteries for Electric Vehicles and Renewable Energy Storage in India

To establish a safe, secure and sustainable energy storage ecosystem

Perspectives from stakeholders

Report prepared for UL by: Energy Alternatives India (EAI)

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Empowering Trust™

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1. Introduction

1.1 Background

As the world increasingly starts relying on clean, renewable and distributed sources of energy, energy storage will take centerstage as a critical enabling component. Be it for electric transportation or for distributed renewable energy source, energy storage will play a critical role for the scalability, reliability and sustainability of the overall energy storage ecosystem.

India is witnessing significant growth and development in the energy storage space, especially in the renewable and e-mobility sectors. The Government of India has beckoned the commencement of a new age of energy storage by putting its focus on accelerating battery manufacturing in the country with a 'Make in India' approach.

As India moves towards a more sustainable energy economy, both for its own energy security and environmental concerns as much as part of its commitments to the international community, it is important for the country to have strong mechanisms in place to address gaps and bottlenecks that impact the smooth deployment and maintenance of energy storage systems.

Large-scale reliance on energy storage (mainly through batteries) for two key components of sustainable energy, viz., distributed or grid energy storage for sustainable energy sources and e-mobility, makes it imperative to have a robust quality for the battery storage ecosystem.

While storage can be used for many sustainable power sources such solar power, wind power, biomass power etc., in India it has so far been used predominantly only for solar power. The reasons are as follows:

- Wind power systems, similar to solar power systems, are infirm sources of power and thus require batteries. However, currently, small scale wind power systems are few in India and large wind power systems cannot yet afford to use batteries.
- Biomass power systems do not need storage as biomass represents a firm source of power generation.
- Other sustainable power sources such as geothermal, wave, tidal power, etc., are not yet prevalent in India.

On the other hand, distributed solar power systems are growing at a significant pace in the country. Some of these already incorporate batteries for storage and the near future holds potential for more battery usages. In addition, ground-mounted solar power plants could soon start employing battery storage.

E-mobility is the other sustainable energy sector that uses batteries and is showing significant growth in India currently with even higher growths expected in the near future.

With the above considerations in mind, this study on battery quality ecosystem focused on two key sectors, the e-mobility and solar power systems, and answered some important questions:

- **What is the current status of battery quality for these two ecosystems?**
- **What are the gaps that need to be filled?**
- **How can these gaps be filled?**

The study was conducted by interacting with more than 40 relevant stakeholders in the e-mobility and solar power domains. This white paper provides insights on the present status of the energy storage ecosystem in India and is intended to initiate dialogue to evolve a robust quality ecosystem for batteries used in these two sectors.

1.2 Objective

The objective of the study was to obtain clarity on gaps in the quality ecosystem for battery use in e-mobility and distributed stationary energy storage value chains and develop a roadmap to bridge the gaps through recommendations on the following dimensions:

- Technology and Research
- Policy and Regulations for Safe and Effective Deployment
- Standards, testing, inspection, certification and continued compliance
- Education and training, skill development
- End of life management

1.3 Battery Storage for Sustainable Energy

For the past several decades in India, batteries have been used for energy storage in stationary applications, mainly as a backup power source or for regulating and stabilizing grid power supply. The battery energy storage systems perform the role of enhancing frequency or voltage regulation, as well as enhance the power quality during grid shutdown.

Recent developments have shown an increase in the usage of battery-based energy storage systems in larger distributed solar power systems. In addition to performing the roles mentioned earlier for conventional stationary applications, energy storage goals for renewable energy sources include the following additional aspects:

- Peak shaving/shifting – Batteries can release the stored energy to the grid during peak power demand periods, thus enabling conventional power plants to reduce their expensive peak power production.
- Renewables firming for grid integration – Where batteries are proposed to be used for large, ground-mounted solar power systems, the main objective is to ensure a more consistent power export to the grid than what would be otherwise possible for an infirm source.

Since 2017, there has been a significant increase in the usage of batteries for traction applications, especially electric vehicles in India. With the expected fast pace of electric vehicle growth in India, one can also expect a parallel increase in the use of batteries in this sector.

1.3.1 Types of Batteries and Applications

1.3.1.1 Types of batteries used in solar power plants

While a wide range of primary and secondary batteries are in use for diverse storage applications, in both e-mobility and solar power plants, the following are the main types of batteries used:

- Lead acid batteries – Flooded electrolyte and Valve-Regulated Lead-Acid (VRLA) batteries are the main types of lead acid batteries used in India for solar power systems and traction applications.
- Lithium-ion batteries – Currently, the cathode chemistry that is dominant within lithium-ion (li-ion)batteries for traction applications is cathode combination of Lithium Nickel Manganese Cobalt Oxide (NMC), while Lithium Iron Phosphate (LFP) is gaining ground. For li-ion batteries used in digital electronics, cathode combination of Lithium Cobalt Oxide (LCO) continues to be the most common choice.

1.3.1.2 Scale and nature of applications where batteries are used

For the two sectors, we can consider two distinct categories for battery applications:

- Large-scale centralized systems – These currently comprise battery use in ground mounted solar power plants, and in the near future, solar-wind hybrid power plants. These battery systems could be as large as 10 MWh, or even larger.
- Small scale, distributed systems – Smaller, distributed storage systems are where batteries find more prevalent use currently within clean and sustainable energy. These are mainly as part of electric vehicles and rooftop solar power systems. These batteries could be as small as 10 kWh.

1.4 Battery Quality Ecosystem

1.4.1 Need for Battery Quality Review

Until recently, use of batteries has been mainly in applications that were stationary and/or in conditions with a high degree of control and access. Be it in Uninterruptible Power Supply (UPS), in electronics, or in cars, these have been used in products that had achieved a moderate or high degree of technology maturity (exceptions are perhaps the newest electronic gadgets such as tablets and smartphones). The products or locations where batteries have been used so far have also enjoyed a high level of access by operations and maintenance personnel (exceptions are perhaps batteries used in remote regions for defense, oil/gas installations, etc.). Finally, the types of applications where batteries were used had fairly predictable usage patterns.

For the two emerging domains, namely, electric mobility and solar power, the use of batteries is relatively new.

Distributed, off-grid solar power plants are still an emerging ecosystem and some of them are located in remote regions, presenting significant proximity and access challenges. For rooftop solar power systems that are grid-tied (works in sync with the grid), grid integration for export or import of power to loads makes usage patterns for batteries quite unpredictable. Finally, for the few large-scale, ground-mounted solar power plants that are now starting to use batteries to stabilize solar power export to grid, the infirmity of solar power generation makes the entire battery charge-discharge phenomenon quite volatile.

The contours are similar for the use of batteries in electric vehicles, which are still an evolving technology. While batteries in electric vehicles do enjoy a similar level of access as do batteries used in conventional automobiles, batteries used for electric mobility will be an order of magnitude heavier compared to those used in conventional automobiles. And as in the case of solar power plants, the usage patterns for batteries in electric vehicles are not well established, given the sector's emerging nature.

Let's consider each of these two aspects of quality, namely, safety and performance, in the context of real-world examples and concerns.

In July 2019, there were news reports about a Hyundai Kona electric car bursting into flames in Montreal, Canada while in garage and not in use. Though the exact causes for the widely reported accident is not confirmed, batteries are the first suspects. This is not the first case of a li-ion battery fire – a more famous case is the battery fire in Samsung Galaxy Note 7 smartphone that led to large-scale market challenges for that product. And such battery fires have been noted across a wide spectrum of products and brands that use li-ion batteries like – cars, mobile phones, laptops, e-bikes, e-cigarettes, and other portable electronic equipment. Cases of fires in battery manufacturing units and a few solar power plants have also been witnessed recently.

Until recently, reports of battery related accidents related to renewable energy storage have been relatively less globally. However, with increasing use of batteries for large-scale solar and wind power systems, there is a change in the trend. In June 2019, for instance, the South Korean government unveiled many new battery safety measures after a string of battery fires at the country's solar and wind power systems.

While such safety accidents increase concerns regarding the safety (manufacturing, handling, deployment, disposing and so on) of batteries, it is critical to understand and give primary importance to both safety, quality and performance of batteries equally. During our interactions with a wide range of stakeholders for this study, it was pointed out that for many end users, performance (especially lifetime) of the batteries was as important as safety. In late 2018, it was reported that many Indian central government officials were hesitant to use electric cars procured by a government energy services company, owing to their poor performance and less-than-stated range. Similarly, the less-than expected lifetimes of lead acid batteries have been a constant source of complaints for many Indian rooftop solar power system owners.

It is clear from the above discussions that safety and performance concerns of batteries are likely to be quite high for both the segments – e-mobility and renewable energy power systems. Hence there is a need for a comprehensive review of the quality ecosystem for batteries used in these two emerging domains.

1.4.2 Battery Quality

Safety and performance are the two main attributes of battery quality. Let's discuss each of them below.

1.4.2.1 Battery Safety

Batteries used in any application should be safe to operate under varying environments like high and low temperature, water, collision, extreme temperatures during charge and discharge and so on. In these contexts, the main safety concerns for battery usage are shared below:

- Fires – The most frequently reported fires in batteries (specifically li-ion batteries) are due to thermal runaway resulting from uncontrollable exothermic reactions. Such incidents and accidents can occur as a result of one or more of the following:
    - Cell failure due to overcharge, over-discharge followed by a charge, external or internal short-circuit, high temperature, loss of containment; propagation of failures to neighboring cells
    - Insufficient heat dissipation
    - External mechanical effects such as a crash
- Electric shocks – Electric shocks from battery use also present an important hazard, especially in electric mobility where business models such as battery swapping necessitate a fair amount of battery handling and logistics. While electric batteries used in conventional cars are unlikely to cause any damage from shocks owing to their low voltage (typically, 12 V), a traction battery in an electric car can have much higher voltages – for instance, Indian models from Mahindra already have 72 V battery packs, while international electric cars such as Tesla have 400 V battery packs. Such high voltage electric shocks can be hazardous.
  Similarly, in the case of solar power, while low voltage (12 – 24 V) batteries might be the norm for small scale rooftop solar power plants, with large solar farms beginning to incorporate batteries, electrical shocks from solar power plants are becoming a concern as well (a 648 MWh/108 MW battery was installed in UAE early 2019).
- Exposure to harmful materials – Outside of explosions and shocks, exposure to harmful materials and chemicals (especially electrolytes) can happen where there are leakages from the batteries. Such instances include cell venting during which gases are vented into the atmosphere.

The above safety concerns for battery users can be at one or more of the following battery “touchpoints”:

- Commissioning/ installation
- Operations and maintenance
- Transport and storage
- Disposal post end of life

1.4.2.2 Battery Performance

Be it for stationary or for traction applications, batteries are expected to demonstrate general baseline performance parameters, which include the following:

- Lifetime of battery (as measured by number of cycles)
- Reliable power output over lifetime
- Discharge performance under various conditions
- Energy density
- Battery energy efficiency (defined as “energy from discharging/energy consumed during charging”)
- Maintenance requirements
- Time taken for charging
- Endurance
    - Under cycling and standby modes
    - Battery system energy efficiency in various ambient conditions
    - Heat losses during various ambient conditions
- Response time, especially for uninterrupted power applications
- The acceptable range for State of Charge (SOC) for optimal battery performance

2. Battery use in Indian Electric Vehicles and Solar Power Plant Sectors

Before we analyze the quality ecosystem for batteries in the two main end user markets, i.e., electric mobility and solar power plants, it will be useful to understand the nature of battery use in these two sectors.

2.1 Highlights of Battery use in Electric Vehicles and Solar Power Plants

Aspect	Distributed Solar Power Plants	Electric Vehicles
Main reasons for use	• For off-grid systems - To supply power during non-sunlight hours • For grid-tied systems - As a reference source during grid shut downs, in addition to backup power supply	• As the source of energy to drive the motor
Key needs and concerns	• Reliable power supply • Long lifetime • Low maintenance • Safety (especially for high ambient temperatures and high voltages)	• Reliable power supply • Long lifetime • Low weight • High energy density for long range • Low charging times • Safety (especially fire hazard)

2.2 Battery use in Indian Solar Power Plants

In 2010, the use of solar power started showing significant growth in India. Under the National Solar Mission, a target of 20 GW of total solar power generation capacity was set for 2022. In 2014, this target was increased five-fold to 100 GW of solar power generation by 2022.

As of June 2019, India had a cumulative of 32 GW (32000 MW) of solar power generation capacity. While trends indicate that India will fall significantly short of the 100 GW target by 2022, the cumulative capacity is expected in the range 65-70 GW, still a substantial amount, and likely to place India in the top five countries worldwide.

While the current installed capacity of 32 GW is indeed considerable, a very large portion of this is in the form of ground mounted solar farms. Estimates suggest that close to 28 GW of the 32 GW are in the form of ground mounted solar power plants, with just over 4 GW (4000 MW) being in the rooftop solar and off-grid solar power installations. Within rooftop solar, only about 500 MW are estimated to be in the residential segment, with a large proportion of the remaining rooftop solar installations belonging to the commercial and industrial sector.

The above differentiation of the distribution of solar power systems between different sectors is important. As of 2019, energy storage in the form of batteries is employed predominantly only in the small-scale rooftop solar power installation segment in many parts of the world. In India, only rooftop solar power installations up to a capacity of about 10 kW use batteries; only recently have larger solar power installations started considering the use of batteries.

Thus, only a small percentage of the total solar power plant installations in India currently uses batteries. By capacity, as of June 2019, it was estimated that it was only about 0.5-1% of the total (or about 150-300 MW of solar power plant capacity),.

While 100% of electric vehicles need to use batteries (even if they are hybrid electric vehicles), only a small percentage of the total installed solar power capacity uses batteries currently in India. The above statistics clearly indicate that batteries are not a high priority for the solar power sector when compared to the automobile sector.

2.2.1 Batteries and Solar Power Plants – An Overview

Type of solar power plant	Typical power generation capacity (in kW)	Typical battery capacity (kWh)	Battery types and specifications	Highlights of the battery ecosystem
Off-grid solar products	0.01-0.1	0.02-0.2	Lead acid	All systems have to use batteries as system not connected to grid
Off-grid solar power packs	0.05-1	0.1-3	Lead acid	All systems have to use batteries as system not connected to grid
Small grid-connected rooftop solar power plant	1-10	0.5-5	Lead acid and li-ion	Almost all systems connected to the grid; some have a battery back-up
Medium and large size, grid-connected rooftop solar power plants	25-1000	10-250	Mostly lead acid	All systems connected to grid; a very small proportion of them include batteries
Large ground mounted solar power plants	1000-100,000	500-20,000	Batteries used rarely and if used, it is mostly lead acid	These are on-grid systems that export all the power to the grid; almost none of them in India currently use batteries
Ground-mounted solar-wind hybrid power plants (medium and large scale)	Not known*	Not known*	There are almost no power plants of this category in India today	The emerging hybrid power plants are expected to use batteries
Micro-grids	25-100	25-100	Lead acid	Almost all micro-grids that do not use diesel gensets use batteries

**Mainly owing to the emerging nature of the sector, there are hardly any ground-mounted solar/wind hybrid power plants in operation today in India*

An analysis of the above table shows that use of batteries in solar power systems in India has so far been:

- Mostly for off-grid and small rooftop systems, and
- Predominantly lead acid based

History, however, might not be a good indicator of the potential for battery use in medium and large-scale solar power systems in India. In the future, the importance of batteries in solar power plant installations in the country could be much higher. An increasing contribution of renewable power sources to the grid, increasing grid peak power prices for industrial and commercial sectors, and a fast growth in microgrids are making utilities, power developers and industrial/commercial sectors keen to use batteries. A parallel decrease in the li-ion battery cost could accelerate this trend.

Evidence for this is already seen in the increasing demand from the commercial and industrial (C&I) sector to have batteries installed for their sizable rooftop solar power plant installations, and recent government tenders to have large ground mounted solar (and solar/wind hybrid) power plants implemented along with battery storage.

2.3 Battery Use in Indian E-mobility Sector

Both solar power generation and e-mobility sectors are slowly beginning to move up the ladder to utilize energy storage as a major source. Although, greater than 25 million motorized two wheelers (scooters and motorbikes) were sold in India in 2018, less than 0.1 million (0.4%) were electric vehicles. Of the three million cars sold in 2018, fewer than 5,000 (only about 0.2%) were electric vehicles. It is only in three-wheelers (mainly electric rickshaws in the National Capital Region (NCR) that India is doing well on electric vehicle sales.

The future looks bright for electric vehicles in India. With significant concerns from the public about air pollution, increasingly stringent government mandates, and with decreasing battery costs, India's electric vehicles market is expected to grow rapidly. Recent initiatives by the government to ban sale of fossil fuel driven two-wheelers and three-wheelers by 2025 point to a possible rapid transformation of the Indian transport sector to electrification.

For the e-mobility sector, batteries will need to be seen in two different contexts: one, as an energy storage device discharging power needed for mobility; and two, in the context of battery charging.

The dichotomy of charging and discharging batteries is much higher in the case of e-vehicles compared to solar power systems. In the latter, both charging and discharging happen at the same location and is seen as a seamless set of activities to the end user. However, in the case of electric vehicles, charging is done in a specific location separately. As a result of this distinction between charging and discharging in electric vehicles, battery quality for e-mobility needs to be viewed in the context of battery use in both vehicles and electric vehicle battery charging stations.

2.3.1 Electric Vehicles and Batteries – An Overview

The following table provides a quick overview of battery use in electric vehicles:

Type of electric vehicle	Type of batteries used (June 2019)	Battery and motor specs
Electric bicycle	Both lead acid and li-ion	Battery: 24-48 V, 6-15 Ah (150-700 Wh) Motor: 250-500 W
Electric scooter	Both lead acid and li-ion	Battery: 36-48 V, 60-80Ah (2-3 kWh) Motor 3-5 kW
Electric motorbike	Mostly li-ion	Battery: 48-72 V, 100-200Ah (4-10 kWh) Motor 5-10 kW
Electric three-wheeler	Both lead acid and li-ion	E-rickshaws Battery: 36-48 V, 60-80 Ah (2-3 kWh) Motor: 1-2 kW E-autorickshaws Battery: 36-48 V, 100-120 Ah (4-8 kWh) Motor 2-4 kW
Electric car	Li-ion	Battery: 72 V, 200-250 Ah (15-20 kWh) Motor 20-30 kW
Electric Light Commercial Vehicle (LCV)	Mostly li-ion	Battery: 48-72 V, 100-200 Ah (5-15 kWh) Motor: 5-20 kW
Electric buses	Li-ion	Battery: 144-288 V, 200-400 Ah (50-100 kWh) Motor: 75-200 kW

3. The Battery Quality Ecosystem in E-mobility and Solar Power Segments

3.1 Battery Quality Standards in India – Background

The standards and certifications for the products and services, including batteries sold in India, fall under the aegis of the Bureau of Indian Standards (BIS),, the national standards body of India. There are other government organizations as well that are authorized to arrive at standards for specific applications, like the Automotive Research Association of India (ARAI) that formulates standards for the automotive sector.

In the context of quality standards for batteries used in solar power plants and in traction (e-mobility) applications, there are thus two main Indian organizations:

- BIS – Responsible for developing standards for batteries in general
- ARAI – Responsible for developing standards for the entire automotive sector, including battery standards for electric vehicles.

To corroborate safety and performance standards of batteries, a variety of tests are prescribed by BIS and ARAI. These tests (and the resulting standards) are usually different for the different applications. For example, batteries used for conventional stationary storage need to follow one standard, while batteries used for stationary storage for solar photovoltaic (PV) power plants need to follow a different standard. In the same way, batteries used for traction applications (e-vehicles) need to follow some other standard. There are two relevant standards for the e-mobility space: one for the usage of batteries in electric vehicles; and and another for the electric vehicle battery charging infrastructure.

Tests listed for batteries in the standards broadly fall into one of the three categories:

- Mechanical tests – Vibration, mechanical shock, crush/impact test, etc.
- Thermal tests – High and low temperature endurance, temperature cycling, etc.
- Electrical tests – External short circuit test, overcharge test, forced discharge, internal short circuit, etc.

3.2 Stakeholders in the Battery Ecosystem

In order to understand the sectors deeply, the following categories of stakeholders were contacted from the e-mobility and solar power sectors for this study:

<table>
<tr><th colspan="2">Key stakeholder segments contacted</th></tr>
<tr><th>Solar power plants</th><th>E-mobility</th></tr>
<tr><td>
• Solar power plant owner/developer
• Engineering, Procurement and Construction (EPC) companies for residential rooftop, commercial/industrial rooftop and ground-mounted solar power systems
• Battery manufacturers – both li-ion and lead acid batteries
• Battery charge controller manufacturers
• Consumer of solar power – residential and commercial/industrial consumer
</td><td>
• Electric vehicle end users – mainly e-scooter users and a few electric car users
• Battery cell and battery pack makers – both li-ion and lead acid
• Original Equipment Manufacturers (OEMs) – Manufacturers of electric two-wheelers (e-bicycles, e-scooters and e-motorbikes), three-wheelers (e-autorickshaws and e-rickshaws), electric buses, electric cars
• Electric vehicle charging station technology providers and EPCs – both AC and DC charging station providers
• Electric vehicle swapping station technology providers and EPCs
• Battery recycling and battery refurbishing companies
</td></tr>
</table>

Overall, 40 stakeholders were interviewed, of which – 25 were from the e-mobility sector and around 15 from the solar power sector. Most of these were face to face interactions, while some were structured telephonic discussions.

3.3 Battery Quality Ecosystem in E-mobility – Current Status and Stakeholder Needs

3.3.1 E-mobility – Current Status

3.3.1.1 Existing standards for battery use in e-mobility applications

There are two ARAI standards that are applicable for e-mobility applications: AIS 048 and AIS 138. The AIS 048 standard is applicable for the usage of batteries in traction applications, i.e., in electric vehicles. The AIS 138 standard is applicable for electric vehicle battery charging operations. The following are the highlights of the two standards:

Parameter	AIS 048*	AIS 138
Battery Application	For traction applications	For electric vehicle charging
Status	Currently in use	Currently in use

Key metrics/aspects tested for	***Performance and abuse testing for traction batteries***
	• **Electrical abuse test**
	- Short circuit test
	- Over charge test
	• **Mechanical abuse test**
	- Vibration test
	- Mechanical shock test
	- Roll over test
	- Penetration test
		Electric vehicle charging station
		• Protection for safety
		• Environmental tests:
		  • Climate environmental test
		  • Mechanical environmental test
		  • Electromagnetic environmental test
		Protection against electric shock
		• Protection against direct contact
		• Accessibility to live parts
		Specific requirements for vehicle inlet, connector, plug and socket-outlet
		• Charge cable assembly requirements
		• Electrical rating
		• Electrical characteristics
		• Dielectric withstand characteristics
		• Mechanical characteristics
		Electrical safety
		• Protection against direct contact
		• Earthing electrode and continuity
		• Detection of the electrical continuity of the protective conductor

** For battery cells, only the electrical tests are required to be carried out, and for the pack-level the mechanical tests are mainly carried out.*

A brief review of the table above shows that while the tests for battery charging (AIS 138) for electric vehicles appear quite comprehensive, the tests for battery use in electric vehicles (AIS 048) appear less so.

It is also pertinent to note that the tests for batteries were originally designed for conventional lead acid batteries, and these have **not been modified** for li-ion batteries which are the most dominant battery type in electric vehicle applications today. This is despite the fact that there are significant differences between lead acid and li-ion batteries on key parameters such as specific energy, cycle life, method of charge and discharge, safety, temperature sensitivity and efficiency.

3.3.2 E-mobility – Stakeholder Needs

In order to get a deeper understanding of the market requirements, our team interacted with a diverse set of stakeholders across the entire e-mobility spectrum – from li-ion and lead acid battery manufacturers to end users of electric vehicles.

While determining the battery quality needs and aspirations for the e-mobility market, it was observed that the awareness of, and concerns about battery quality varied significantly across the e-mobility value chain. While such awareness and knowledge were quite high in the upstream part of battery value chain (especially among battery cell and module manufacturers), it was mediocre for the OEMs and practically non-existent at the end user level. Interestingly, within the OEM segment, the awareness was high for the electric bus segment alone – perhaps because of the large batteries that they use.

As a result of the above circumstances, we were able to obtain specific recommendations on standards, tests and certifications only from select stakeholder segments. The rest of them were able to articulate these only in a general manner – in the form of needs, concerns and aspirations rather than as specific recommendations for standards or tests.

Here are the key inputs and the insights from these discussions on the needs and concerns in the context of battery safety and performance for use in electric vehicles.

Safety priorities for end users	Key performance for end users
• Safety of batteries is not as high a priority for electric vehicle users (especially two-wheeler users) as is its performance. This input was given by many different stakeholders. The reasons behind this could either be because of the early stage of the sector or because of lack of awareness of safety hazards present in electric vehicles. Or it could also be because electric vehicles are considered "pricey" and as a result "value for money" becomes a high priority for electric vehicle buyers. **Temperature test** • A concern most stakeholders had was about battery safety at high temperatures. This could happen owing to exposure to hot ambient temperatures as well as from a short circuit thermal runaway. With this in mind, most of them preferred battery standards to comprise	• Performance aspects and life cycle were given most importance by the electric vehicle end users. Thus, in the context of testing and standardization, it was felt that higher emphasis should be given to battery lifecycle testing, including testing for deep discharge. • Some stakeholders had a highly pessimistic opinion of the quality and performance of Indian batteries, regardless of the certification. The opinion was that, even with all the certification, the charging characteristics (current and voltage) were poor for the batteries, and that many products with same certification had vastly differing performance. • Another input was that most of the machineries used to make the battery packs were from China, and some of these machineries produce sub-standard battery packs.

tests done for a range of temperatures, from perhaps -10 degrees centigrade all the way to 70 degrees centigrade. The wide range of temperature for testing was preferred due to the very different regions in India.

Charging and swapping

- One clear need expressed by several stakeholders was for separate standards for battery swapping, since there are not any right now in India. While one stakeholder felt that swapping was a fairly simple operation whose processes were already covered under electric vehicle battery charging standards, few others felt that swapping merited separate standards, especially because of the handling and logistics involved during the process. One of the tests suggested by stakeholders for battery swapping was "drop test".
- It was pointed out that separate tests for swapping stations could be relevant because: swapping stations might have higher power requirements than charging stations, and this could necessitate the presence of high capacity transformers at many swapping stations.

Emergencies

- Safety concerns were expressed in the context of fire emergencies. The following concerns were raised:
    - When an electric vehicle catches fire, how does one approach the vehicle?
    - Who should be the first responders (police, fire department, others)?
    - What should the first respondents be aware of/alerted about in the context of battery safety?
- With the above in mind, respondents suggested that tests pertaining to the above should be included in the battery standards for traction applications.
- Some stakeholders were keen to know if the current tests for batteries for traction applications adequately factored in circumstances specifically surrounding an electric vehicle crash.
- An interesting need expressed was for tests for thermal propagation at battery pack level, in addition to those for cell level – the underlying reasoning being that the propagation dynamics at the pack level could be quite different from those at the cell level.

End of life

- It was pointed out that there were no standards

- Regarding performance under different environments, one key concern was about battery lifetime and performance under high temperatures.

Maintenance

- A key observation was that, equally important to standards was the need to create awareness for optimal maintenance practices (such as daily checking of water/electrolyte levels) for good battery performance. This was specifically suggested for lead acid batteries.
- A related suggestion was that awareness should also be created about best practices for the battery during storage while waiting to be sold (for instance, at a distributor warehouse). A battery could spend quite a few months on the shelves before it reaches the customer, and this is a critical period during which there is a need for well laid-out procedures for maintaining optimal state of charge as well as ambient conditions such as temperature and moisture. Awareness of such best maintenance practices is especially necessary for the distributors and wholesalers of batteries.

Charging and Swapping

- Some of the stakeholders felt that the charging process constituted one of the most critical causal factors for poor battery performance. It was hence felt that a more comprehensive review of the electric vehicle charging standards was important to help with high battery performance, more so with India likely to have many fast charging facilities soon.

BMS

- It was pointed out by many stakeholders that there were no tests specifically for BMS performance.
- How relevant are tests for BMS alone, given that these anyway get tested when the battery packs get tested? Here, an interesting perspective emerged: For small capacity batteries with a few cells, testing the battery pack could imply testing the BMS too, but in cases where a BMS acted as master BMS and interacted with multiple slave BMSs, standards and tests specifically designed for BMS could be relevant.

Other tests suggested

- Some stakeholders suggested doing

for recycling of batteries – be it VRLA or li-ion batteries.

- Should there be standards for battery recycling, it was suggested that these need to be different for li-ion and lead acid batteries, as the recycling methods are likely to be different for the two.

Water protection

- Many stakeholders mentioned the need for water protection standards such as IP 67 or IP 69 for batteries.

Unique testing requirements

- Electric vehicles accommodate regenerative braking, a phenomenon in which batteries get charged from the energy generated during braking sessions. Some stakeholders questioned whether a separate test was needed for such charging as significant heat could be generated during this process.
- While the current standards for electric vehicle charging stations might be suitable for AC charging, there were concerns about the suitability of these standards for rapid and flash charging, which could be at the speed of 4C rate and higher (15 minutes or faster).
- A unique requirement stated by a stakeholder making electric motorbikes involved tests specifically for the Battery Management System (BMS). The stakeholder mentioned that in Indian motorbikes it was the BMS that terminated the power supply during emergencies while in some international motorbikes, there are alternative mechanisms to terminate the power supply. Thus, should the BMS fail, power does not get terminated as this can constitute a risk for Indian electric motorbikes. The concern was that this risk was not measured currently during the testing of the battery pack.

Others

- A query raised by some stakeholders was the extent to which the BMS can help in the safe operations of the battery. It was not clear to them whether the role of a BMS adequately covered all the safety aspects of the battery, and if it did not, what steps can be taken to bridge the gaps.

accelerated vibration test for battery packs.

- Suggestions were also made for testing the cells and packs under extreme conditions
  - Low and high temperatures
  - Testing through extreme abuse of the vehicle
  - Testing it by carrying much higher weights than the vehicle was supposed to carry
- There were also suggestions that the performance tests could be customized for two-wheelers, four-wheelers and heavier vehicles, instead of having similar tests done regardless of the vehicle type and weight.

Balance of battery systems

- It is not the battery alone that always determines the system performance. Many times, poor cabling and connection to controllers too result in poor performance. Some respondents were keen to know how this would be accounted for and explore if we could come up with an “ecosystem approach” while testing the batteries.

Other suggestions

Suggestions were also made for the following types of tests:

- High altitude tests for battery performance
- Testing batteries for IT-communication protocols such as OCPP 1.6 used in electric vehicle charging stations
- Customized tests for different li-ion cell chemistries

3.3.2.1 Other inputs, needs and concerns

3.3.2.1.1 Costs

- Many stakeholders across both the electric vehicle and battery charging value chain were concerned about the high costs of battery testing. The concerns were especially pronounced for cases where the battery costs per vehicle can be very high – for electric buses, for instance.

3.3.2.1.2 Types of tests and standards

- According to ARAI, there are studies underway to upgrade AIS 048 to GTR20 (Global Tech Regulation), a more comprehensive global standard for batteries used in electric vehicles. While this effort was welcomed by all the respondents, they were interested in understanding the timeline by which ARAI would be able to finalize the upgraded standards.
- At least one stakeholder wanted to know why a separate test for battery packs and motors in the vehicle was required while these packs and motors had been tested individually already.

3.3.2.1.3 Testing infrastructure

- Some queries and concerns were raised about the quality of testing facilities available in the country for testing large, heavy and specialized electric vehicle batteries.

3.3.2.1.4 Awareness

- While ARAI and ICAT organize regular seminars and workshops, it was felt that there could be seminars at more cities, as well as seminars and training workshops in specialized technical areas such as safe battery design, BMS, component design, etc.

3.3.2.1.5 Policy and Administration

- While most respondents were satisfied with India using international standards as a reference for Indian standards, there was a suggestion that a higher degree of customization was needed for these standards for Indian conditions.
- There were some queries on the need for two different organizations - ICAT and ARAI – performing similar roles.

3.3.2.1.6 Li-ion versus lead acid

- There is a market perception that li-ion batteries present more operational hazards than lead acid batteries (especially fire hazards). Interestingly however, at least two of the respondents mentioned that there were explosion accidents involving lead acid batteries in the recent past in their geographies, while there were none involving li-ion batteries during the same period. This could however be because the prevalence of lead acid batteries is currently much higher than that of li-ion batteries in India.

3.3.2.1.7 End user awareness

- Some stakeholders felt that end users did not have the background expertise to understand intricate aspects such as technical standards and testing; they can more easily appreciate benchmarks such as AA/AAA, or benchmarking through "number of stars", etc.

3.3.3 E-mobility Battery Quality Ecosystem – Key Gaps

A comparative analysis of market needs and the current quality of batteries used in the Indian e-mobility sector provides the following insights on the existing gaps:

3.3.3.1 Batteries – Safety

Key gaps

- No separate safety standards available for battery swapping.
- Need for battery tests to be done at high temperatures.
- All tests prescribed are for lead acid; these need to be customized for li-ion too.
- Need for standards or procedures for first responders during emergency conditions.
- Need for water protection tests such as IP 67/69 for battery packs.

Others

- Need for standards for battery recycling.
- Need for module level propagation tests for batteries, in addition to similar tests currently done for cells.
- Need for accelerated vibration tests for battery packs.
- Drop test for battery packs could be considered, especially if swapping becomes commonplace.

3.3.3.2 Batteries – Performance

Key gaps

- More tests desired for testing battery lifetime.
- User education and awareness creation for battery maintenance and performance, during operations and during battery storage.
- Specialized tests needed for fast charging.
- Need for specialized skill development programs – especially for BMS design.

Others

- Need for high altitude tests for battery performance (as already mentioned earlier).
- Standards and tests needed specifically for BMS.
- Different tests needed for different battery chemistries.
- Need for testing to be done for performance of entire system, including cabling (and not just for battery pack alone).
- Testing for common communication protocol for battery packs.

3.3.3.3 Electric vehicle charging and battery swapping infrastructure

- Need for standards and tests for battery swapping.
- IP protection test for electric vehicle charging infrastructure.
- Standards for communication protocols for electric vehicle charging infrastructure.

3.3.3.4 Other gaps/ needs

- Need for improved testing facilities for emerging li-ion battery chemistries and for fast charging.
- Need to bring down the overall cost of testing.
- Need to enhance awareness among charging technology providers about the variations in battery technologies, standards and certifications.

3.4 Battery Quality Ecosystem in Solar Power Plants – Current Status and Stakeholder Needs

3.4.1 Solar Power Plants – Current Status

3.4.1.1 Existing standards for use of batteries in solar PV applications

The BIS has issued a standard, IS 16270:2014, in its latest April 2019 circular. This is based on IEC 61427 series (Part 1 and 2) that gives general information relating to the requirements for the secondary batteries used in PV energy systems and to the typical methods of test used for the verification of battery performances.

This standard is applicable for the following types of batteries:

- Stationary lead acid battery (both vented type and valve regulated/tubular gel)
- Stationary nickel cadmium (NiCd) batteries (both vented type and Partial Gas Recombination)
- Portable NiCd batteries
- Portable nickel-metal hydride (NiMH) batteries

The following table provides details of tests prescribed under the BIS standard:

Type of test	Lead acid	NiCd	NiMH
Capacity test	X	X	X
Endurance test	X	X	X
Charge retention test	X	X	X
Cyclic endurance test	X	X	X
Sulphation test	X		
Water loss test	X (only for vented type, not for VRLA)		

X denotes the applicability of the test for the battery type

Note: Even though the BIS guidelines cover three types of batteries, (Lead acid, NiCd and NiMH) as mentioned earlier, the Indian solar power plants predominantly use only lead acid batteries.

3.4.2 Solar Power Plants – Needs and Aspirations

Findings from the study reveal that in the case of most solar power sector stakeholders, awareness of battery standards and certifications is practically non-existent. While this does not imply that quality is not important to the stakeholders, it more likely implies that **emphasis on specific standards and tests has been low for this sector**.

- There is almost no awareness of battery standards and certifications at the small EPC/ developer level. All they look for are warranties.
- Awareness of standards and certifications is relatively higher for larger EPCs, but even here, the extent of knowledge is not deep. For instance, most large EPCs we spoke to were not able to recollect the IS number for the standard. In contrast, almost all the battery pack, cell manufacturers and electric vehicle charging station manufacturers had a good knowledge of the standards.

The reasons for the lack of awareness and appreciation of battery standards for solar power plants could be the following:

- In India, batteries are predominantly used by small rooftop solar and off-grid solar power projects. Currently, these solutions are provided mostly by small players. The only exception is when organized solutions providers supply battery based off-grid systems for large government projects for rural areas or for select communities.
- Where batteries are used, these have usually been lead acid batteries until recently. As this is a mature battery category, uncertainties and concerns about safety and performance of these batteries were few.

The study has highlighted that while large developers and solar EPCs are relatively more aware about the standards and certifications requirements than small and unorganized EPCs, even among large players, only few had reviewed or analysed battery performance and safety for solar power plants. Their reviews and analyses were mainly about the expected lifetime (number of cycles) and the warranties available from the battery manufacturer. Even while applying for government tenders or contracts, many EPCs just review the standards mentioned in the tender and ensure that the batteries they procure conform with these. Rarely do they analyze the merits of these standards.

Owing to this significant lack of awareness, we were able to gather only generic details and concerns from the solar power system segment, and except in rare cases, there was no input on specific standards and certifications. The following are the insights gathered from solar power stakeholders on performance and safety requirements for batteries:

3.4.2.1 Performance

- According to the stakeholders, in most cases the customer (the solar power plant owner/investor) has little idea about standards or certifications, and almost always needs the EPC to specify the performance and safety standards. The EPCs normally specify the lifetime, the number of cycles and the number of years of warranty for the battery. Only in select cases, the EPCs specifically look for certifications.
- The significance of inverter and charge controller for battery performance was raised by a few stakeholders. It was pointed out that performance issues for rooftop solar power plant batteries many times arose owing to poor charging profiles from the inverter/charge controller. For instance, according to one EPC, some inverters for solar power plants do not do trickle charging towards the end and instead continue charging at the same rate, leading to serious battery degradation.
- Performance challenges also arise owing to poor battery maintenance – examples include not replenishing the water and improper charging/ discharging practices.
- Performance of batteries for solar power sector could become a more critical concern as used li-ion batteries (post their use in electric vehicles) could be used in these sectors.

3.4.2.2 Safety

- Interestingly, some prominent EPCs serving the commercial and industrial rooftop solar space mentioned that for their clients, **battery safety was more important that battery performance.** This is intriguing especially given that performance was perceived as more important than safety by many electric vehicle end users.
- The reason for the emphasis on safety was mentioned as follows: The immediate customers for commercial and industrial rooftop solar systems are mainly engineering managers taking care of building safety, energy and environmental aspects. For them, solar power is considered a service, as most of these are offered under what is called Operational Expenditure (OPEX) model where the customer only pays for the power consumed even where the solar power plant is on their premises. Given these circumstances, for this segment, the safety of the overall solar power plant, including the batteries, is far more important than its performance. In fact, one of the respondents mentioned that his clients did not even mind battery damage (and associated costs) as long as there were no accidents and hazards from such damage.
- In the case of off-grid solar power solutions, batteries are frequently kept outside (either on rooftop or attached to street lights). In hot regions, some of these battery tops blow off and in few cases, there is significant swelling in the batteries. So, tests on the batteries for withstanding high temperatures was voiced as an important need.
- While most EPCs were not aware of safety standards and tests for batteries used in solar power plants, they agreed that they needed to learn more on safety with the advent of li-ion batteries into the solar power plant sector. This is owing to a clear perception that li-ion batteries are more prone to fire and explosion than lead acid batteries.
- How important is training for battery safety and performance for the solar power plant sector? To this question, many end users are more in favour of safe and fool-proof batteries rather than effective training for safety and maintenance.

3.4.3 Solar Power Plants Quality Ecosystem – Key Gaps

- **The most important gap for the solar power sector in the context of battery quality is the lack of awareness about standards and tests among the various stakeholders.**
- Among tests needed for batteries used in solar power plants, the following are inferred to be the key gaps:
  - Need battery testing at higher temperatures
  - Need testing for Ingress Protection (IP); this is mainly a test for protection against water ingression
  - There are no standards and tests specifically for li-ion batteries – these currently exist only for lead acid batteries. Given than li-ion batteries are likely to find a much higher use in solar power plants in the near future, a separate standard for use of li-ion batteries in solar power plants could be relevant.

4. The Battery Quality Ecosystem – Bridging the Gaps

In this section, we attempt to provide some preliminary inputs that would help bridge the gaps in the battery quality ecosystem for both e-mobility and solar power plants sectors in India.

4.1 Battery Quality Ecosystem Gaps – Highlights and Inferences

The current status of battery tests and standards and the key needs of the two segments, the following are the critical gaps common to both:

1. Lack of battery tests at high temperatures, especially in the Indian environment.
2. Tests currently prescribed mainly for lead acid batteries and not for li-ion batteries.
3. Lack of procedures and standards for first responders during emergency conditions.

4. Lack of Water protection tests such as IP 67/69.
5. Lack of standards for battery recycling.
6. Limited user education and awareness for battery maintenance and performance, both during operations and during battery storage.
7. Limited awareness among select stakeholders (charging technology providers for e-mobility and solar EPC segment in solar power plants) about the standards and certifications.
8. Lack of standards for battery swapping (relevant only to the e-mobility sector).
9. Lack of training infrastructure to develop superior design skills, especially for BMS design. (This gap was not mentioned by any stakeholder in the solar power plant sector, but the criticality of BMS for the safety and performance of li-ion battery makes this an important gap for both sectors).

While some of the above gaps were explicitly stated by both sectors, some others (for instance, enhanced awareness about standards and certifications among some stakeholder segments) were implied.

The feedback from the two market sectors indicate that if the above gaps are taken care of, a significant portion of the safety and performance requirements for batteries, especially li-ion batteries, will be met.

As a quick observation will show, not all gaps mentioned above are related to testing or standards. We categorize the gaps as follows:

Category	Gaps
Testing and Standardization	1. Lack of battery tests at high temperatures, especially in the Indian environment context 2. Tests currently prescribed are mainly for lead acid batteries and not for li-ion batteries 3. Lack of standards for first responders during emergency conditions 4. Lack of Water protection tests such as IP 67/69 5. Lack of standards for battery recycling 6. Lack of standards for battery swapping
Education and Skill Development	1. Limited user education and awareness for battery maintenance and performance, both during operations and during battery storage 2. Limited awareness among select stakeholders (charging technology providers for e-mobility and solar EPC segment in solar power plants) about the standards and certifications 3. Training infrastructure to develop superior design skills, especially for BMS design. 4. Emergency response to a catastrophic event such as a fire and thermal runaway.

4.2 Bridging the Gaps – Recommendations

What are the avenues that will help to bridge the identified gaps and create a high-quality ecosystem for batteries for the two sectors in India? We present some perspectives, based on the data and analyses provided in this white paper.

4.2.1 Collaboration

How can we arrive at more appropriate and effective standards for battery quality for e-mobility and grid energy storage systems in India?

As pointed out earlier, ARAI is already working on upgrades to standards for batteries used for both mobility and battery charging. How can these efforts be accelerated? One suggestion here is for the stakeholders to collaborate more intensely with ARAI to expedite the launch of the new standards.

4.2.2 Selective Research and Development (R & D)

Consider battery swapping as a viable option for the e-mobility sector in India. The country already has some companies doing pioneering work in this area. Given this status, companies need to undertake relevant, applied research efforts that enhances the overall quality of India's battery swapping solutions and also lays the groundwork for evolving effective standards for battery swapping. Having said this, the safety (which includes quality and performance aspects) facet of battery swapping need to be taken into consideration while research studies or other initiatives are implemented.

The R&D relevant to the Indian environment (by considering temperature changes, weather, water and air qualities and so on) in niche, select domains for batteries could make a significant difference for India and perhaps even for rest of the world.

4.2.3 Awareness Creation

Given that most relevant stakeholders for battery quality ecosystem are in the B2B segment, reaching out to them to create focused awareness should be relatively easy.

At the same time, India is a vast country, and many of the B2B stakeholders could be quite small in size (many rooftop solar EPCs, for instance). The framework to continuously engage them for effective awareness creation hence needs to be well thought out. One recommended path could be to start off with the use of online and cloud-based awareness creation training programs, followed by selective physical outreach programs.

4.2.4 Development of High-end Skills

Focusing on skill development, right from low-end skills to the high-end skills such as BMS design, has both short-term and long-term benefits. In the short term, it helps in addressing concerns of quality and safety of batteries. In the long run, it will facilitate the establishment of a robust battery manufacturing ecosystem in the country. A more inclusive dialogue and collaborations between different stakeholders such as the government, academia and industry, is recommended, to facilitate and expedite such high-end skill development initiatives.

Acronyms and Abbreviations

Ah – Ampere Hour
AIS – Automotive Industry Standard
ARAI – Automobile Research Association of India
B2B – Business to Business
BIS – Bureau of Indian Standards
BMS – Battery Management System
C&I – Commercial and Industrial
EAI – Energy Alternatives India
EPC – Engineering, Procurement and Construction
EV – Electric Vehicle
GTR – Global Technical Regulation
GW – GigaWatt
ICAT – International Centre for Automotive Technology
IT – Information Technology
KW - KiloWatt
kWh – KiloWatt Hour
LCO – Lithium Cobalt Oxide
LFP – Lithium Iron Phosphate
Li-ion – Lithium-ion
LCV – Light Commercial Vehicle
MW – MegaWatt
MWh – MegaWatt Hour
NCR – National Capital Region
NiCd – Nickel Cadmium
NiMH – Nickel Metal Hydride
NMC – Nickel-Manganese-Cobalt
OCPP – Open Charge Point Protocol
OEM – Original Equipment Manufacturer
SOC – State of Charge
UL – Underwriters Laboratories
UPS – Uninterrupted Power Supply
V – Volts
VRLA – Valve Regulated Lead Acid
W – Watt
Wh – Watt Hour

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