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KNOWLEDGE PAPER ON LITHIUM-ION BATTERY ASSEMBLING IN INDIA

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Report Insight

This paper delivers an overview of battery pack assembly process and the status of the industry in India. The knowledge gained from this paper will guide the reader in evaluating and understanding the battery pack assembly facilities needed to meet the growing battery market and demand. As the industry eagerly awaits the forthcoming storage policy, the information in this paper will guide the reader in evaluating opportunities to setup battery pack assembly facility and capture the share of the growing battery market and demand in India.

Introduction

Energy storage market is on rise across the world. Every company, new or old, that is in the field of renewables or electric vehicles, is looking for even more reliable and affordable storage technology. Battery energy storage provides several valuable services and advantages in stationary, renewable grid services and electric mobility. In stationary storage and renewable grid service battery energy storage provides for frequency regulation, peak shaving as well as mitigating the fluctuations in generation from variability in renewable sources. In electric vehicles, batteries comprise around 50-60 percent of cost of the vehicle, creating a pressing need for highly reliable, efficient and low-cost solutions. As such there exists a huge market potential for battery pack manufacturers to provide stationary storage, renewable grid services or electric vehicles, with reliable and affordable energy storage technology.

Li-ion battery technology has become preferred technology in many battery storage applications due to its relatively high energy and power density, better volumetric and gravimetric densities and low maintenance.

In order to deliver the required power and energy as per the application, it is necessary to assemble the individual Li-ion cells in series and parallel configuration to make up a Li-ion battery pack. Hundreds of individual cells are assembled in series and parallel configurations to form battery modules. These battery modules are further assembled in series and parallel configurations to form a battery pack that will deliver the required power and energy. **(Refer Fig 1)**

In India, lithium cells are imported from countries such as China, Korea, Taiwan, Japan, Malaysia, Singapore and the USA. China holds the maximum share for import of the lithium cells into India followed by Korea, Taiwan and Japan. These cells are then assembled in India in different configurations as per voltage and capacity (Ampere-hour). Also, they are segregated in terms of packaging i.e. prismatic, cylindrical or pouch packing.

The battery pack manufactures in India are currently assembling high capacity packs with the goal to target electric vehicles and stationary storage market. Assembling of Li-ion battery packs is a dynamic industry in India.

Advanced equipment and machinery are available to assemble high quality packs with reliable and quality performance and safe operations. Once the battery pack has been designed the assembly should be carefully done in order to deliver the performance as per the design specifications. If the processes for assembling of Li-ion packs are not precisely followed, the pack will not perform according to the specification which will affect the safety and operating cost of the battery energy storage system. In the following paper, we will be listing the challenges faced by the battery pack manufacturing industry, guiding the reader through the assembly process and the required equipment and glimpse of the market outlook of lithium ion Industry.

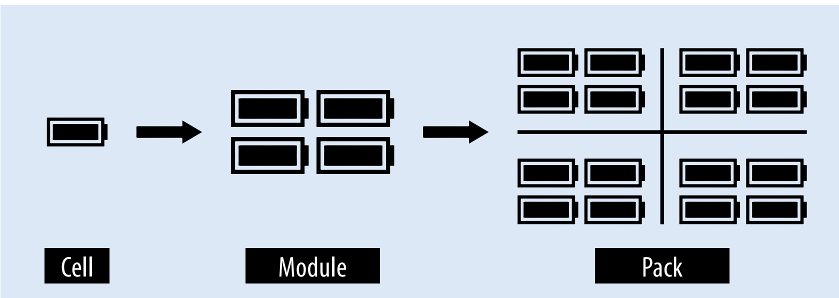


Fig.1 – Stages of Assembling

Challenges for Assembling Industry

A battery pack is a hierarchical and repetitive assembly of individual cells. The challenges in battery pack assembly process are:

a) **Different Battery Cell Types:** Due to different cell size, shape, form factor, and capacity the assembly process needs to be setup for each type of battery cell type. This adds to the investment cost if the decision is to make packs with different battery cell types.

b) **Varying Pack Configurations:** The pack design changes with the application requirements which in turn changes the number of cells in the pack. Thus, varying pack configuration makes it's difficult to fully automate the assembly process if the target is to cater to several different markets. The assembly lines need to be flexible to accommodate different battery pack designs and their varying rates and capacity.

c) **Shock and Fire Hazards:** The packs are assembled with cells at 40-50% state of charge. As the pack size increases the voltage and current through the pack increases. This increases the shock and fire hazard in the assembly process.

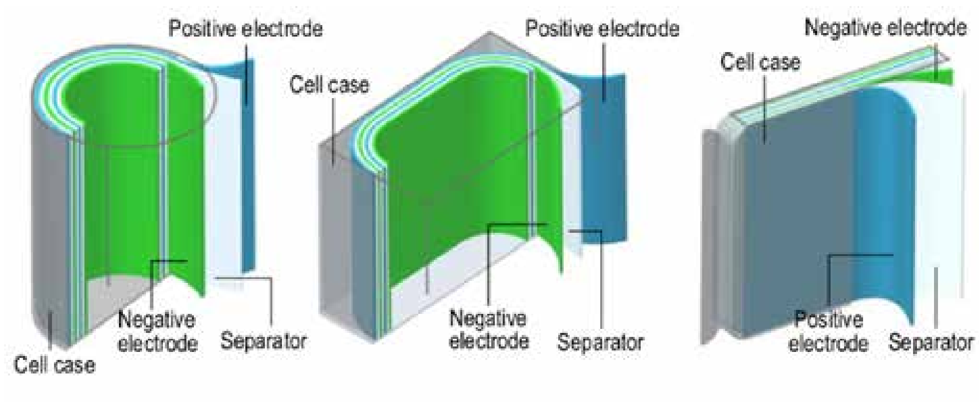
d) **Auxiliary Components:** Modules and packs need to have a battery management system installed for better operational control. Also, the pack may need a cooling system component. All such and other auxiliary structural, mechanical and electrical components add to the complexity of the assembly process.

The Battery pack assembly market is slow in adapting the technological advances in this space. In India battery pack production is still in an evolutionary phase (at least for high-power applications), i.e. requirements for automated production are changing rapidly. The cost of to set up an assembling plant for a superior, state-of-the-art assembly line for battery-packs is upwards of INR 7 to 10 crore required. Therefore, many industries in India do not use engineering approach for design, and manufacturing of battery packs. The Indian battery pack industry has yet to adopt the advanced equipment and in-line quality check systems developed specially for battery pack assembly.

Overview of Lithium-ion Battery & Pack Assembling

There are different types of energy storage available in the industry at present like electro chemical (battery, flow battery and hydrogen), mechanical (flywheels and compressed air), electrical (capacitors, super capacitors and superconductive magnetic) and thermal (hot water storage, thermal fluid storage and ceramic thermal storage). Each type has its own advantages and disadvantages. For solar energy, wind energy and electric vehicles the most promising technology will be the electro-chemical technology, especially battery storage. Going into more specifics, the Li-ion battery is currently the most reliable energy storage option due to high energy and power density and low maintenance, steady drop in the cost of the battery packs. Li-ion cells come in different shape, size, and form factor.

Basic outlook of Li-ion cells:



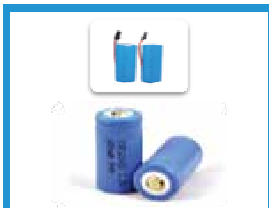
(a) Cylindrical cell (b) Prismatic cell (c) Pouch cell

Source: techsciresearch

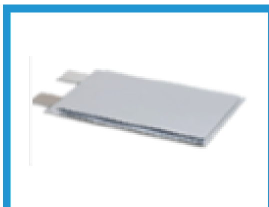
Fig. 2 – Shapes of lithium-ion cell

Different shapes of the lithium-ion cell:

1. **Cylindrical:** Cylindrical lithium cells are used for high specific energy density and good mechanical stability. This shape offers good safety and a high cycle life at a low cost. The disadvantage is that it has low packaging density.
2. **Pouch:** Cells in this shape have a laminated architecture in a bag. Exposure to high temperature and humidity can shorten the life of this cell, but it is light and cost effective.
3. **Prismatic:** These cells are packaged in aluminum or steel for good stability. It is expensive to manufacture but is a space effective solution compared to the cylindrical cell.



Cylindrical Li-ion battery
- Tightly spiral wound electrodes packed inside a cynlidrical can.
- Small cylindrical solid body with large threaded terminals
- Large Solid cylincrical body with flat terminals
- Venting system may be availble.



Pouch Li-ion battery
- Layered stacking of electrodes in thin flexible rectangular pouch
- Soft, flat body, such as those used in cell phones

Prismatic Li-ion battery
- Layered stacking of electrodes in hard rectangular casing
- High capacity cells with venting system

Source: India Energy Storage Alliance

Fig. 3 – Types of Li-ion cells

Nomenclature of lithium-ion cell/battery:

Lithium-ion batteries have a unique way of naming (it can be used for both batteries with multiple cells and single cell).

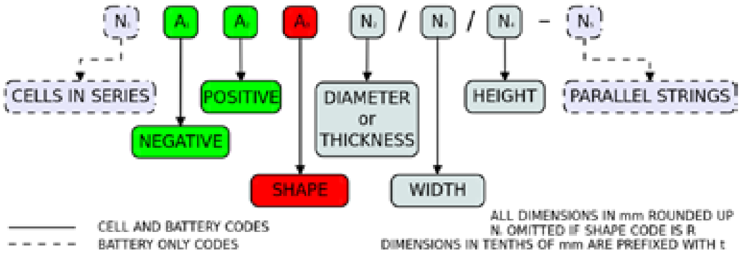


Fig. 4 – Nomenclature of lithium-ion cell/battery

Source: IEC-60086 lithium battery codes

Design will be specified as:

$$N_1A_1A_2A_3N_2/N_3/N_4\text{-}N_5$$

Where

- N_1 denotes number of cells connected in series and N_5 denotes number of cells connected in parallel (these numbers are used only when the number is greater than 1. Also, these numbers only apply to batteries).
- A_1 denotes the basis of negative electrode phase, where we use "I" for lithium-ion and "L" is for lithium metal or alloy.
- A_2 denotes the basis of positive electrode phase, where we use "C", "N", "M", "V" or "T" for cobalt, nickel, manganese, vanadium and titanium respectively.
- A_3 denotes the shape of the cell, where we use "R" for cylindrical cell and "P" for prismatic cell.
- N_2 denotes the maximum diameter (in case of cylindrical cells) or thickness (in case of prismatic cells) in mm.
- N_3 denotes the maximum width in mm (it is only used for prismatic cells).
- N_4 denotes the maximum overall height in mm.

Some examples of this nomenclature are:

o ICR19/66 o 2ICP20/34/70
o ICPt9/35/48 o 1ICP20/68/70-2

NOTE– Industry also uses one more nomenclature for representing lithium-ion cylindrical cells: D_1H_1 where D1means diameter and H_1 means height in mm.

Some examples of this type of nomenclature are-

o 18350: 18mm x 35.0mm
o 18650: 18mm x 65.0mm
o 14500: 14mm x 50.0 mm

The industry has adapted a more functional nomenclature for battery packs; it generally refers to the module size by the number of cell strings in series and parallel and pack with number of modules in series and parallel.

For example– A 14S5P module will have 14 cells in series and 5 such strings in parallel.

Overview of Li-ion battery packs assembling process:

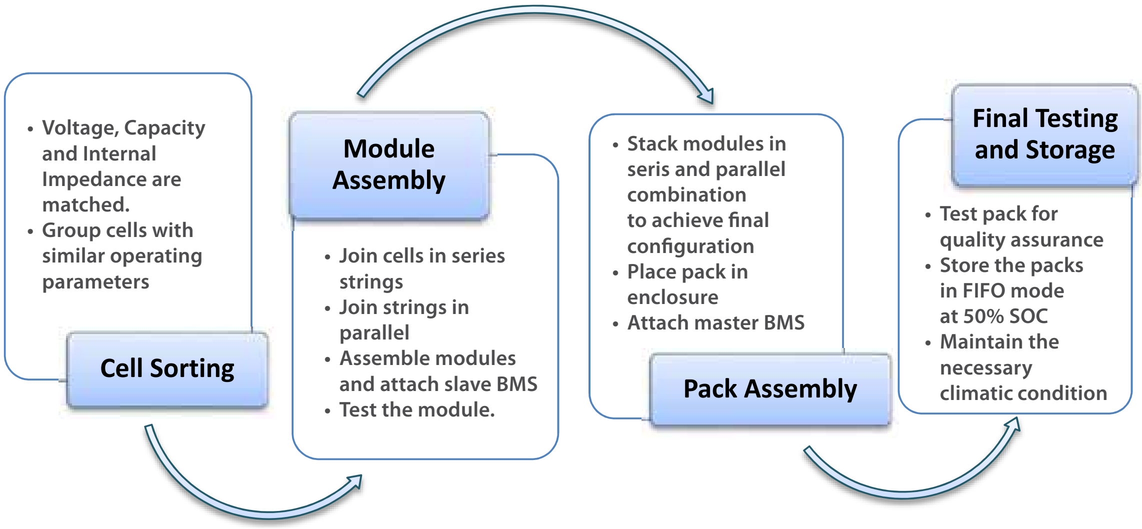


Fig. 5 – Battery-pack assembly line

Source: India Energy Storage Alliance

i. **Cell sorting-** Cell sorting is a process of identifying and grouping the cells with similar parameters and characteristics so that they have similar performance during operation cycles. Cell sorting is the most critical step to assure safety of the battery pack. There are few cell sorting methods, available for the battery pack manufacturers. The common sorting method is based on voltage, capacity, and AC internal impedance (VCI). The other sorting methods are based on electrochemical impedance spectroscopy and its equivalent model parameters, charge and discharge voltage curve, dynamic parameters, and thermal behavior. In the commonly used VCI method all the primary characteristic parameters of the cells are matched. The voltage and capacity are measured with charge-discharge cycle. The AC internal resistance is measured at a constant frequency of 1 kHz with low AC currents. The equipment used for cell sorting process is a standard battery cycler and an impedance tester. The cells with same operating voltage, capacity and internal resistance are grouped together in a battery pack, so that consistency and stability of the whole battery pack is assured during its life. The other methods can have better sorting results but are time consuming and require extensive data analysis and processing. As a trade-off voltage, capacity and AC internal impedance are used for cell sorting process. Typically, a 1-2-1 philosophy is adapted, which means cells within 1% variation in voltage, 2% variation in capacity and 1% variation in AC internal impedance are grouped together for better performance of battery pack. After the cell sorting process is complete the groups of sorted cells are sent for welding process.

Fig. 6 – Cell testing machine

Source: Keysight Technologies

ii. **Module Assembly-** The cells from a group are welded in a series and parallel combination to form a module. The cells can be first joined in parallel then series or first series then parallel or mixed series and parallel connections. The cells are welded either tab-to-tab or tab-to-bus bar connections. After module assemble a slave battery management system is installed onto the module. The modules are tested as per the specifications for quality assurance.

Fig. 7 – Module testing machine

Source: Keysight Technologies

iii. **Pack Assembly-** The modules are assembled in series and parallel configuration to achieve the final pack level voltage and capacity. The pack is enclosed in a housing and sealed to avoid any structural damage. Other auxiliary components such as cooling systems and mechanical connections are made. Finally, the master BMS is installed onto the pack.

Fig. 8 – Pack testing machine

Source: Keysight Technologies

iv. **Final Testing and Storage-** The pack is tested for uniform charging of all cells and other pack parameters such as voltage, and impedance. The pack is then stored at 50% SOC in the warehouse as per first-in-first-out mode (FIFO). The warehouse temperatures are maintained to approximately 25°C for safety and performance. Due to high voltages of the battery pack they are electrical shock hazards and appropriate safety measures are taken during storage, handling and shipping of the packs.

It is necessary to follow these processes in the defined order so that quality and performance of the product is maintained.

Detailed flowchart for Li-ion battery pack assembling with Cylindrical cells:

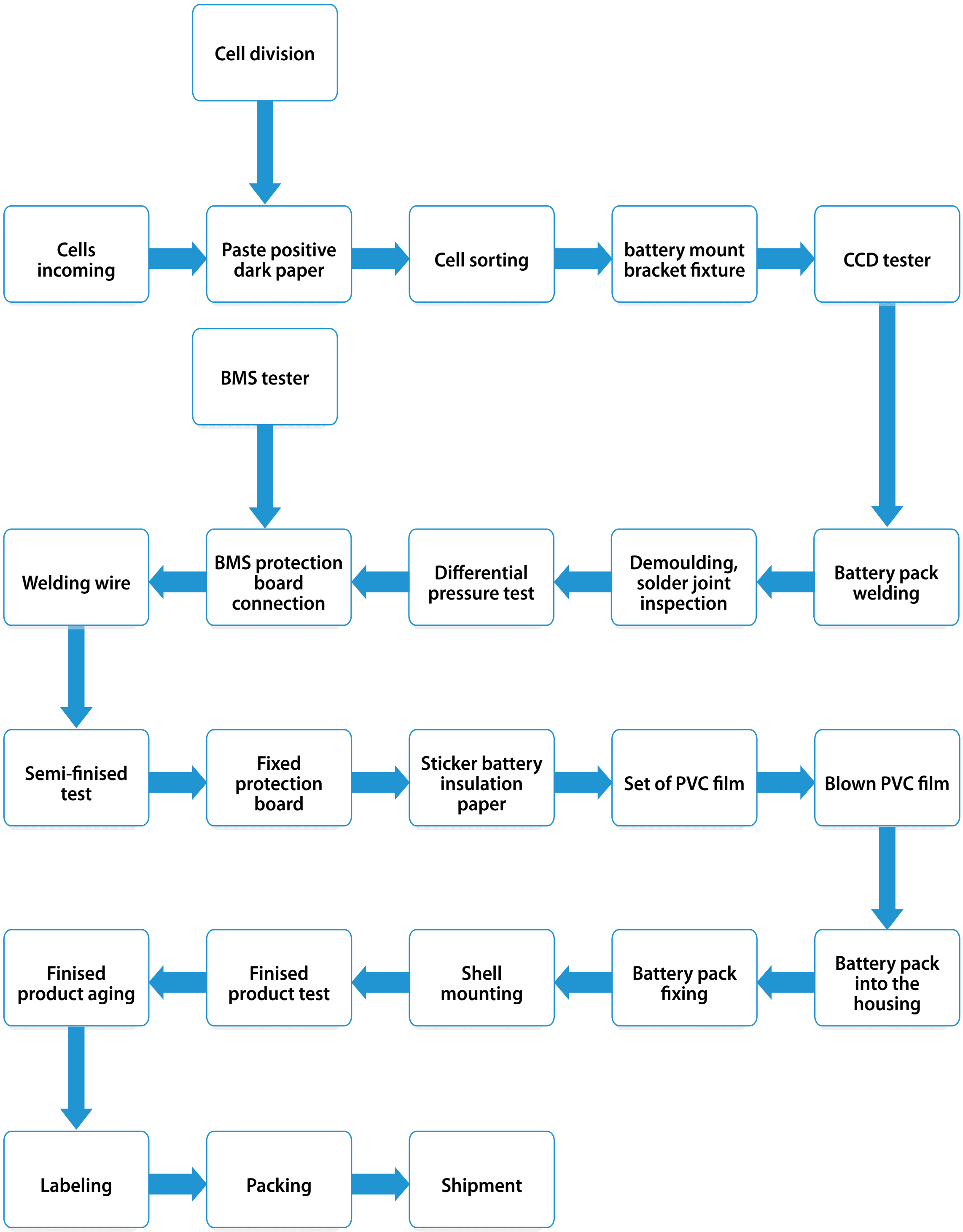


Fig. 9 – Process flow diagram of Li-pack assembly with Cylindrical cells

Source: India Energy Storage Alliance

Detailed flowchart for Li-ion battery pack assembling with Pouch cells:

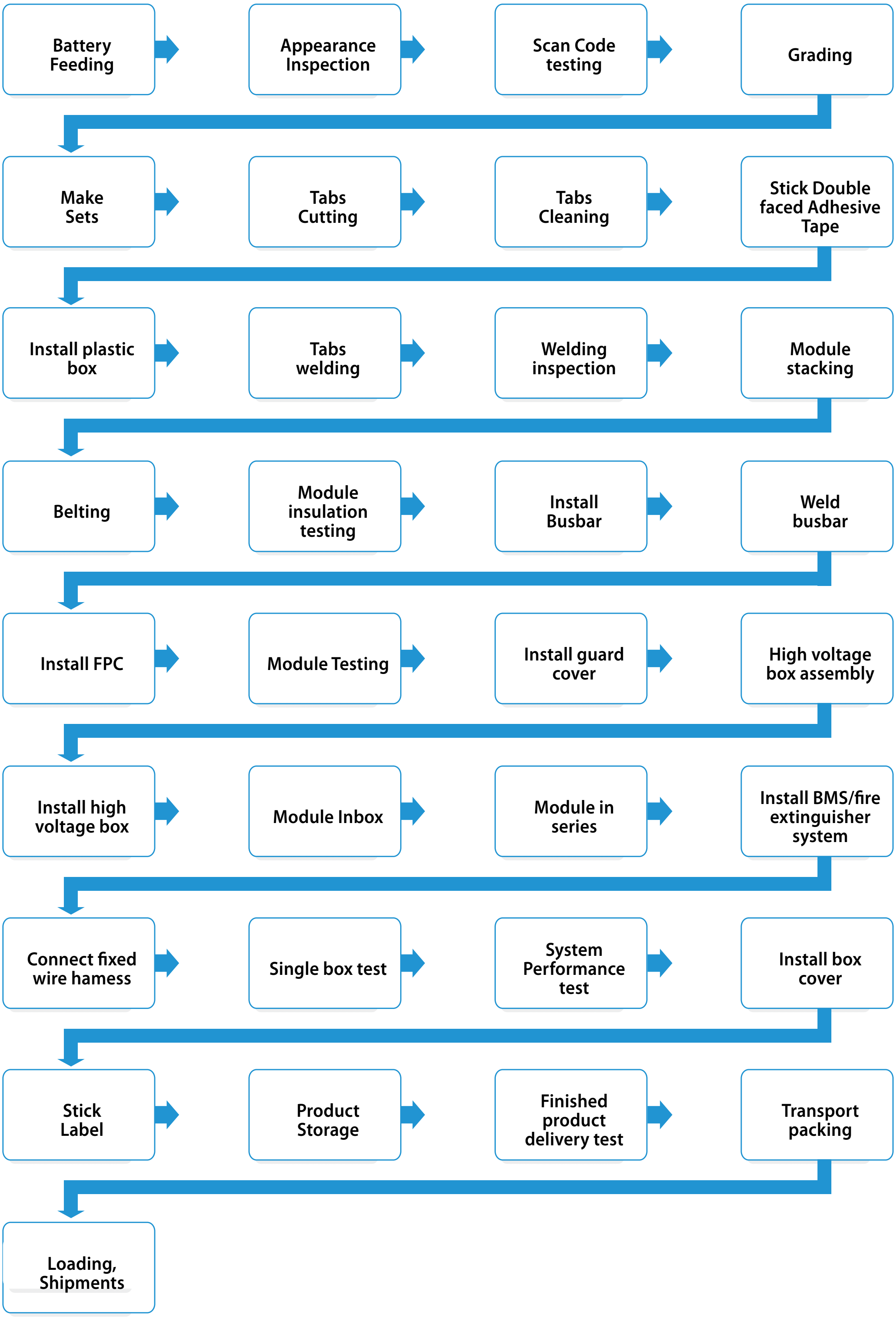


Fig. 10 – Process flow diagram of Li-pack assembly with Pouch cells

Source: India Energy Storage Alliance

Detailed steps to be followed in making Li-ion battery packs:

Step 1: Material testing/Cell testing- Testing is done to establish the cell parameters i.e. voltage, capacity, cycle life etc.

Fig. 11 – Capacity tester

Source: SMC racing

Step 2: BMS testing- This step checks whether the battery protection circuit functional indicators fall within the parameter range

Fig. 12 – BMS Tester

Source: JXC

Step 3: Pasting insulating paper on the positive pole- Small insulating paper is pasted on the poles of cells to prevent a short circuit

Fig. 13 – Insulator pasting machine

Source: Shenzhen TWSL

Step 4: Battery Sorting- Batteries are sorted according to their voltage and internal resistance. The same voltage and internal resistance value battery are kept together, so that consistency and stability of the whole battery pack is assured during its life.

Fig. 14 – Cell sorting machine

Source: Shenzhen TWSL

Step 5: Putting the cells in brackets and moulds- Cells are given a supporting structure to weld them together. Nickel strips are also placed in the moulds to weld cells together.

Fig. 15 – Placing cells in brackets and nickel strips in a mould

Source: JXC

Step 6: CCD testing- Before welding the cells, CCD testing is done to ensure that the positive and negative poles of the battery are above and below to prevent short circuiting

Fig. 16 – CCD testing machine

Source: JXC

Step 7: Welding the cells- Welding of multiple cells provides a higher capacity battery. A company uses any one of the welding techniques - spot welding, laser welding, bolt welding or ultra-sonic.

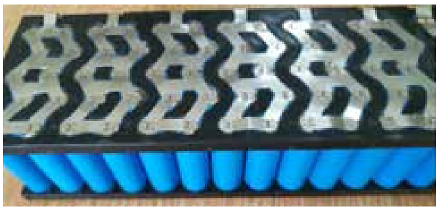


Fig. 17 – Welding machine

Source: Shenzhen TWSL

Step 8: Pasting insulation paper and pre-treatment of battery poles- Insulating paper is pasted on the battery pack to prevent the aging of PVC and so that chances of short circuit are reduced. Pre-treatment of the battery poles is required to weld BMS easily.

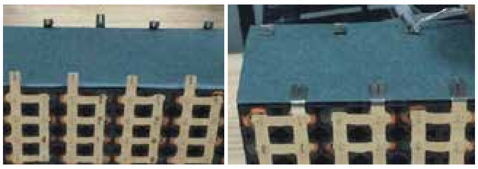


Fig. 18 – Insulating paper pasting and pre-treatment of battery pole

Source: JXC

Step 9: Connecting BMS- Battery Management System is connected to the battery pack, so that it can be operated in the desired range.

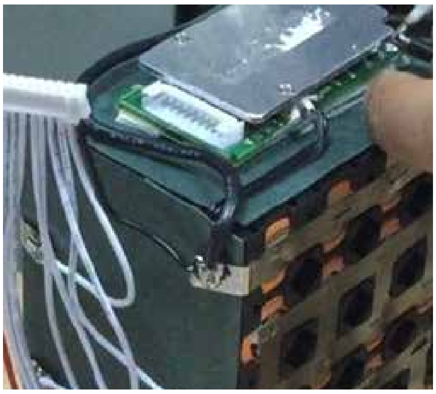


Fig. 19 – Connecting BMS

Source: Shenzhen TWSL

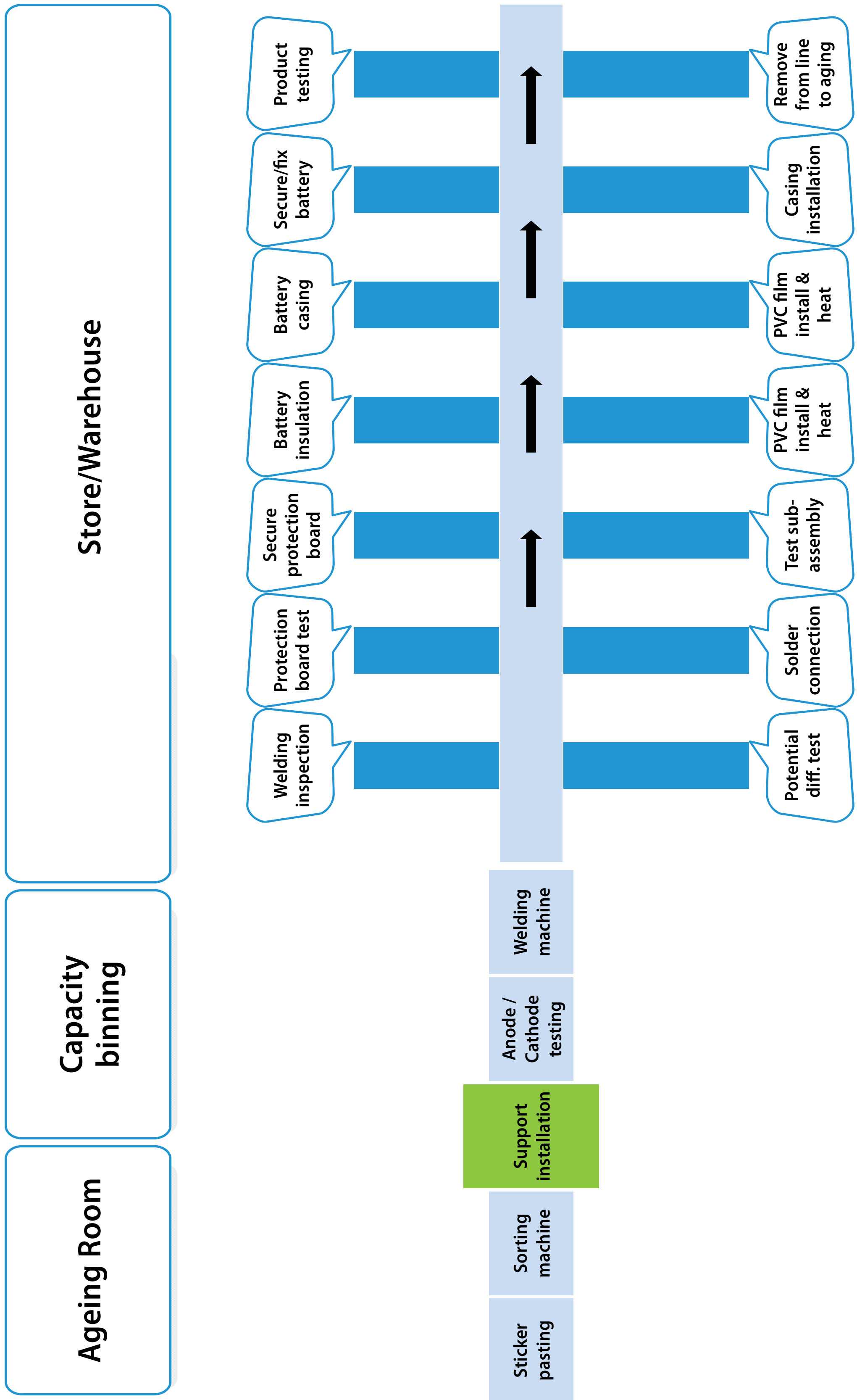
Step 10: Battery pack testing- A finished battery pack is tested to determine the charge and discharge voltage, charge and discharge current and total internal resistance.

Fig. 20 – Battery pack tester

Source: Shenzhen TWSL

Step 11: Battery aging test- A battery pack is charged and discharged several times and its capacity is recorded at each charge and discharge to detect the battery charge protection and discharge protection.

General Plant layout for Lithium-ion Pack Assembling



India's Industrial chain for the Li-ion battery

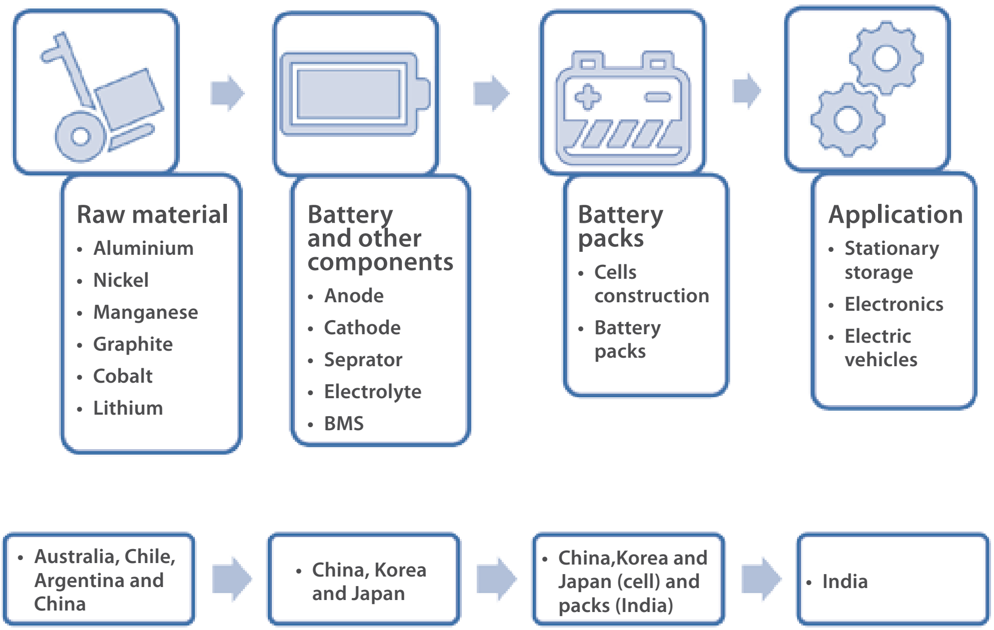


Fig. 21 – Li-ion supply chain

Source: India Energy Storage Alliance

Lithium Production

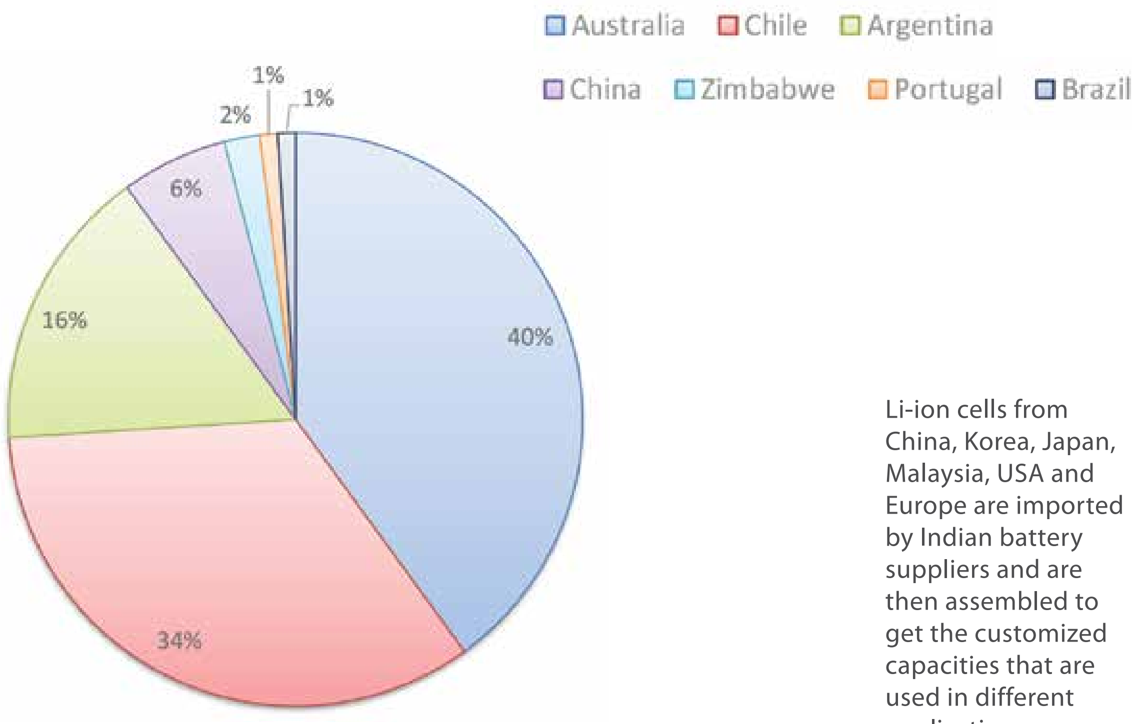


Fig. 22 – Lithium production around the globe

Source: Minerals - Lithium resources and production by Mohr, S. H., Mudd, G. M. and Giurco, D.,

Li-ion cells from China, Korea, Japan, Malaysia, USA and Europe are imported by Indian battery suppliers and are then assembled to get the customized capacities that are used in different applications.

Cell Imports

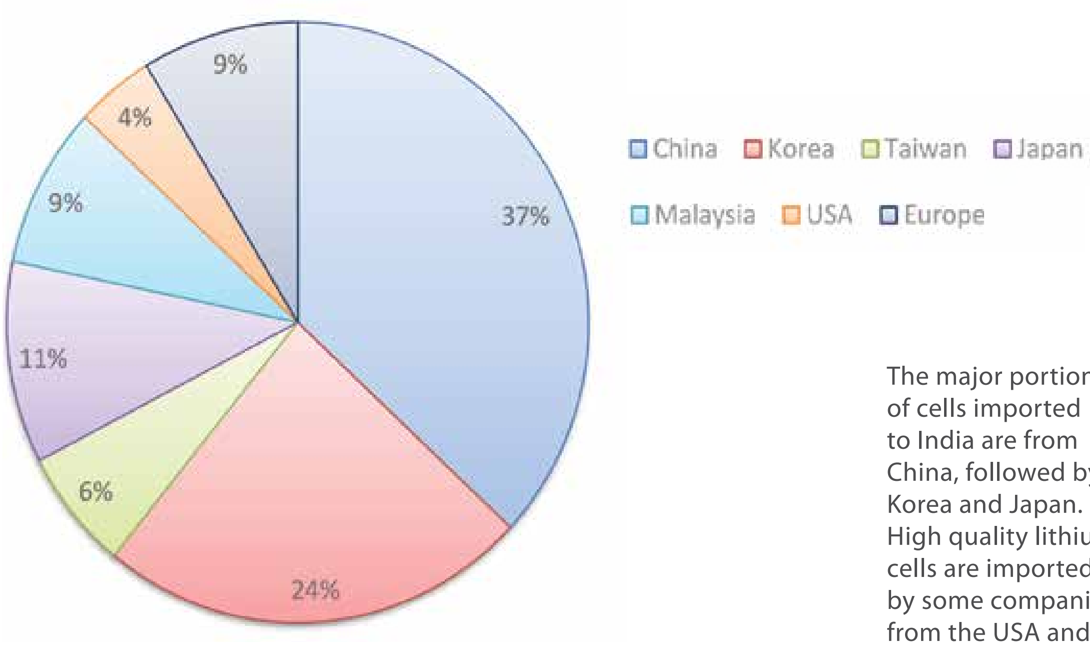


Fig. 23 – Lithium-ion cells imported to India

Source: India Energy Storage Alliance

The major portion of cells imported to India are from China, followed by Korea and Japan. High quality lithium cells are imported by some companies from the USA and Europe.

Battery Management System

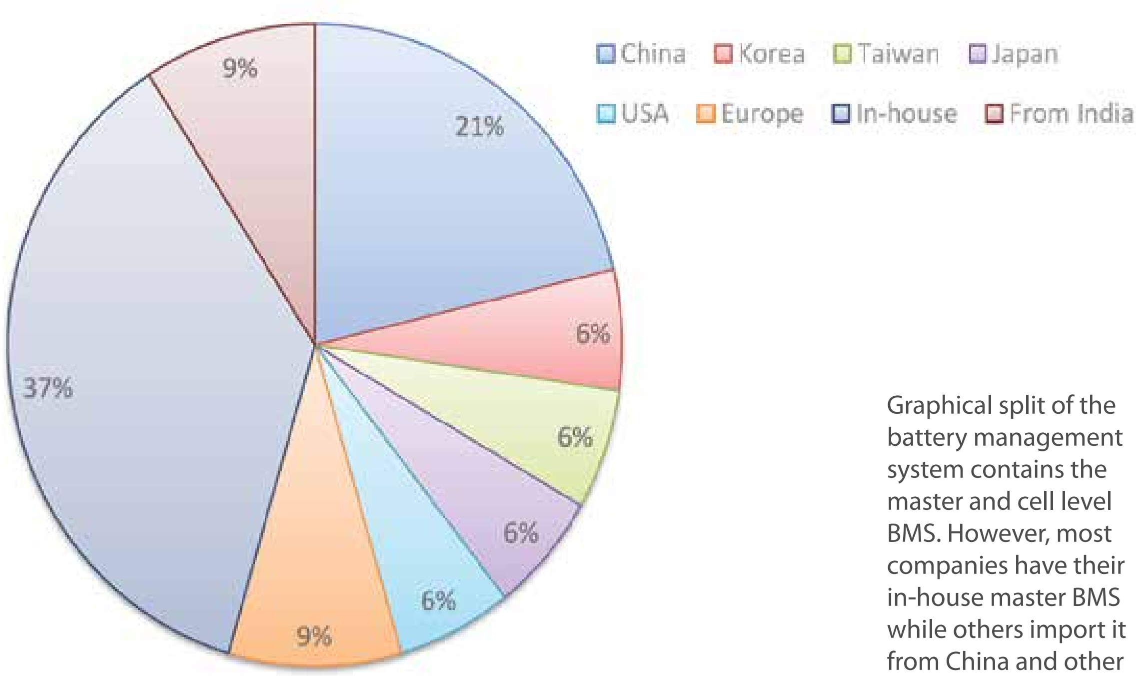


Fig. 24 – Graphical split of BMS sourcing by countries

Source: India Energy Storage Alliance

Graphical split of the battery management system contains the master and cell level BMS. However, most companies have their in-house master BMS while others import it from China and other countries.

India's market outlook for the Li-ion battery

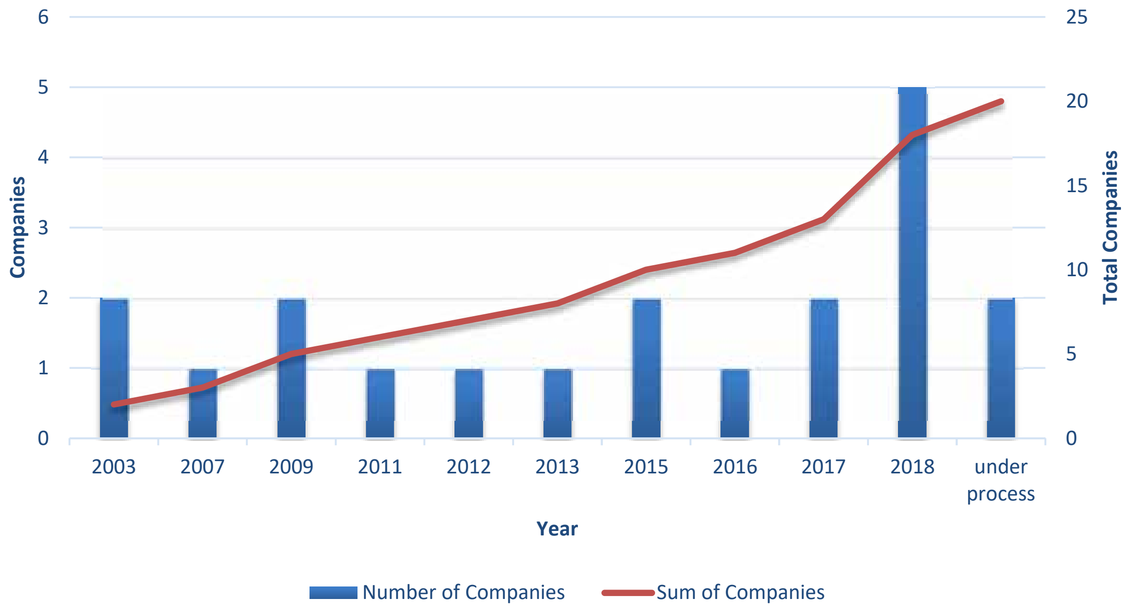


Fig. 25 – **Lithium-ion pack assemblers in India**

Source: India Energy Storage Alliance

After the announcement of the Jawaharlal Nehru National Solar Mission and thanks to the continuous push by the Indian government towards its renewable energy goal made at the Paris Agreement, we see many new companies in the lithium-ion pack assembly market. Currently, during the wait for the announcement of the storage policy, we are seeing a renewed market trend towards lithium cell manufacturing.

Few of the companies have started Li-ion pack assembling in India in 2003. Although, it was at the initial level at that time, primarily for mobile phones and other small application like POS, medical and testing instruments. Many of the companies in India provide batteries for smaller applications whose voltage is below 5V and upto 10Ah.

For grid storage, the most desirable feature for batteries is a high cycle life and high energy density. Storage enables the high penetration of renewables, as stated by the Ministry of New and Renewable Energy in order to achieve its target of 225 GW of renewable energy by 2022. A grid with effective storage will not only help to integrate renewables with other conventional sources of energy, but also ensure a high-quality of power or electricity supply. In grid-connected storage, the battery would hold around 5 GW of power by 2022 and will further increases to 7.8 GW by 2032, as per NITI Aayog's India Energy Security Scenario 2047.

In India, the Lithium Iron Phosphate (LiFePO4) battery holds the largest market share as many companies deal in this chemistry due to the high specific power, life and safety. Similarly, Lithium Nickel Manganese Cobalt Oxide (NMC) batteries also hold a substantial market. The market share of other chemistries like Lithium Titanate (LTO), Lithium Nickel Cobalt Aluminum (NCA) is very small but expected to grow in near time as many companies are taking an interest in these types of materials. A few companies also deal in Lithium Manganese Oxide (LMO) and Lithium Cobalt Oxide (LCO) for specific customers and applications.

Most of the companies which are into Li-ion pack assembling in India use a combined machinery in their facility - either a combination of automatic and semi-automatic or semi-automatic and manual machineries for assembling the Li-ion packs. Using manual machinery increases the chances of error. Only very few companies use fully automatic machinery in their facility. In most cases the automatic machinery used by the companies in these assembling plants are testing machines.

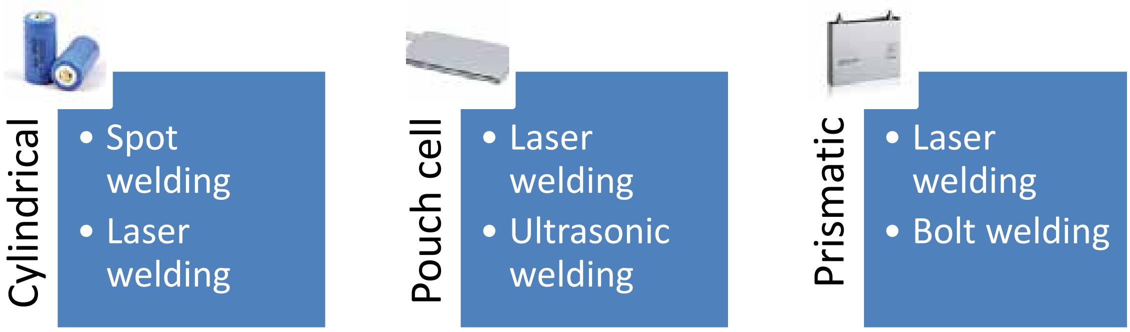


Fig. 26 – Best welding practices for different types of cell

Source: Research Paper by The University of Warwick

Spot welding is the most favored technique used in India for stacking Li-ion cells. A few companies also deal in bolt and laser welding, but for the majorly it is a mixed type of market in which companies usually do stacking as per the application and customer requirements. Laser welding is preferred as it gives a better performance.

For electric vehicles, the most desirable feature is a high-power density battery, although high energy is also a desirable. In India, as per the study, all companies supply batteries for electric vehicles. The most commonly used battery is the Lithium-Ferrous Phosphate Oxide (Li-FePO4).

As per the applications in which batteries are used, different companies provide different configurations of batteries to capture a wide variety of products. Due to the evolving electric vehicle market and the anticipated storage policy of India, most of the company's target higher capacity batteries of 48V and above.

Assembling of Li-ion battery packs is a dynamic industry in India and is currently slowly moving towards cell manufacturing as well. As per the current scenario, all cells are imported and only the assembling is done in India.

Market trends and development

Currently many battery companies in India are involved with the lithium-pack assembling. Even companies like Exide, which is setting up its unit for manufacturing the lithium cell, is starting initially with battery pack assembling.

Gradually however, companies are setting up manufacturing plants for lithium-ion cells: Suzuki Motor Corporation, the parent company of Maruti Suzuki, has tied up with Toshiba and Denso to setup a Li-ion cell manufacturing plant in Gujarat at an estimated cost of INR 1150 crores. Mahindra and Mahindra through its arm Mahindra Electric is set to invest INR 1000 crores for an R&D center and battery manufacturing plant in Chakan, Maharashtra and at the same time expand its electric vehicle manufacturing capacity at Bengaluru. Mahindra has forged an alliance with South Korean's LG Chem for the manufacture of lithium-ion batteries. BHEL, in a joint venture with LIBCOIN (20 percent owned by Manis), are in the final talks to build India's first lithium-ion Gigafactory with capacity of 1GWh which will be scaled to 30GWh. Tata Power collaborated with AES and Mitsubishi to commission a 10 MW battery energy storage system in Delhi. The 10 MW grid-connected system is owned by AES and Mitsubishi Corporation. Lithium-ion batteries are supplied by Fluence, jointly owned by Siemens and AES. ISRO has also shortlisted the 10 companies mentioned below to share its lithium-ion cell technology: Amara Raja Batteries Ltd, Chittoor, Andhra Pradesh; Bharat Electronics Ltd, Pune; Carborundum Universal Ltd, Kochi; Exicom Tele-Systems Ltd, Gurgaon; GOCL Corporation Ltd, Hyderabad; Jyoti CNC Automation Ltd, Rajkot; National Aluminium Company Ltd, Bhubaneswar; Sukhbir Agro Energy Ltd, New Delhi; Tata Chemicals Ltd, Mumbai; Thermax Ltd, Pune.

Recently Tata Chemicals signed a MoU with ISRO for the transfer of lithium cell technology to manufacture cells of varying capacities, sizes, energy and power densities and cater to wider spectrum of power storage requirements.

Under the Phased Manufacturing Program (PMP) of Ministry of Heavy Industries and Public Enterprise, import duty on battery packs used in manufacturing electric vehicles will be increased to 15 percent from the current 5 percent from April 2021. Also import duty on lithium-ion cells for use in the manufacture of lithium-ion accumulator for EVs will be doubled to 10 percent from April 2021 as the center wants to promote Make in India and encourage EVs through schemes like FAME II. Energy Storage is one of the most crucial and critical components of India's energy infrastructure strategy and an essential support for India's sustained goal towards renewables.

BIS certification for lithium-ion cell

Bureau of Indian Standard (BIS) certification is required in order to import lithium-ion cells in India. Under the certification, a unique license number (R-123***78) is been provided to the seller/manufacturer which authorizes them to sell their lithium-ion cells in India. This license number is valid for two years, after which one must obtain the certification and license number again (renewal of license application should be filled three months prior to the expiration of license).

Seller/Manufacturer needs to provide some information to the BIS in order to obtain the certification, such as product name, Indian standard number (IS-16046 (PART 2):2018&IEC 62133 2:2017), brand and model name and factory address. The license cannot be transferred to another manufacturer. Also, in case of shifting of the factory/machinery from the registered location/premises to a new location, the manufacturer cannot use the same license number. The manufacturer should also appoint their Indian representative in India.

A monogram of 'Standard Mark' needs to be present on every product and package imported into India. A 'Standard Mark' can be displayed either in single color or multi-color (red, blue and black). IS number, registration number and words shall not be displayed in less than Arial font size 6.

Fig. 27 – Standard Mark

Source: BIS India

Reference

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We have been at the forefront to contribute in development of enabling policy frameworks for adoption of Energy Storage and e-mobility technologies in India. We provide a eco-system to our members to network and grow their business in India and around the world through in-depth analysis and active dialogue among the various stakeholders. Our initiative 'IESA Academy' addresses the much-required skill development area through capability building programs and customized trainings with collaboration of Industry and academia.
Our members encompass all the vertices of the Industry covering energy storage manufacturers, research institutes, renewable energy, power electronics, EV manufacturing companies.

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