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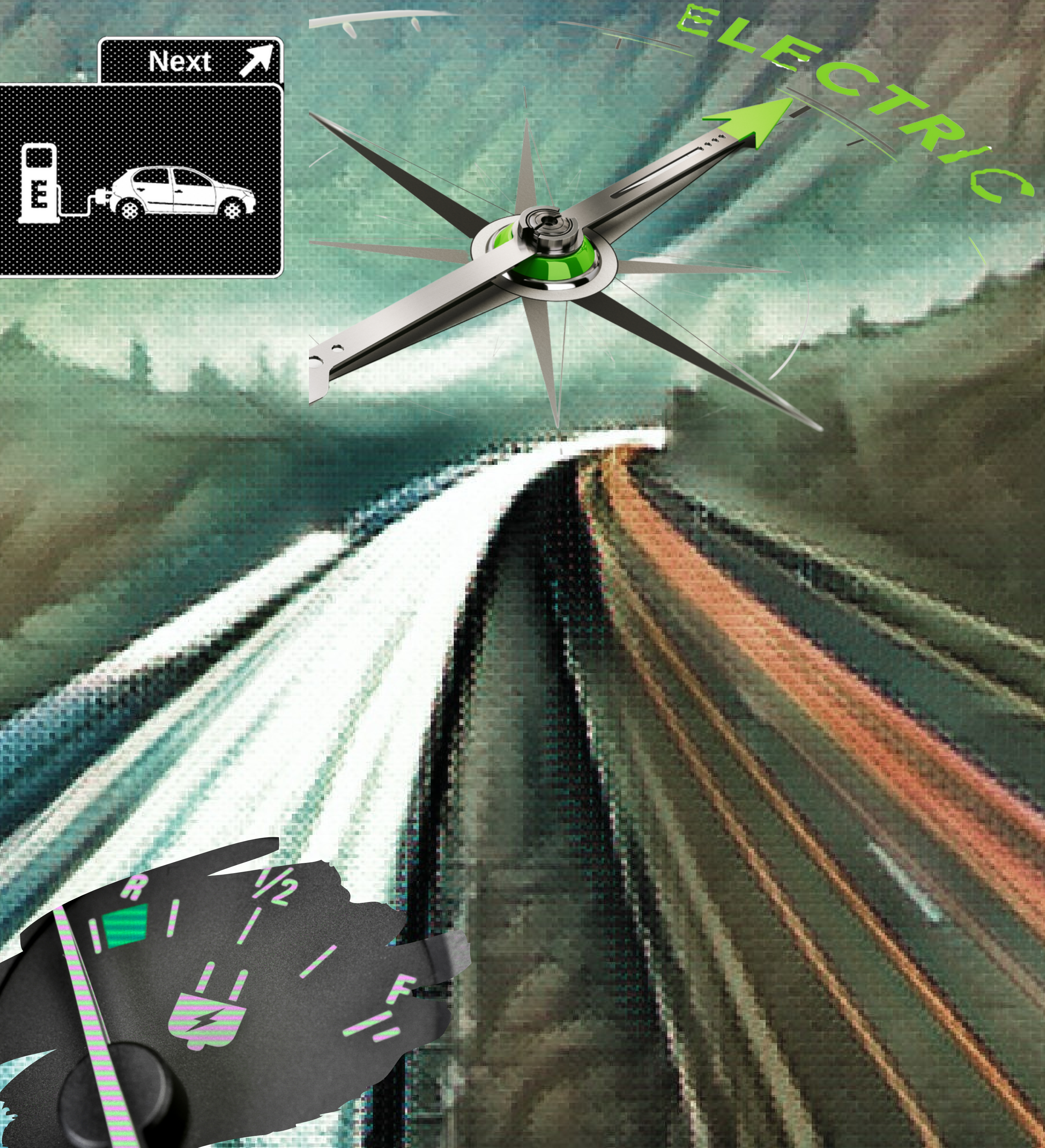
# EVreporter

APRIL 2022 | MAGAZINE



# WHAT'S INSIDE


**Hero MotoCorp** announces brand **Vida** for its emerging mobility solutions, including upcoming electric vehicles. The first EV will be unveiled on July 1, 2022 and deliveries to customers will begin later in 2022. Production will be done at Hero MotoCorp's 'Green' manufacturing facility in Chittoor, Andhra Pradesh. Hero MotoCorp also holds 34.58% stake in electric 2W manufacturer Ather Energy, and entered into a partnership with Gogoro last year, to establish battery swapping infrastructure.

**TVS Motor Company is readying a complete portfolio of electric two and three-wheelers in the range of 5-25kW, all of which are expected to be in the market within the next 24 months**. The company committed Rs. 1,000 crores towards EV business, a good portion of which has already been invested. It has **sold over 12,000 units of its high-speed electric scooter TVS iQube**. TVS has also partnered with Jio-bp to explore the creation of a public EV charging infrastructure for e2Ws and 3Ws, building on Jio-bp's growing network.

**Suzuki Motor Corporation has signed an MOU with the State of Gujarat** to invest approximately INR 104 billion to manufacture EVs and EV batteries.

| | Signees of MOU with the State of Gujarat | Description | Investment | Planned year |
|---|---|---|---|---|
| 1 | Suzuki Motor Gujarat Private Limited (SMG) | Increasing production capacity for BEV manufacturing | 31 billion rupees | 2025 |
| 2 | | Construction of plant for BEV batteries (land neighboring to SMG) | 73 billion rupees | 2026 |
| 3 | Maruti Suzuki Toyotsu India Private Limited (MSTI) | Construction of vehicle recycling plant | 450 million rupees | 2025 |

The MOU was signed on 19 March 2022 at India-Japan Economic Forum held in Delhi, in the presence of Japanese Prime Minister Mr Fumio Kishida and Indian Prime Minister Mr Narendra Modi.

**Toyota Kirloskar Motor** and ICAT are conducting a pilot project to study and evaluate Toyota Mirai (which runs on hydrogen) for Indian roads and climatic conditions.

As a part of the effort, Nitin Gadkari, Minister of Road Transport and Highways, launched Hydrogen Fuel Cell Electric Vehicle **(FCEV) Toyota Mirai** in New Delhi.

**Hero Yamaha JV (HYM Drive Systems) to manufacture electric drive units for e-cycles in Ludhiana**. Hero Motors and Yamaha Motor Co. (Japan) had entered into an agreement in Oct 2021 to create a Global E-Cycle (Electric) Drive Unit company at Hero E-Cycle Valley in Ludhiana. The 100-acre Hero E-Cycle Valley currently manufactures Cycles and E-Cycles for Global Cycle OEMs and will start manufacturing Cycle components like Alloy Rim, Aluminum Frames, Handlebars, etc. This new facility inside Cycle Valley will start production by Nov 2022 with a capacity of 1 million drive units in phases.

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## Auto PLI Scheme Update

The Production Linked Incentive (PLI) Scheme for Automobile and Auto Component Industry scheme has two components viz. Champion OEM incentive scheme and Component Champion incentive scheme. MHI had earlier approved 20 applicants (along with their 12 subsidiaries) for the Champion OEM Incentive scheme. Subsequently, **MHI has now approved 75 applicants (along with their 56 subsidiaries) under the Component Champion incentive scheme**. The Component Champion Incentive scheme is a 'sales value linked' scheme, applicable on Advanced Automotive Technology components of vehicles, Completely Knocked Down (CKD)/Semi Knocked Down (SKD) kits, Vehicle aggregates of 2-Wheelers, 3-Wheelers, passenger vehicles, commercial vehicles and tractors, etc.

- Apart from Indian business groups, approved applicants include groups from countries such as Japan, Germany, USA, UK, Republic of Korea, Ireland, France, Belgium, Netherlands and Italy.
- The PLI Scheme for the Automobile and Auto Component Industry has attracted a proposed investment of ₹ 74,850 crores. The proposed investment of ₹ 45,016 crores is from approved applicants under Champion OEM Incentive Scheme and ₹ 29,834 crores from approved applicants under Component Champion Incentive Scheme.
- Incentives are applicable under the scheme for Determined Sales of Advanced Automotive Technology (AAT) products (vehicles and components) manufactured in India from 1 April 2022 onwards for a period of 5 consecutive years.

## PLI Scheme for ACC Battery Storage

- **Ola Electric (20 GWh), Hyundai Motors (20 GWh), Reliance New Energy Solar (5 GWh) and Rajesh Exports (5 GWh)** have qualified for the PLI ACC scheme final selection. These companies will receive incentives under the ₹ 18,100 crore programme to boost local battery cell production.
- The manufacturing facility would have to be set up within a period of two years. The incentive will be disbursed thereafter over a period of five years on the sale of batteries manufactured in India.

| S.No | Applicant | Quoted Capacity | Status | Awarded Capacity |
|---|---|---|---|---|
| 1 | Rajesh Exports | 5 GWh | Awarded | 5 GWh |
| 2 | Hyundai Global Motors | 20 GWh | Awarded | 20 GWh |
| 3 | Ola Electric | 20 GWh | Awarded | 20 GWh |
| 4 | Reliance New Energy Solar | 20 GWh | Awarded | 5 GWh |
| | | | Waitlisted | 15 GWh |
| 5 | Mahindra & Mahindra | 15 GWh | Waitlisted | - |
| 6 | Exide Industries | 6 GWh | Waitlisted | - |
| 7 | Larsen & Toubro | 5 GWh | Waitlisted | - |
| 8 | Amara Raja Batteries | 12 GWh | Waitlisted | - |
| 9 | Indira Power Corporation | 5 GWh | Waitlisted | - |

# PLI SCHEME FOR ACC BATTERY STORAGE - CHALLENGES AND OPPORTUNITIES

Production Linked Incentive (PLI) Scheme for Advanced Chemistry Cell (ACC) Battery Storage was the highly anticipated policy that the industry was looking forward to setting up manufacturing of Lithium-ion cells and other advanced technologies in India. PLI for ACC is one of the 13 schemes approved by the Indian Government. The Department of Heavy Industries (DHI) had notified about this scheme in June 2021. It encourages companies (domestic and foreign) to set up Giga-scale (minimum 5GWh) battery storage manufacturing in India over a period of 5 years.

- The PLI for the ACC scheme has been allotted ₹18,100 Crores to support 50GWh annual capacity of manufacturing setup in India.
- ₹362 Crores has been capped for each GWh. The incentives will be disbursed over 5 years, starting from 2024.
- **The winners of the PLI for ACC scheme are Rajesh Exports (5GWh), Hyundai Global Motors (20GWh), Ola Electric (20GWh) and Reliance New Energy Solar (5GWh).** The program agreement with the winners will be signed in June 2022, and the winners will be given two years to set up an initial manufacturing facility and gradually ramp up production as per the plan they bid.
- Although it is called a production linked incentive, the incentives are actually dependent on the sales volume.
- The PLI for ACC scheme is eligible for all types of battery storage technologies that meet the minimum technological requirement as mentioned in the below image.

| INR Per KWh | | Energy Density (Wh/Kg) | | | | |
|---|---|---|---|---|---|---|
| | | ≥ 50 | ≥ 125 | ≥ 200 | ≥ 275 | ≥ 350 |
| Cycle Life | ≥ 1000 | - | - | - | A | A*(1.2) |
| | ≥ 2000 | - | - | A | A*(1.2) | A*(1.2^2) |
| | ≥ 4000 | - | A | A*(1.2) | A*(1.2^2) | A*(1.2^3) |
| | ≥ 10000 | A | A*1.2 | A*(1.2^2) | A*(1.2^3) | A*(1.2^4) |

Any company bidding in the PLI for ACC scheme must have a battery technology that has a cycle life to gravimetric energy density ratio at least in the 'A' cell. Any company able to achieve A*(1.2) would achieve 1.2x of the incentive they asked for in their bid. Similarly, A*(1.2^2) would mean 1.44x the incentive, A*(1.2^3) would mean 1.728x the incentive, and A*(1.2^4) would mean 2.0736x the incentive. **In my opinion, there is no technology today that can be manufactured on the GWh scale and can fit in the A*(1.2^2) and higher category.**

Since the prices of battery technologies are expected to fall in the coming years, the scheme has a reduction factor applicable to the subsidy amount, as shown below:

| FY | 1 year 2022-23 | 2 year 2023-24 | 3 year 2024-25 | 4 year 2025-26 | 5 year 2026-27 | 6 year 2027-28 | 7 year 2028-29 |
|---|---|---|---|---|---|---|---|
| Reduction | 0% | 0% | 0% | 0% | 10% | 20% | 40% |
| Year on year effective phasing of base Subsidy (benchmark amount) | 100% | 100% | 100% | 100% | 90% | 72% | 43% |

The first two years are for the initial manufacturing setup, so not much production is expected. The subsidy in 2024-25 and 2025-26 is 100%, and it is reduced by 10% in 2026-27. The subsidy is further reduced by 20% in 2027-28, making it effectively 72% of the original subsidy. The subsidy is again reduced by 40% in 2028-29, making it effectively 43% of the original subsidy.

## Challenges

From my analysis of the import data from 2021, **India imported less than 3GWh of Lithium-ion cells and battery packs in 2021**. This data excludes Lithium-ion cells that go for cell phone manufacturing since no player in the PLI for ACC scheme bid for manufacturing cell phone batteries. **Battery packs made with LFP prismatic cells accounted for close to 1GWh. NMC 18650 cylindrical cells accounted for close to 1GWh. The rest 1GWh imports were a mix of NMC 21700 cylindrical, NMC 26650 cylindrical, NMC pouch, NMC prismatic, LFP 26650 cylindrical, LFP 32650, LFP 32700, LFP pouch, LFP prismatic, LTO cylindrical and NMC battery packs.**

The 3GWh Indian market in 2021 should reach a minimum of 50GWh by 2029 for the scheme to work efficiently since incentives are related to the sales volume. The winners will have to strictly adhere to their production plans as described in their bidding document. Any deviation can lead to penalties.

Moreover, other companies will be manufacturing and selling their batteries in India by 2029, which will further expect the market demand to be higher than 50GWh by 2029. The author is aware of at least **three other companies planning to set up Lithium-ion cell manufacturing in India by 2029.**

The scheme did not encourage technology start-ups with the potential to raise funds in future to directly participate since there was an eligibility criterion of net worth. However, consortiums of multiple companies were encouraged. A company bidding must have a net worth of ₹225 Crores for every GWh they bid for. Since the minimum capacity was 5GWh, a company must have a minimum net worth of ₹1,125 Crores. A company having a net worth of more than ₹1,500 Crores could bid for any amount of GWh.

It was also difficult for companies working with start-ups with innovative technologies to participate in this scheme since there are various compliance certificates required from the technology companies. New start-ups do not always have such compliance certificates, and a lack of such certifications can lead to disqualification under this scheme.

## Opportunities

If PLI for ACC scheme is implemented well, it would mean one of the fastest industrial growths in the history of the battery industry, since presently, there is no mass manufacturing of advanced chemistry cells such as Lithium-ion batteries in India.

All the four winning companies are already active in the Indian market. They are focusing on manufacturing for captive consumption, and their products are well placed with a potential to grow multi-fold by 2029. PLI scheme also allows incentives on export sales.

**Rajesh Exports** is expected to manufacture batteries for heavy-duty EVs. They are likely to produce **LTO** cells.

**Hyundai** is expected to launch multiple models of electric cars in India in the coming years, including various budget-friendly EVs. **They are expected to bring LG Chem's NMC pouch cell technology to India.**

**Ola Electric's** 500-acre Futurefactory is expected to be one of the world's largest electric two-wheeler factories, with a capacity to manufacture 10 million EVs annually.

**Reliance New Energy Solar** needs no introduction. It is one of the fastest-growing companies in the solar space and is expected to add battery storage to its solar operations since solar with BESS is seeing an increasing trend across the globe. The company has acquired LFP battery technology company Lithium Werks and Sodium-ion battery company Faradion. **The LFP technology by Lithium Werks is market-ready.**

**About the author**

*Rahul Bollini is an independent R&D consultant in the field of Lithium-ion cells and batteries with 7 years of industry experience. The author can be reached at bollinienergy@gmail.com or +91 72049 57389*

EV OEMs **Ampere Electric Vehicles and Batt:RE** have come on board to use **Bounce's Battery Swapping Network** for their electric vehicles. Also, Bounce electric scooter Infinity E1 with a swappable battery system is expected to start deliveries soon.

**Hero Electric has partnered with Sun Mobility to deploy** electric two-wheelers **integrated with the latter's swappable battery technology**. The companies will jointly begin deployments in the next three months with a target of around 10,000 electric two-wheelers by the end of this year.

**Swapping solution provider Battery Smart has partnered with Tata Power-DDL** to set up Swapping Stations for electric 2 and 3-wheelers at various locations across North Delhi. The first swap station is live and operational at Azadpur, one of the busiest marketplaces in the capital.

**CNG seller Indraprastha Gas Limited (IGL) and Kinetic Green** have announced a strategic partnership to establish battery swapping stations for e2Ws and 3Ws. Their first **Battery Swapping station called "Energy Café" was launched in Delhi on 16th March 2022.**

**SKS CleanTech announced that Swappie has officially partnered with e3W maker Triyaan** as an exclusive swapping partner for PAN India launch of their swapping stations catering to First Mile and Last mile logistics players. SKS CleanTech aims to set up swapping infrastructure catering to 1000 EVs in the next 1 year. Triyaan's e-cargo vehicle has a payload capacity of 750+Kg and comes with a 6KW motor.

ENEOS HONDA Kawasaki SUZUKI YAMAHA

**In Japan, electric 2W OEMs have come together with energy company ENEOS to provide swapping services using standardised batteries for electric motorcycles.** Eneos holds 51% of the equity in the newly formed company Gachaco, followed by Honda (34%). Yamaha, Kawasaki Motors and Suzuki Motor hold 5% each. **The four OEMs have agreed to a common specification for a swappable electric 2W battery.** Gachaco plans to launch the sharing service in the autumn of 2022, commencing in Tokyo and other major Japanese cities, with **Honda Mobile Power Pack**, which meets the common specifications.

**Gogoro Inc.,** a global leader in battery swapping ecosystems, announced the **world's first solid-state lithium ceramic battery prototype for 2W battery swapping**. Jointly developed with solid-state battery technology company ProLogium Technology, this prototype integrates with Gogoro's existing vehicles and swapping network. Gogoro estimates that its solid-state batteries will increase the capacity of current lithium batteries by 140% or more, from 1.7 kWh to 2.5 kWh.

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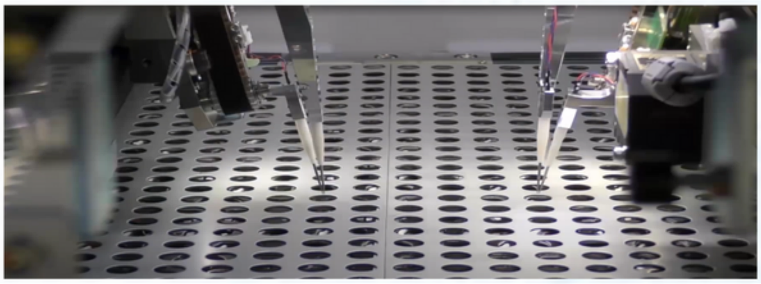
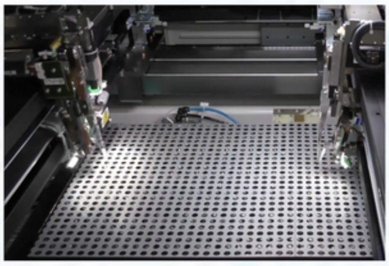
# Hi-speed Auto Test of Battery Module Terminal Welding

**Completely Automated Test Solution for LIB Module Terminal Welding Production Line of EV**

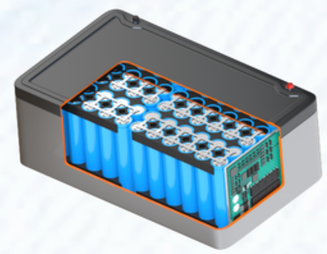
**Electric Vehicle (EV), Hybrid Electric Vehicle(HEV) Manufacturing, Production line**



Battery Pack Testing



Battery Pack



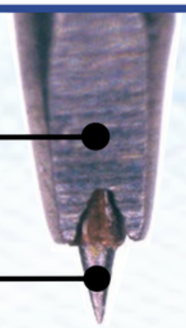
Module with Cylindrical Cells


**FA1240-60 Series**

**Test speed :** Maximum 2,400 points / min.
**High-Accuracy DCR meas. :** 4.000mΩ range (Std.) 10.00000mΩ range (SP)
**High-Resolution DCR meas. :** 1μΩ min. (Std.) 0.01μΩ min. (SP)
**Max. testable area :** 510 × 460 mm (Std.) 870 × 610 mm (Large)
**High-precision probing :** ±100μm (Std.) ±150μm (Large)
Contactable space min. □100μm, Completely Automated, Cell position shift & terminal Height Alignment feature, Contact check & moving retry feature.

## Unique Low Resistance Test Method

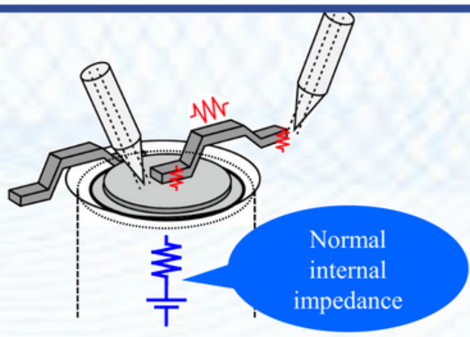
Current terminal



Voltage terminal

**Unique extra fine 4-wire probe achieves**

## Definitely detect out FAIL cell




**Quickly and efficiently detects out terminal connectivity FAIL cell in parallel circuit with same potential in block. Furthermore, it is also possible to measure internal impedance (AC-IR) by building inbattery tester.**

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# HOW MODEL-BASED DESIGN CAN HELP ACCELERATE BMS DEVELOPMENT

With the increase in software content in today's electric vehicles, companies are turning toward virtual vehicles to test their software as soon as possible. **Adopting Model-Based Design can be a game-changer for developing battery management systems, writes R Vijayalayan from MathWorks India.**

## Importance of BMS

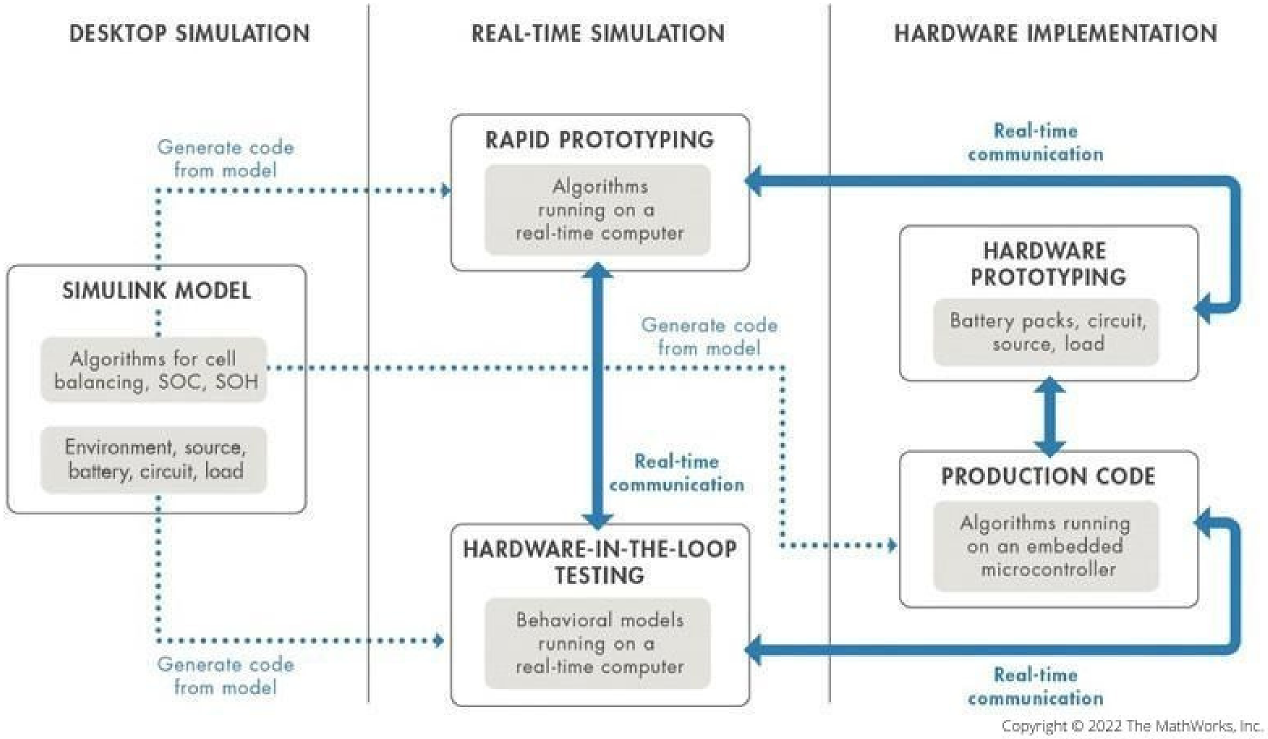
Lithium-ion battery packs are the predominant energy storage systems in aircraft, electric vehicles, portable devices, and other equipment requiring a reliable, high-energy-density, low-weight power source. The importance of battery management Systems in a Lithium-ion battery pack is much underscored by the dependence on batteries across industries. A good Battery Management System (BMS) is necessary to ensure maximum performance, optimal life, and safe operations under diverse charge-discharge and environmental conditions.

When designing a BMS, engineers develop feedback and supervisory control that:

- Monitors cell voltage and temperature
- Estimates state-of-charge and state-of-health
- Limits power input and output for thermal and overcharge protection
- Controls the charging profile
- Balances the state-of-charge of individual cells
- Isolates the battery pack from the load when necessary

**This article looks at how engineers could develop BMS algorithms by performing system-level simulation**.

With Model-Based Design, engineers can develop closed-loop battery models which can serve as a basis for all design and development activities through desktop simulation of the design's functional aspects, formal verification and validation to industry standards, and automatic code generation for real-time simulation and hardware implementation.




## 1. Using desktop simulation to verify functional aspects of BMS

Desktop simulations enable you to verify functional aspects of the BMS design, such as charge-discharge behaviour (using single-cell equivalent circuit formulation), electronic circuit design, and feedback and supervisory control algorithms. On the desktop, the battery system, environment, and algorithms are simulated using behavioural models. For example, you can explore active vs passive cell balancing configurations and algorithms to evaluate the suitability of each balancing approach for a given application. You can use desktop simulation to explore new design ideas and test multiple system architectures before committing to a hardware prototype. You can also perform requirements testing in desktop simulations, for example, by verifying that contactors are prevented from opening or closing when an isolation fault is detected.

## 2. Using real-time simulation for rapid prototyping

Once validated via simulation, these models can be used to generate C and HDL code for rapid prototyping (RP) or hardware-in-the-loop (HIL) testing to further validate the BMS algorithms in real-time. With RP, instead of handwriting control software code for real-time testing, you generate code from your controller model and deploy it to a real-time computer that performs the functions of the production microcontroller. With automatic code generation, algorithm changes made in the model can be tested on real-time hardware in hours rather than days. Further, you can interact with real-time control hardware to change algorithm parameters and log test data.

As with rapid prototyping, HIL testing involves generating code and deploying it to a real-time computer. In the case of HIL testing, code is generated from the battery system models rather than the control algorithm models, providing a virtual real-time environment that represents the battery pack, active and passive circuit elements, loads, charger, and other system components. This virtual environment lets you validate the functionality of the BMS controller in real-time before developing a hardware prototype and in an environment where hardware will not be damaged. Tests developed during desktop simulation can be carried over to HIL testing to ensure that requirements are met as the BMS design progresses.

### 3. Hardware implementation

Desktop simulation, RP, HIL, and PIL simulations all enable you to verify and validate the control algorithms for the BMS. Model-Based Design enables you to use those same algorithm models as the basis for generating production-ready code—either optimized and stable C/C++ code for implementation on microcontrollers or synthesizable HDL code for FPGA programming or ASIC implementation. If necessary, production code generation can be incorporated into workflows compliant with formal certification standards used in the automotive, aerospace, and other industries.

Automatic code generation eliminates manual algorithm translation errors and produces C/C++ and HDL code with numerical equivalence. By simulating your control algorithms over all possible operating and fault conditions, you increase confidence that the generated code will handle those same conditions in the real system, even if you are unable to test for all of them. If hardware tests later indicate that algorithm changes are needed, you can simply modify the algorithms in your model, rerun simulation test cases to verify the correctness of the changes, and generate new, updated code. All generated C/C++ and HDL code is fully portable, optimizable with a range of options, and bi-directionally traceable to the model.

### Summary

Model-Based Design enables engineers to gain insight into the dynamic behavior of the battery pack, explore more software architectures, test more operational cases, and begin hardware testing earlier with fewer design errors. Overall, Model-Based Design addresses the challenges caused due to growing software and system complexity in developing Battery Management System.

### About the author

*R Vijayalayan manages the automotive industry and control design vertical application engineering teams at MathWorks India. He specializes in the field of Industrial Automation, Robotics and Model-Based Design. He can be reached at vijayr@mathworks.com.*

**Reliance New Energy has acquired** LFP battery technology and manufacturing company **Lithium Werks for USD 61 Million**. Incorporated in 2017 through the acquisition of certain assets of Valence and A123 industrial division, Lithium Werks holds ~219 patents related to LFP process and technology. It has a 200 MWh annual production capacity, including coating, cell and custom module manufacturing capability.


**Ola Electric has made a multi-million-dollar investment in Israel based fast-charging battery company StoreDot**. Ola Electric will get access to the company's XFC battery technology which claims to charge a battery from 0 to 100% in 5 minutes. Ola will also have exclusive rights to manufacture batteries integrating StoreDot's fast charge technology in India. StoreDot says it is on track to mass-produce its silicon-dominant lithium-ion cells by 2024.

Bangalore based EV drivetrain design and manufacturing Startup **Physics Motors has raised Pre-Series A investment** from Florida based serial entrepreneur Dr Kiran C Patel in exchange for close to **30% stake.** Incorporated in 2019, Physics Motors has developed Indigenous Hub Motors and Mid Motors of various power specifications for 2W EVs. Their current product specification is 1.2KW Nominal to 2KW Nominal Hub Motor on 10 Inch Rim Platform.

Charging solutions company **EVRE raised a pre-series round** (amount undisclosed) led by Acko Technology & Services and CreedCap Asia Advisors. EVRE currently operates over 700 EV chargers across 50 charging hubs in 12 cities in India, said a company statement.

Climate Impact fund **EverSource Capital has invested in electric car operator Lithium Urban Technologies (Lithium) for a majority stake**. Lithium will be EverSource's core platform for providing B2B e-mobility solutions across passenger and freight segments. Lithium recently expanded its offerings to corporate clients providing large form factor buses and freight management solutions using a 100% electric fleet.

**Pi Beam Electric has raised $1.7 million in a Pre-Series A** round led by Inflection Point Ventures. The start-up is currently present in Bengaluru and Chennai and provides **EV as a service** platform for logistics and commute applications.

**Indian Renewable Energy Development Agency Ltd. (IREDA),** the largest lender of the Renewable Energy sector in India, has **sanctioned a loan of INR 267.7 crores to BluSmart Mobility** for the purchase of 3,000 electric cars.

EV financing platform **Revfin** has **raised Rs 100 crore in debt,** which it plans to use to expand into new geographies for financing 3Ws and make a foray into 2W loans for e-commerce delivery space. They are currently operational in Bihar, UP, Uttarakhand and Jharkhand, and plan to expand to Assam, Rajasthan, MP and Punjab.

**Exicom** announced that it has completed 5,000 charging installations across 200 cities. The installations are spread across 20 states with the majority at bus depots, fleet operators, public charging stations, residential communities and households. These EV chargers comprise of nearly 3600 AC Chargers and 1400 DC chargers.

# CHARGE+ZONE ELECTRIFIES 1000 KM OF NATIONAL HIGHWAYS IN INDIA

## Aims to electrify 10,000 kms of National and state highways in India by 2025


**EV Charging Network company CHARGE+ZONE has successfully electrified over 1000 km of National Highways in India, by setting up a network of 20 unmanned, app-driven EV charging points along the Gujarat-Maharashtra National Highway. The charging stations have been installed at key locations on highways connecting Mumbai, Nashik, Ahmedabad, Surat, Navsari and Rajkot.**

Through this, the company has cracked Dealer Owned Company Operated (DOCO) and Company Owned Company Operated (COCO) Models for Public Charging Network on the Highways.

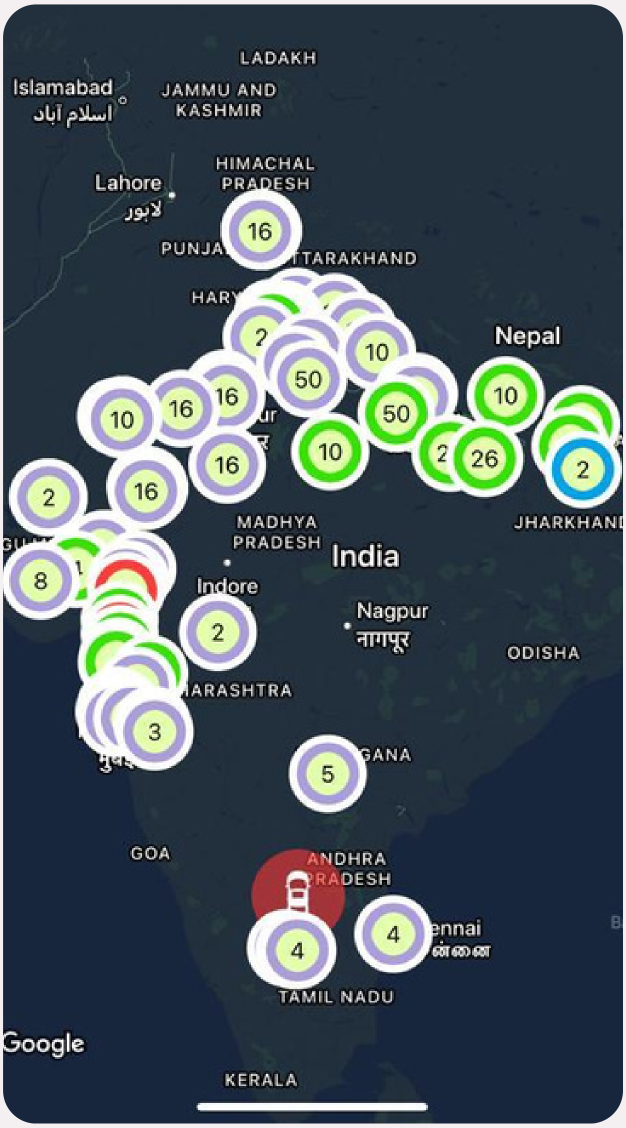
Designed for both personal and public e-mobility, these charging stations have been installed as part of the company's larger goal of electrifying 10,000 km of National and State Highways over the next 3 to 5 years. Deployed at convenient and strategic locations along the highway, **CHARGE+ZONE's charging stations are Rapid DC charging points with CCS2 as charging protocol, catering to electric four-wheelers. These stations can provide up to 80% charge in 45-60 minutes** and a full charge in 90-120 minutes, depending on the EV's battery size.

# Company Feature

*"We are immensely proud to have accomplished this milestone as part of our larger vision of building a robust network of* ***one million EV charging points by 2030.*** *Through our NH electrification program, we have implemented full stack EV charging solutions across multiple cities and states that are accessible, affordable and easy to use.* ***We want to bring about a paradigm shift in the way people perceive EVs by addressing issues of range anxiety and the availability of energy for long hauls****."*

**Kartikey Hariyani**
**Founder & CEO**
**CHARGE+ZONE**

## CHARGE+ZONE EV CHARGING NETWORK




- CHARGE+ZONE has created an active B2B and B2C network for EV charging stations for both fleet and retail customers by setting up **1250+ charging points across 650+ EV charging stations serving around 4000 EVs on a daily basis**.
- In December 2019, CHARGE+ZONE launched India's first Fast Charging Network for Electric Buses. Currently, **125+ Electric Buses of Ashok Leyland are getting charged daily with its 7 Fast Charging Hubs across 3 cities** for Intra-city Public Transportation.
- In December 2021, the company signed an MoU with the Government of Gujarat to install 10,000 charging stations along national and state highways within the state.
- To know more, please visit **www.chargezone.com** or email info@chargezone.com.

## About CHARGE+ZONE

CHARGE+ZONE is a leading tech-driven EV Charging infrastructure company specializing in B2B and B2C charging services for both dedicated and opportunity-based charging using smart-grid networks. CHARGE+ZONE is on a mission to establish one million charging points across important markets of EVs in India for cars, buses and even trucks.

# LITHIUM CHEMICALS CONTINUE TO RISE | NICKEL LEVELS AFTER A MAD RUSH

The market prices for LIB raw materials are soaring. The ongoing Russia Ukraine conflict triggered tensions about Nickel availability that led to chaos at London Metal Exchange. **Manish Dua, Principal consultant at Benchmark Mineral Intelligence,** takes stock of the situation.

## What are the current market price trends for key LIB raw materials?

The 2022 market prices for LIB raw materials are soaring steeply, similar to 2021. There has been a **push toward LFP in China,** with cathode makers rushing in to buy whatever Lithium Carbonate material has been available in the spot market at outrageous prices over the last few months. **Lithium Carbonate** prices have more than doubled over February and March 2022, with transactions recorded at around **$70,000 to $73,000 per ton at spot levels, forcing most** buyers to buy the material at steep prices.

The Nickel price rally in March this year is a very recent story that many stakeholders in the industry have hooked on to. Lithium chemicals - Carbonate and Hydroxide have been in the limelight for much longer as the prices have doubled compared to Oct-Nov levels.

## What's your analysis of this price rally?

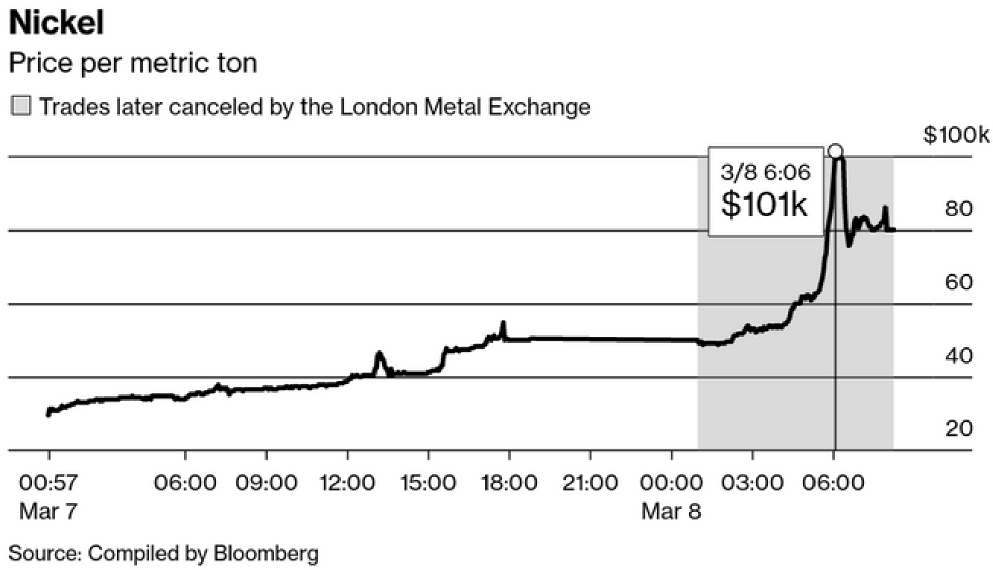
The prices I mentioned are spot prices. In the near term, the material is in shortage, and whoever can get their hands on any sort of Lithium materials will grab it even for the price levels of $70,000, especially the Chinese buyers.

From a long term point of view, the prices will be significantly lower compared to spot levels, with most of the volumes sold into the Asian market through medium and long-term contracts. As far as the market structure goes, more than **85% of tonnages are sold on a medium to long-term contract basis,** whereas 10-15% are sold at spot levels. However, these spot prices will ultimately transition into contract prices, albeit partially.

## What made the LME suspend Nickel trading in March 2022?

On morning of **March 8th 2022**, the Nickel market finally broke and the problems started spreading to other metal markets too.

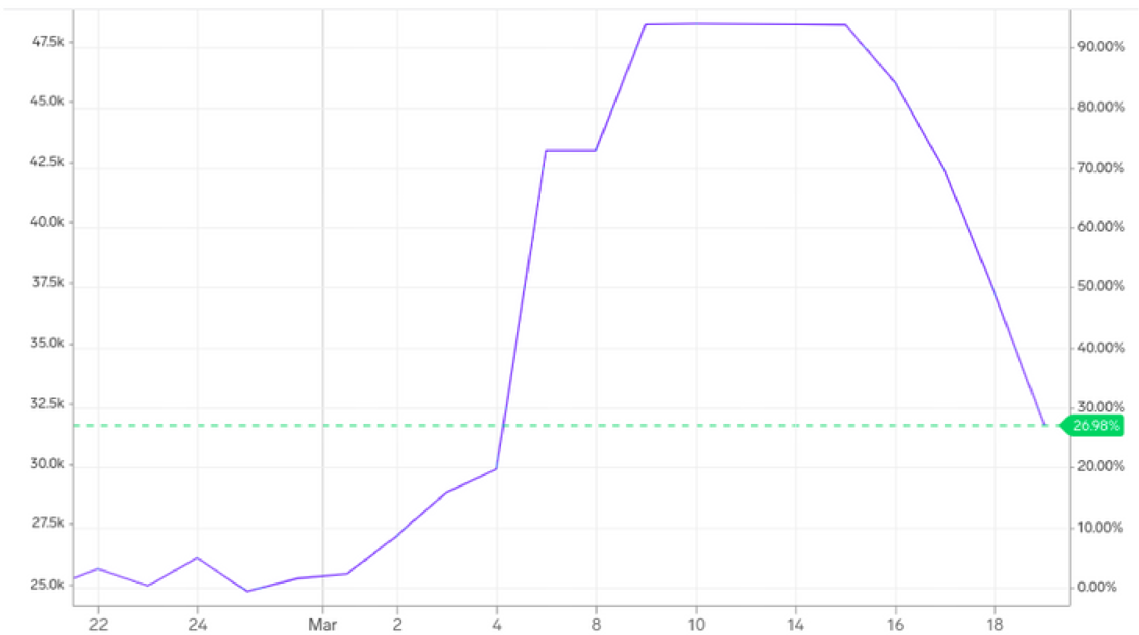
Nickel price typically moves a few hundred USD per day and typically traded between $15,000 to $25,000 in the past year. Yet the day before the market started to go wild, the prices soared to almost $48,000. On March 8th morning in London, the market price more than doubled, trading at **$100,000 a ton as China's Tsingshan Holding Group, one of the world's top producers of Nickel, bought large amounts to reduce its short bets on the metal.**




Nickel's 250% price hike on March 8th led the London Metal Exchange (LME) to suspend trading. The LME also decided to cancel all the Nickel trades that had happened on March 8th. **According to Bloomberg calculations, trades worth nearly $4 billion were cancelled in the interest of the market as a whole.**

On March 16th Wednesday, LME attempted to resume Nickel trading. It imposed a 5% upper or lower circuit limit per day, but a 'system error' occurred at the LME back-end, and the glitch allowed a small number of trades to go below the 5% limit, and the exchange was temporarily halted again.

The LME then updated the trading range for 17th and 18th March with an 8% and 12% circuit limit per day. When trading began, both the sessions saw a price hit to the lower level with $42,150 and $37,115, respectively. On March 21st, the price fell again to $31,580.




Source: Market Insider

The LME has deliberately imposed circuit limits to prioritize stability in the market by setting a relatively narrow range of daily trading limits. These **limits have been widened to 15% for Nickel and other base metals.**

The market is now controlled by fear, not supply and demand. **The sanctions imposed due to geopolitical tensions for Russia's Class1 Nickel export spooked all the market participants**. So that was one of the reasons, but having a lot of speculations and the short squeeze happened in which people on one side of the trade went to the other side to hedge their losses, which also led to a significant price hike.

The price of Nickel matters to the global economy; it is an important metal in the automobile industry, mostly used in making stainless steel, alloys, magnets and rechargeable Li-Ion batteries for EVs.

## What is Russia's role in the global Nickel supply?

Nickel Market price spike at LME was a major move in metal prices since Russia's invasion of Ukraine. Russia is the world's third-largest producer of Nickel, producing about **10% of the global Nickel mined**. Importantly, Russia produces **refined Nickel or Class 1 Nickel (99.8% pure), which is accepted at the LME.** About half of the world's Nickel is less refined or Class 2 metal in the form of Ferronickel and Nickel pig iron. Nickel sulfide deposits are ideal for Class 1 Nickel, and **Russia holds close to a third of the world's Nickel sulfide ore**. The targeted sanctions from the U.S. and European buyers for Russia's Nickel exports impacted the price of Class 1 Nickel traded at the LME.

Nickel Market price hike at LME was the first major market failure since Russia's invasion of Ukraine. It showed how removing one of the world's largest producers of an important commodity from the financial system could lead to chaos in global markets.

## What would be your assessment concerning the current trend in increasing prices for Lithium Carbonate and Nickel? How expensive will an electric vehicle battery be as a result?

If one is looking for Lithium Carbonate or Lithium Hydroxide at spot level prices, numbers would be around $65,000 to $70,000 at the highest levels. Considering these prices, the LFP cathode would be more expensive than the NCM variant. Lithium Carbonate prices have risen significantly, making the cell prices at spot levels 20% to 30% more expensive than NCM.

But if you are a producer of Cathode and you are buying Lithium chemicals on medium or long-term contracts basis wherein the price is locked at significantly lower levels, you are definitely on the cheaper side. In this case, LFP will be cheaper than NMC.

**Exide Industries** entered into a long-term technical collaboration agreement with **SVOLT Energy Technology (China)**. SVOLT will grant Exide an irrevocable right and license to use and commercialise its technology for lithium-ion cell manufacturing in India. Exide is forming a Special Purpose Vehicle by way of a wholly-owned subsidiary for carrying out lithium-ion cell manufacturing business. It is in a fairly advanced stage of discussions for finalising the land parcel for this facility. The company plans to set up a multi-gigawatt facility to manufacture two cell chemistries and three cell formats.

**Gulf Oil India** and **TechPerspect Software (ElectriFee)** have entered into a strategic partnership to provide EV charging solutions for electric 2Ws, 3Ws and 4Ws leveraging their strengths. This is the second move by Gulf Oil in the e-mobility space after making an investment in the **UK based EV charger manufacturer INDRA Renewable Technologies in 2021.**

**Ather Energy** has partnered with **Bharat FIH, a Foxconn Technology Group company**, to develop and manufacture key components for Ather scooters. Bharat FIH will offer manufacturing services for PCB assemblies for battery management systems, dashboard assembly, peripheral controlling units and drive control modules.

Delhi based **TSUYO MANUFACTURING** recently joined hands with China's Ningde Contemporary Electric Technology Co., Ltd (**CETL**) to develop electric powertrains for the Indian market. The products will be jointly developed and manufactured in TSUYO's **Greater Noida manufacturing plant.** TSUYO is looking to invest USD 8 Million in R&D and approximately USD 50 Million in the coming 6 years to manufacture electric powertrains for the Indian conditions.

Visitor and Society management app **NoBroker** and EV charging solution provider **ElectricPe** have partnered to set up 100,000 electric **charging points in residential communities** in 2022. Through the NoBrokerHood app, vehicle owners will be able to scan and pay their bills instantaneously or have the payment added to their electricity bill. Residents will be able to see available EV charging options within the ElectricPe app, book slots to charge their EVs, and pay. Residents will also have the opportunity to request a charging station to be set up in their private parking lots after their RWA's approval.

**Omega Seiki Mobility** has signed an agreement with Nepal's **MAW Vriddhi Commercial Vehicle** to retail its range of Rage Plus electric 3Ws in Nepal.

**Honda and Sony sign MoU for a strategic alliance in mobility**. The MoU outlines their intent to establish a joint venture company in 2022, through which they plan to engage in the development and sales of high value-added EVs, alongside providing mobility services. **Sales of the first EV model from the new company are expected to start in 2025**.

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INNOVATIONS

# RELIABLE AND COST-EFFECTIVE ELECTRIC MOTORS

EMF Innovations Pvt Ltd (EMFi) is a technology provider specialising in the design and manufacture of electric motors & controllers for green mobility and other applications based on customers' technical specifications. EMFi is headquartered in Singapore with substantial R&D and manufacturing operations in India.

## Our Products

### ELECTRIC MOTORS

We design and produce BLDC Hub and Inner Rotor Motors, Switched Reluctance Motors (SRMs) and Permanent Magnet Synchronous Motors (PMSMs) for 2-wheelers, 3-wheelers, and various other applications.

Our motors come in various sizes, output powers, and IP ratings. They come in rim-mounted and spoke-mounted models.

We also customise our motors according to your needs. We have designed motors for applications such as boats and heavy vehicles.

### MOTOR CONTROLLERS

Electric motors must be paired with the best controllers. We design custom controllers for electric motors which optimise their performance. Our locally produced controllers outperform imported, off-the-shelf controllers.

**Our Manufacturing Address**

*Manufacturing Site 2/209, Rajiv Gandhi Nagar, Mylampatti Village, Neelambur, Coimbatore—641062*


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Call us at

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or email us at

**sales@emf-i.com**


Commercial electric vehicle maker **EKA (a subsidiary of Pinnacle Industries) unveiled its first e-bus, E9**. EKA E9 is powered by a 200 KW electric motor, offers 17 per cent gradeability and comes with a regenerative braking system.

EKA has also partnered with Log9 Materials to use their **InstaCharge RapidX battery packs,** which can be fully charged within 30 minutes.

**MG India** launched **ZS EV 2022** model which offers a **461 km certified range** with its 50.3kWh battery. It is equipped with a new motor that delivers the power of 176PS and accelerates from 0 to 100 in 8.5 seconds.

The new model will be available in 2 variants (Excite & Exclusive), priced INR 21,99,800 and 25,88,000, respectively. While the bookings for Exclusive have started, bookings for Excite will begin from July 2022.

Bengaluru based **Oben Electric** unveiled its first electric motorcycle **Rorr.** It can go up to 200 km on a single charge and has a top speed of 100 km/hr. It can go from 0 to 40 kmph in 3 seconds and can be fully charged in 2 hours. The bike starts at INR 99,999 (ex-showroom price Maharashtra), post state and Fame II subsidy. Comes with a 3-year battery and motor warranty and free roadside assistance up to a range of 60,000 km. Bookings are open at INR 999, and the test drives will start from May 2022.

**Okinawa Autotech** launched the **OKHI-90** electric scooter. The scooter is powered by a centrally mounted 3800-watt motor and can accelerate from 0 to 90 kmph in 10 seconds. In Eco mode, the rider can reach speeds of up to 55-60 km/h, and in Sports mode, up to 85-90 km/h. Powered by a removable 72V 50 AH lithium-ion battery, OKHI-90 can go up to **160 km** on a single charge. The scooter is priced at **INR 1,21,866** post FAME II Subsidy.

**Crayon Motors launched its second low-speed Electric scooter - Envy.** The scooter has a top speed of 25 kmph and a 250-Watt BLDC motor. Envy comes in different variants with a range of up to 160 km per charge. The scooter starts at Rs. 64,000/- and comes in four colours white, black, blue, and silver.

# TRANSITION TO ELECTRIC VEHICLES | IMPACT ON THE AUTOMOTIVE ECOSYSTEM - CHAPTER 1

The transformation of automobiles from ICE to EV powertrains will have a long-lasting impact on the automotive ecosystem. In this first article of the series, **Dr Maruti Khare (Head EV and Special Projects at SKF India) outlines the aspects of the automotive ecosystem that are going to feel the impact of this global transition.**

## Automotive Ecosystem – ICE and EV Macro View

It is largely regarded that year 1886 as the birth year of the automobile when German inventor Carl Benz patented his invention "Benz Patent-Motorwagen", which was running on its own power source – An internal combustion engine. Automobiles became popular as personal transport vehicles and started becoming widely available in the early 20th century. In North America, one of the first cars available as an affordable private transport option for the masses was the 1908 Model T, an American car manufactured by the Ford Motor Company. The first automobile ran on Indian road around 1897, even though it was imported. Indian automotive industry emerged in the 1940s, and Hindustan Motors launched its first Ambassador car in 1942, long-time competitor Premier in 1944, building Chrysler, Dodge, and Fiat products, respectively. Post this, players like Maruti Suzuki, Mahindra, Tata, Hyundai, and many others joined the industry

The first practical electric vehicle was born in 1870 and ran on the road around the same time as the IC engine vehicle. Hybrid vehicles got ready around the year 1900, which were wheel hub motor driven. IC engine-powered vehicles surpassed electric vehicles due to their many advantages, and electric vehicles almost got to the cold shell. However, beginning the 21st Century, interest in electric and alternative fuel vehicles in passenger vehicles increased due to growing concern over the problems associated with hydrocarbon-fueled vehicles, concerning damage to the environment due to emissions; the sustainability of the current hydrocarbon-based transportation infrastructure; and improvements in electric vehicle technology. Elon Musk promoted Tesla Motors made big waves about electric vehicles, and with the launch of Model 3, it became the talk of the industry. Presently, almost all the major OEMs across the globe have announced plans to build EVs and phase out ICE vehicles.

## Evolution of automotive ecosystem

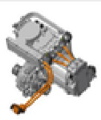
It is close to a century and a half since the world has experienced the evolution of automobiles from basic performance to modern vehicles. Significant progress has been made in developing the automotive ecosystem, right from vehicle manufacturing, supply chain management, and customer experience [pre-and post-sales] by automotive players. OEMs have developed their authorized vehicle sales and services network. The OEM developed network is working well for sales and service to the extent of the warranty period of vehicles [based on Indian market experience]. The vehicle owners, for multiple reasons, also like to consider a parallel service network for the vehicles. Parallel to the OEM network, the extended automotive ecosystem also started developing considering the convenience, affordability as well as availability of more personalized services for the vehicle. The parallel ecosystem became equally popular over time, and this network expanded and contributed to automobile market development and growth. At present, the ICE powertrain parallel ecosystem is also equally strong and competent.

**With EV transformation, this ecosystem will feel a considerable impact. A significant section of this ecosystem needs to be rebuilt, re-skilled, and enhanced to tackle future requirements of electric vehicles.**

## Changes impacting automobile ecosystem - ICE vs EV

ICE-powered vehicles and EVs have fundamental differences in how they convert energy into usable mechanical energy. In the case of the ICE, the base fuel is available in the form of chemical energy, which is converted into thermal energy and then to mechanical energy. In the case of an electric vehicle, the electric energy is stored in battery [chemical] form, which is used for driving the motor. In both the powertrains, available energy is finite. However, re-fueling [recharging] takes time and needs different sources. In this section, let's understand important considerations which are likely to impact the ecosystem.

## Performance / reliability

| Parameters |  |  |
|---|---|---|
| Performance / Reliability (TCO) | Lower | Higher |
| Parts count | Higher | Lower |
| Technology Maturity | Higher | Lower |
| Supply Chain Availability | Full Developed – Locally | Evolving |
| Broad Prices Parity | - | ++ |

An internal combustion engine is a complex machine in which a huge number of parts need to work in coordination to produce the power at the required efficiency. In the engine, parts have relative motions and are subject to wear-tear, damage, and deterioration of performance over time. Therefore, regular servicing and upkeep are required. ICE has lower efficiency and reliability, so the total cost of ownership is higher.

In the case of the electric powertrain, motors are efficient and have fewer components rotating relative to each other. Hence, the reliability as well as maintenance requirements of vehicles, are lower compared to the ICE vehicle.

A survey published by Bloomberg (in March 2022) on 48,000 people representing 57,000 cars, including 2,184 EVs, suggests the opposite of the conventional belief that EVs will be more reliable than ICE. 31% of EVs reported issues within four years of service, compared with 19% petrol vehicles and 29% diesel vehicles. Faulty EVs spent an average of five days off the road compared with just three and four days for petrol and diesel cars, respectively. **However, the most common faults raised by EV drivers were software problems rather than issues with the motor or battery.**

EV will impact the service ecosystem both at the OEM end and the external network. The service centres need to be more equipped to handle issues related to electronics, batteries as well as software which make significantly lower instances in ICE cars. This means the ecosystem needs modern, sophisticated equipment and a highly-skilled workforce. It will also impact the supply chain and handling of the customers. The business of conventional spare parts is likely to go down, and expenses to run the service stations will be more expensive going forward.

## Parts count

As mentioned earlier, the number of components is less in the case of EVs compared to ICE vehicles. This reduction has a direct impact on supply chain partners and their offerings. EVs are getting more and more popular; suppliers solely offering engine parts need to diversify their product portfolios. Even though the parts count is shrinking, electrical and electronic parts are increasing in the case of EVs. This will create opportunities for new supply chain partners and new service opportunities.

## Supply chain

The EV supply chain is constrained in many ways. In the case of critical systems like batteries, cells and power electronics components, there is industry dependence on a few players. This is an opportunity as well as a challenge. The opportunity is for new players to enter, and the challenge is for the existing players to diversify. For EVs, parallel ecosystem building and expansion will be constrained in the short to medium term.

## Vehicle penetration

The automobile ecosystem is expanded based on the population of vehicles in different life stages. As the population of ICE vehicles is large, the ecosystem is well balanced to serve it. However, the electric vehicle population will take some time to build numbers so it makes business sense to have a parallel ecosystem. Currently, it is a catch 22 situation where EV penetration is influencing initial investment, infrastructure, etc. As EV penetration increases, it will complement the ecosystem.

*In CHAPTER 2 (May 2022 magazine), we will discuss the micro view and system-level impact of EV transformation on the automotive ecosystem.*

## ABOUT CHARGE+ZONE

CHARGE+ZONE is building Electric Vehicle Charging Service Infrastructure globally integrated with its indigenously developed IoT based Charging Station Management System (CSMS) & Mobile Application. The company was incorporated in July 2018 and has made strides by installing more than 750+ charging points across India as of March 2021.

CHARGE+ZONE™
AN EV CHARGING COMPANY

## SPECIFICATION

### Video Wall, 7.7kW AC Type 2 Dual Gun Charger

- **Input:** 415V AC 3 Phase, 32A Max., 50 Hz
- **Number Outputs / Guns:** 2 Each Output connector rating : 240V AC, 32AMx, 50 Hz
- **Output Power:** 7.7 KW x 2
- **Output connector type:** IEC62196 - 2 Type 2 Plug , 5m cable
- **Protection:** Over Voltage , UnderVoltage , Over Current , Residual Current , Short Circuit , Over Temperature , Ground Fault , Surge Protection
- **Push Buttons:** Emergency Stop
- **Ambient Temp.:** -25°C to +45°C
- **Humidity:** <95%, Non condensing
- **Altitude:** Up to 2,000m
- **User Interface:** Vertical 55" HD Display , status indicators ,
- **User authentication:** QR code / RFID / OTP
- **Communication:** OCPP 1.6J Forced Cooling , Floor Mounting
- **Complies to:** IEC61851-1, IEC61851-21-2
- **Installation:** Semi Outdoor
- **Communication Interface:** Ethernet / Wi-Fi / GSM
- **Mechanical:** 850x2250x300MM (Appx)
- **Ingress protection:** IP54


## SPECIFICATION

### 8" Screen, 7.7kW AC Type 2 Dual Gun Charger

- **Input:** 415V AC 3 Phase, 32A Max., Number of Outputs :2
- **Each Output connector rating:** 240V AC, 32A Max,50 Hz
- **Output Power:** 7.2 KW x 2
- **Output connector type:** IEC 62196-2 Type 2 Plug, 5m cable
- **Protection:** Over Voltage, Under Voltage, Over Current Residual Current, Short Circuit, Over Temperature, Ground
- **Fault Push Buttons**: Emergency Stop
- **Ambient Temp.:** -25°C to +55°C
- **Humidity :** <95%, Non-condensing
- **Altitude :** Upto 2,000 m
- **User Interface:** 8" LCD screen, status indicators, user authentication by QR code/ RFID/ OTP
- **Communication:** OCPP 1.6J Natural Cooling, Floor Mounting
- **Complies to:** IEC61851-1, IEC61851-21-2
- **Communication Interface:** Ethernet/WiFi/ GSM
- **Mechanical:** 350W x 300D x 1525H (**all Dimensions are in MM)
- **Ingress protection:** IP54 50 Hz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# SOLID STATE BATTERIES - KEY PERFORMANCE INDICATORS VS LIB

The evolution of volumetric and gravimetric energy densities of Lithium-ion Batteries (as shown in Figure 1) indicates peak values of up to 770 Wh/litre and 260 Wh/kg, respectively. There is an ever-increasing demand for batteries with even higher energy density and high power density to enable quick charging and discharging capability. Solid-state batteries (SSBs) that use solid electrolytes instead of liquid ones could offer both high energy and high-power density.

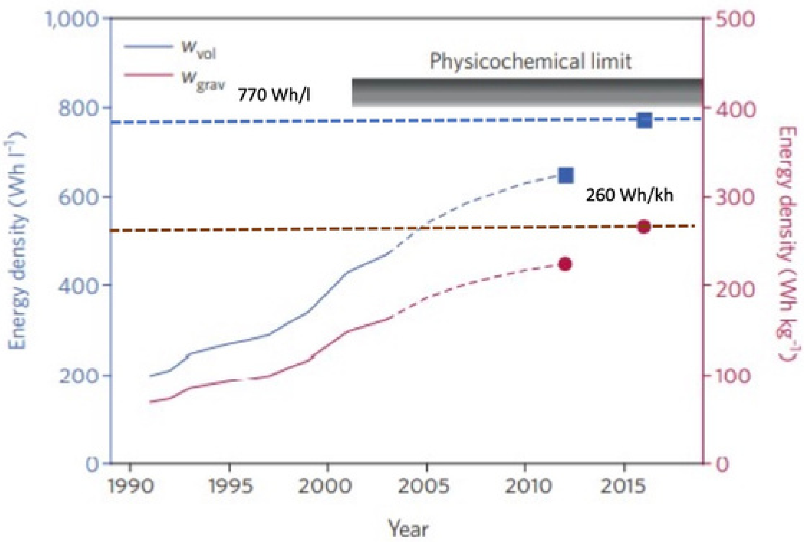


Figure 1. Evolution of Energy Densities of Lithium-ion Batteries over 3 decades with data presented for standard cylindrical 18650 LIB cells with a volume of approx. 16 cm3 and a mass of 48 g (Ref [1])

**For the successful design, manufacture, and launch of SSBs, many challenges remain in both technological maturity and manufacturing readiness, including:**

- what benefits in volumetric & gravimetric energy densities can be achieved using SSBs
- what type of Solid Electrolytes (SEs) can be used in SSBs
- what are the different materials and compositions of solid electrodes that can be used
- what are the potential solutions for the inherent mechanical stability issues of SSBs
- how do we ensure the safety of SSBs for mobility and energy storage industries

## Key performance indicators (KPIs) for SSBs

For SSBs to be serious contenders to LIBs, which are continuing to improve in performance with further reduction in cost/kWh, they need to show a significant performance jump in one or more of the key properties such as energy density, power density, long-term stability, safety, and cost. Though energy density is the top priority for SSBs to compete with LIBs, power density is also important for quick charging. Long-term stability is important in terms of both long cycle and calendar life as the volume changes of the electrodes during cycling of the SSB cause mechanical strain and stability problems, directly impacting the lifetime of batteries in terms of the number of discharge/charge cycles and time after production (calendar life). Safety is another important performance indicator for SSBs. Finally, the cost per kWh of energy storage capacity, highly dependent on production technology, is also important for SSBs to compete with LIBs (Ref [2]).

### a) KPI - Energy Density

In Figure 2, the architectures for Li-ion battery or LIB (middle), Li-metal based SSB (left), and Li-ion based SSB (right) are presented. As we move from LIB in the middle towards LiM-SSB on the left, the volumetric and gravimetric energy densities (Wvol and Wgrav) increase by 70% and 40%, respectively. Similarly, as we move from LIB in the middle towards Li-SSB on the right, Wvol and Wgrav, change by 0% and -10%, respectively.

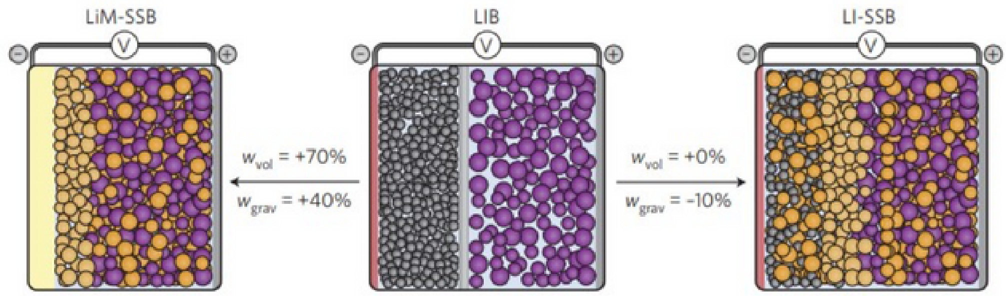


Figure 2. Typical battery architectures for LIB (middle), LiM-SSB (left) & Li-SSB (right) (Ref [1])

If only the liquid electrolyte of an LIB is replaced by a SE (Figure 2, right), there is 0% change in Wvol. As Solid Electrolytes have a higher density than liquid electrolytes, there is about a 10% reduction in Wgrav. By using cathode materials of high-capacity or materials that can withstand 5V redox potential and increasing the cell voltage from 4.2 V to 5 V, up to 20% increase in energy density can be achieved in SSB cells.

### b) KPI – Power Density

Power density is a measure of how quickly batteries can deliver stored energy, how well they can handle high currents during faster charging or discharging, what impedance values result in cells, and what levels of material degradation and heat release occur in electrodes.

With higher thermal conductivities and better thermal dissipation in solids compared to liquids, hot spots can be prevented in SSBs. An important design criterion in SSBs with highly conductive SEs is the cell kinetics at the solid electrode -- solid electrolyte interface (SESEI), which in turn depends on the cell manufacturing process and quality. The study of cell kinetics at SESEI in SSBs is still preliminary and evolving. As bulk polarization is not possible in SEs, unlike in liquid electrolytes, SSBs allow higher current densities and higher operating temperatures. However, issues may still arise at the solid electrolyte/cathode interface due to the formation of lithium depletion layers in the SE, blocking cell kinetics in one direction at high potentials (similar to a diode), thus requiring additional interface protection. Research is still ongoing on fast cell kinetics at anode-SE-cathode interfaces with favourable design expectations to leverage the key advantages of SSBs.

### c) KPI – Cyclability & Long-Term Stability

Though the long-term stability of SSBs is one of the major incentives for their development, significant research is still being carried out to better understand their electrochemical window (measured using cyclic voltammetry, Ref [2]) and the relatively small thermodynamic range of stability.

As SEs typically use sulphides and thiophosphates, they react with lithium metal upon contact and form an interphase. The long-term operation and cyclability of SSB is assured if a highly conductive solid electrolyte interphase (SEI) is formed. Typically, mixed/average conductivity of SEI leads to fast deterioration of SSB. Interfacial instabilities may also occur on the cathode leading to degradation in SSBs, similar to LIBs. Though coating of cathode provides long-term stability allowing high-voltage operation and facilitating high-energy cells, the stability of the interphases remains challenging. Unlike LIBs, SSBs with SEs prevent unwanted electrode 'cross-talk', but still the extraneous outputs from side reactions form at SEI, impacting cell kinetics and cyclability. More research is being carried out to better understand the kinetic instability of lithium anode itself due to the pore formation during discharge and the dendrite formation during charge to improve long-term stability of SSBs.

### d) KPI – Safety

The safety of SSBs would be assured if only oxide ceramic components, which are inherently stable against lithium, were used. However, as the best-suited ionic conductors are sulphides, the formation of toxic H2S in case of battery damage or the formation of SO2 by oxidation of the solid electrolyte may present a potential risk (Ref [2]). Recently, garnet-type crystal LLZO has attracted much attention as a crystalline SE because of its high conductivity of 3 × 10−4 S/cm and high chemical stability against lithium negative electrodes (Ref [2]). However, oxide SEs are not as mechanically soft and lead to short-circuits and mechanical failure as dendrites may enter into polycrystalline solids along grain boundaries. Sophisticated protection techniques may be required, which complicates production and increases costs.

### e) KPI – Architecture and Manufacturing of SSB

Over the past decade, costs of LIBs have been dropping significantly with the recent cost per kWh around $145, with a further drop in cost expected to reach $100/kWh in the next few years. No reliable cost estimate for SSB production is available yet. Approximately $30/kg material and manufacturing costs at the cell level are projected for the cost of $100/kWh in LIBs (Ref [3]). For SSBs to match the cost of LIBs with the same material cost, they will have little room because of complex materials processing in SSBs.

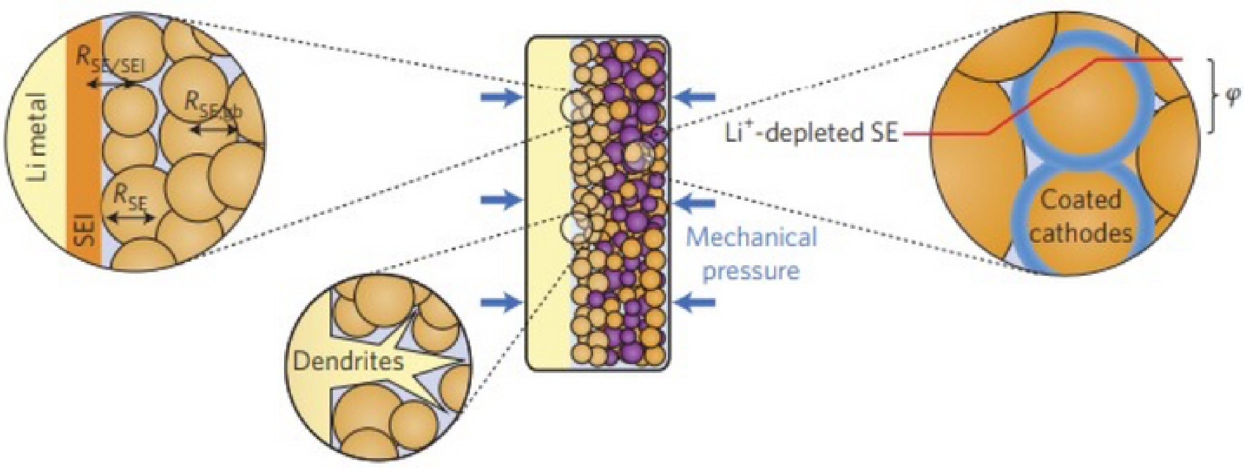


Figure 3. Architecture & Major challenges in developing solid-state batteries (Ref [1])

Figure 3 shows a schematic architecture of a single cell in an SSB. Owing to its high specific capacity, using a lithium metal anode can significantly increase the cell energy density. However, significant challenges exist in developing SSBs, such as (i) a resistive SEI may form between the lithium anode and the SE, (ii) resistance formation between the grains and grain boundaries of the SE, (iii) risk of short-circuiting from dendrite formation due to highly inhomogeneous lithium metal deposition.

Coating and protection of electrode active materials is required as most SEs react with cathode active materials. Coating also helps prevent potential Li depletion at the cathode (space charge with rectifying effect). The red curve in Figure 3 (Ref [1]) indicates the drop of the electric potential φ across the space charge schematically. While the use of liquid electrolytes ensures good electrode contact and efficient ionic pathways, a solid electrolyte will typically have a microstructure consisting of small grains that must be in good contact with the electrode material and other electrolyte grains. In SSBs, solid composite electrodes must be formed to ensure sufficient electronic and ionic percolation and establish an independent network of electronically conducting particles. As intercalation electrodes are known to exhibit volume changes, the mechanical integrity of the solid composite is a critical issue. The blue arrows in Figure 3 (Ref [1]) indicate that mechanical pressure is required both to avoid contact loss due to local volume changes upon lithiation/de-lithiation and to achieve high power density. The electrode can 'breathe' and cycle reversibly in a liquid electrolyte. The challenges in solid electrolyte/electrode include increased interfacial resistance, over-voltage, and capacity fading as pores can form, cracking, and loss of particle contact may occur in solids. It is helpful to use mechanically soft ionic conductors such as sulphide and thiophosphate glass SEs in SSBs.

The manufacture of conventional LIBs involves separate lines of manufacture for anodes and cathodes coated onto foil current collectors, which are then integrated with a polymer separator, followed by various packaging operations, including injection of the liquid electrolyte. The serial production of LIBs results in high productivity though it involves many steps.

So far, manufacturing SSBs has followed a similar approach of discrete manufacturing processes for the anode, cathode, and electrolyte; however, the electrolyte tends to be formed first, and the positive electrode (a powder-based composite of the active cathode material, carbon, and the solid electrolyte) and the Li-metal negative electrode (anode) are then added in separate operations. As the SE requires mechanical mixing and the particle contacts are extremely sensitive to mechanical effects, **SSBs will require a revolutionary change of production technology.** The electrolyte, usually either an oxide (e.g. LLZO or a sulphide like $Li_6PS_5Cl$), is generally required to be largely pore-free to maximise ionic conductivity. Sulphides offer a manufacturing advantage because they can be pressed to a high density at room temperature. In contrast, oxides tend to require relatively high process temperatures (up to 1000 ∘ C or higher) and pressures (up to 500 MPa) for several hours of sintering for useful density and ionic conductivity. When the oxide electrolyte is mixed with carbon and active material and consolidated to form a positive electrode, these high pressing temperatures tend to lead to excessive reactions and burn out of the carbon. Both oxides and sulphides exhibit sensitivity to water vapour, with LLZO forming unhelpful but benign $Li_2CO_3$ whereas sulphides generate toxic $H_2S$ gas. Particularly for sulphide based SSBs, manufacturing must be done in a dry room or under inert atmosphere.

## Conclusion

Significant progress has been made on SSBs over the last few years, building upon past few decades of research on LIBs. However, the understanding of interfacial reactions and cell architecture and performance are still at an early stage. SSB development may be prompted by superior kinetics when using intercalation anodes.

**Three main points can be pointed out from SSB development to date:**

- **Optimization of poor interfacial kinetics between solid electrolyte and active materials requires more investigation**
- **Mechanical pressure is required to guarantee stable operation of a solid-state cell with additional modelling and quantitative studies**
- **LiM-SSB achieves significant improvement in energy density using Li-metal anode.**

Sulphide electrolytes have several advantages: high conductivity, single Li+ ion conduction, wide electrochemical window, and intimate solid/solid contact. An advantage of SSBs is the possible use of active materials with large capacities, such as sulphur and lithium metal, which are not available in conventional LIBs using liquid electrolytes. As solid electrolytes allow high current densities without concentration polarization, high power densities may be achieved in SSBs with intercalation anode and cathode.

## Future work

Future research should focus on further increase of Li+ ion conductivity and chemical stability of sulphide electrolytes and the formation of electrode/electrolyte interface achieving rapid charge transfer. For the success of SSBs, it is also essential to have control of size, morphology, and dispersibility of both SE and active material properties for better cell kinetics at SEI. For further increase in energy density and power density of SSBs, researchers should focus on how to increase the amounts of active materials in the composite electrode layer.

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## About the author

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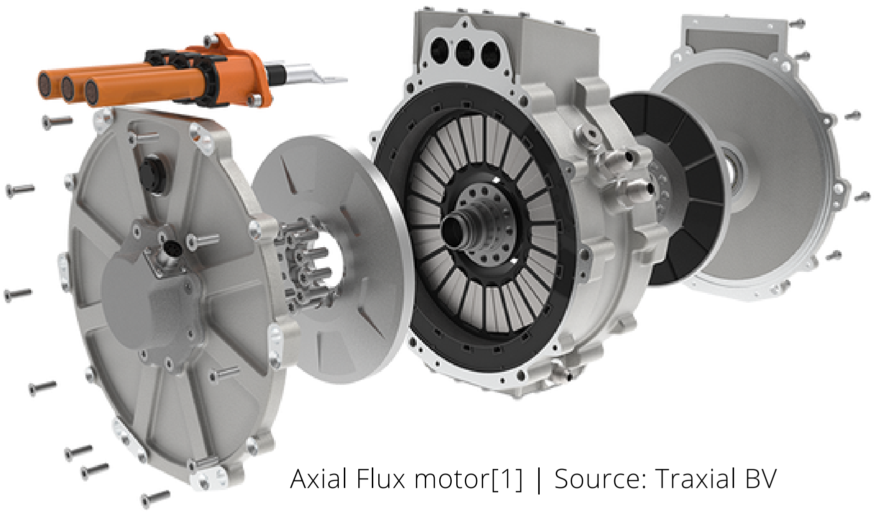
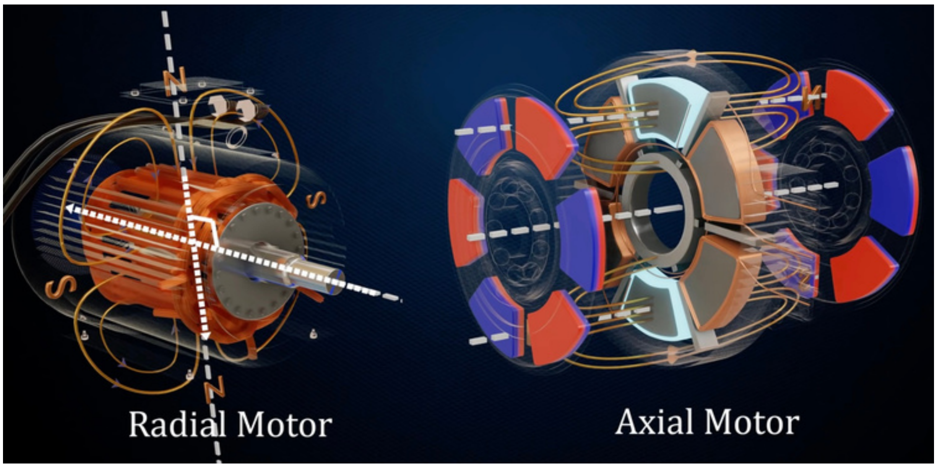
# A BETTER MOTOR TECHNOLOGY FOR E-MOBILITY | AXIAL FLUX MOTORS

Many companies around the globe are working on axial flux motor technology for electric vehicles. **Govind Kedia** discusses the technical challenges around Axial Flux motors and some updates on the players in India and outside bringing the technology to real-world applications.



Axial Flux motor[1] | Source: Traxial BV

In 1889, Nikola Tesla patented a new motor called the axial flux motor. Axial flux motors have been used in stationary applications for a long time. Over 100 years later, axial flux motors are being explored commercially in the e-mobility sector.




Comparison of Radial Flux and Axial Flux Motors [2] | Source: Lesics YouTube Channel

In an axial flux motor, the magnetic flux direction is parallel to the machine's rotational axis. Whereas in a radial flux motor, the magnetic flux direction is perpendicular to the axis of rotation.

Axial flux motors provide better torque density, produce less noise, and reduced vibrations than radial flux motors for the same volume. And these motors are two to five times lighter than radial flux motors of similar output, making them a better choice for the electric mobility sector.

## Axial flux motor technology and challenges

### Mechanical design

Axial flux motors have the stator sandwiched between rotor discs. An air gap separates the rotor and stator. Since the stator is configured between the rotors, these motors do not require a yoke for mounting the stator coils. These configurations give axial flux motors a pancake shape, unlike the cylindrical shape of radial flux motors.

Axial flux motors have higher efficiency since the stator and rotor are so close to each other. They also produce higher torque due to the large rotor diameter. One of the main issues in Axial flux motor design is the challenge of mounting the stator and rotor so close together without the rotor disc bending or the bearings failing during operation.

### Thermal issues

In an axial flux motor, windings of the stator coil are deep within the housing of the motor, and these parts get hot during operations. Removing heat from the stator coils is essential for improving the efficiency of the motor and keeping it at steady power output.

**Direct oil cooling the stator coil is the most preferred method for cooling axial flux motors.** Improving the cooling effectiveness is one of the challenges being solved by companies at present.

### Manufacturability

Axial flux motors require precision engineering and assembly. Mass manufacturing these motors has been a challenge for some time. Manufacturing challenges have been solved for low power applications by removing the inner stator iron assembly and using more powerful magnets. For electric vehicles, the motors should operate at higher power ratings and for longer durations.

Designing the motors for manufacturability is essential in reducing costs and increasing the mass adoption of these motors.

Axial flux motors are being preferred by high-end car and bike manufacturers. High-end vehicles are sold based on performance and luxury; price is less of a concern. For mass-market adoption, the price of the motor will have to be reduced.

## Axial flux motors usage in electric vehicles

Axial flux motors are ready for the market, and they are going into production vehicles soon. Some recent announcements and news attest to the viability of using axial flux motors in EVs soon.

- In March 2019, British company **YASA** announced that a YASA axial flux electric motor would power Ferrari's first hybrid series production sports car, the SF90 Stradale. In July 2021, YASA was **acquired by Mercedes-Benz**.

- In November 2020, UK-based Saietta Group got a significant grant from the Advanced Propulsion Center (APC) for Axial Flux Traction electric motor production. **In May 2021, Saietta Group partnered with Padmini VNA to introduce its axial flux electric motor technology in the Indian market and accelerate its product sales.**

- In June 2021**, Renault Group** signed a partnership with **Whylot** to develop an axial flow automotive e-motor on a large scale.

- In India, IIT Delhi incubated **Quanteon Powertrain** is close to commercialising axial flux motors for electric 2Ws and 3Ws. Named **AF5**, these axial flux motors will come in 4 variants. The two variants for electric 2Ws have a nominal power of 3 kW and 4kW, while the two motors for electric 3Ws have a nominal power of 5kW and 7kW. Quanteon is expected to start production of **4,000 units per month per variant come December 2022.**

- A new entrant is Ahmedabad based **Naxatra Labs**. The start-up claims to have completed prototyping and they are working on Design for Manufacturing (DFM). The young company aspires to enter production by June 2022.

## References

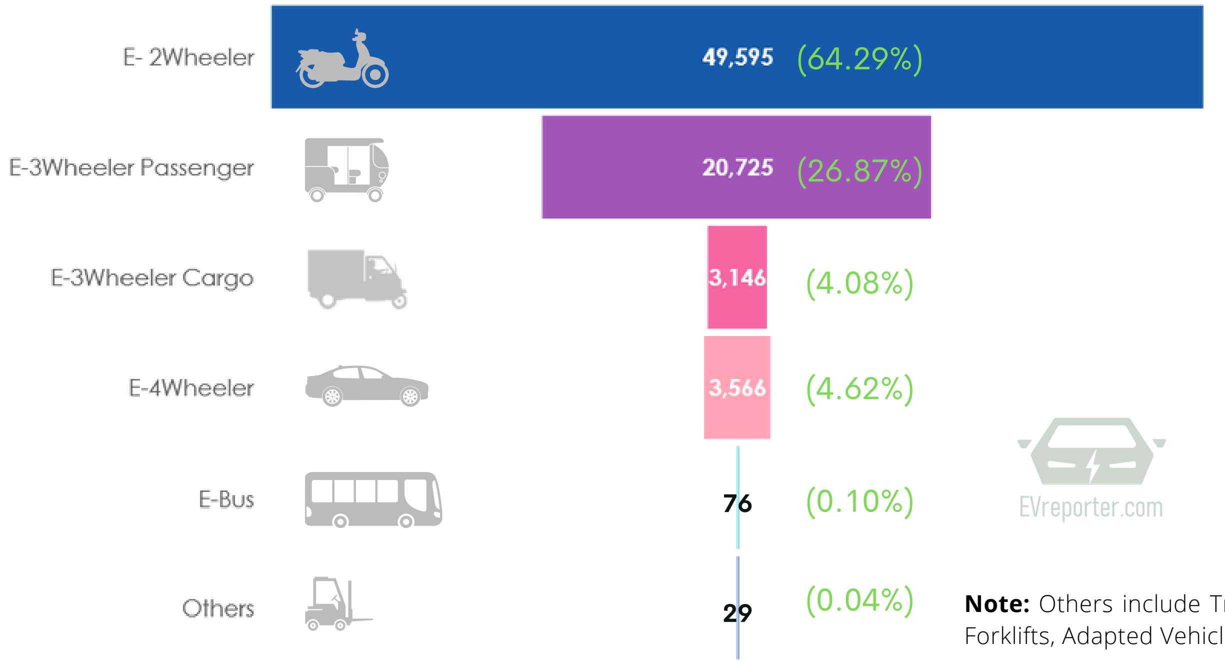
*[1] https://www.traxial.com/blog/why-arent-all-electric-vehicle-motors-axial-flux-yet/*
*[2] Lesics YouTube Video: - https://www.youtube.com/watch?v=8EEVPVNJHjM*
*[3] https://www.emworks.com/blog/electromechanical/axial-and-radial-flux-permanent-magnet-machines-what-is-the-difference*

### About the author

Govind Kedia is Managing Director at Artic Invent. Arctic Innovation Consulting Solutions (arcticinvent.com) provides industry specific patent trend news and databases. In addition, they also help technology companies protect their intellectual property via patents, trademarks, designs, and copyrights. The author can be reached at **govind@arcticinvent.com**

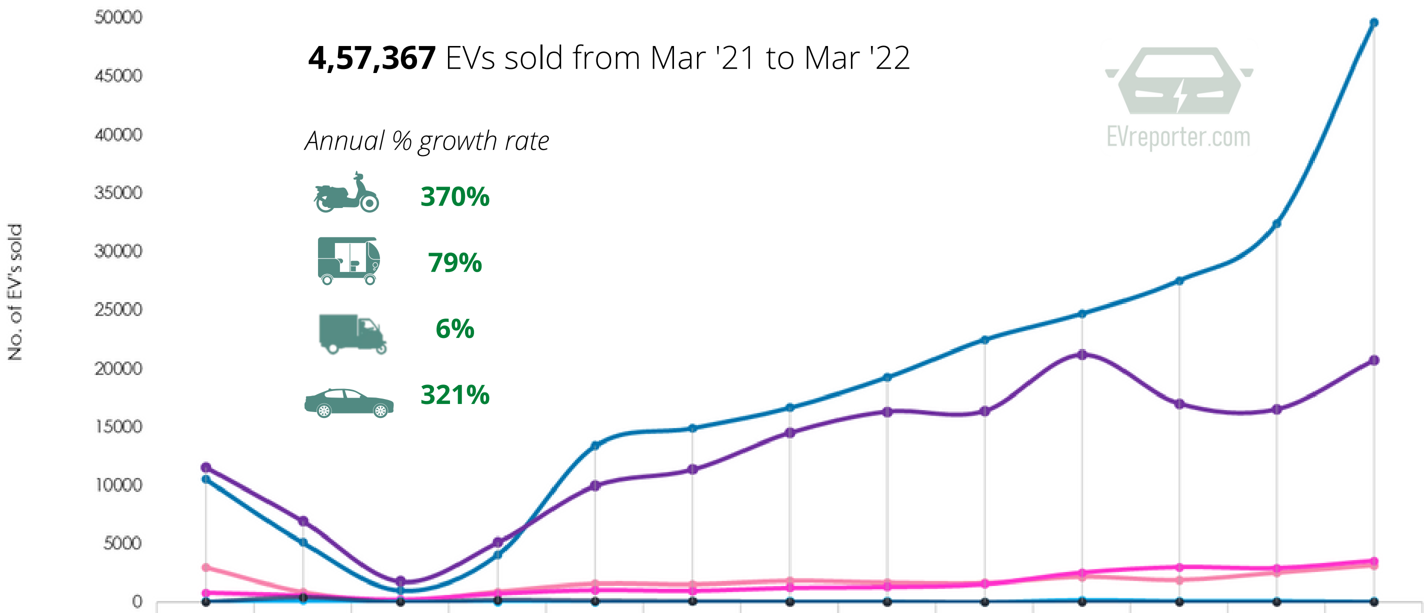
# Category-wise Electric Vehicle sales, March 2022

Total Registered Electric Vehicle Sales - **Mar '22 - 77,137** | Feb '22 - 54,552




**Note:** Others include Tractors, Forklifts, Adapted Vehicles, etc.

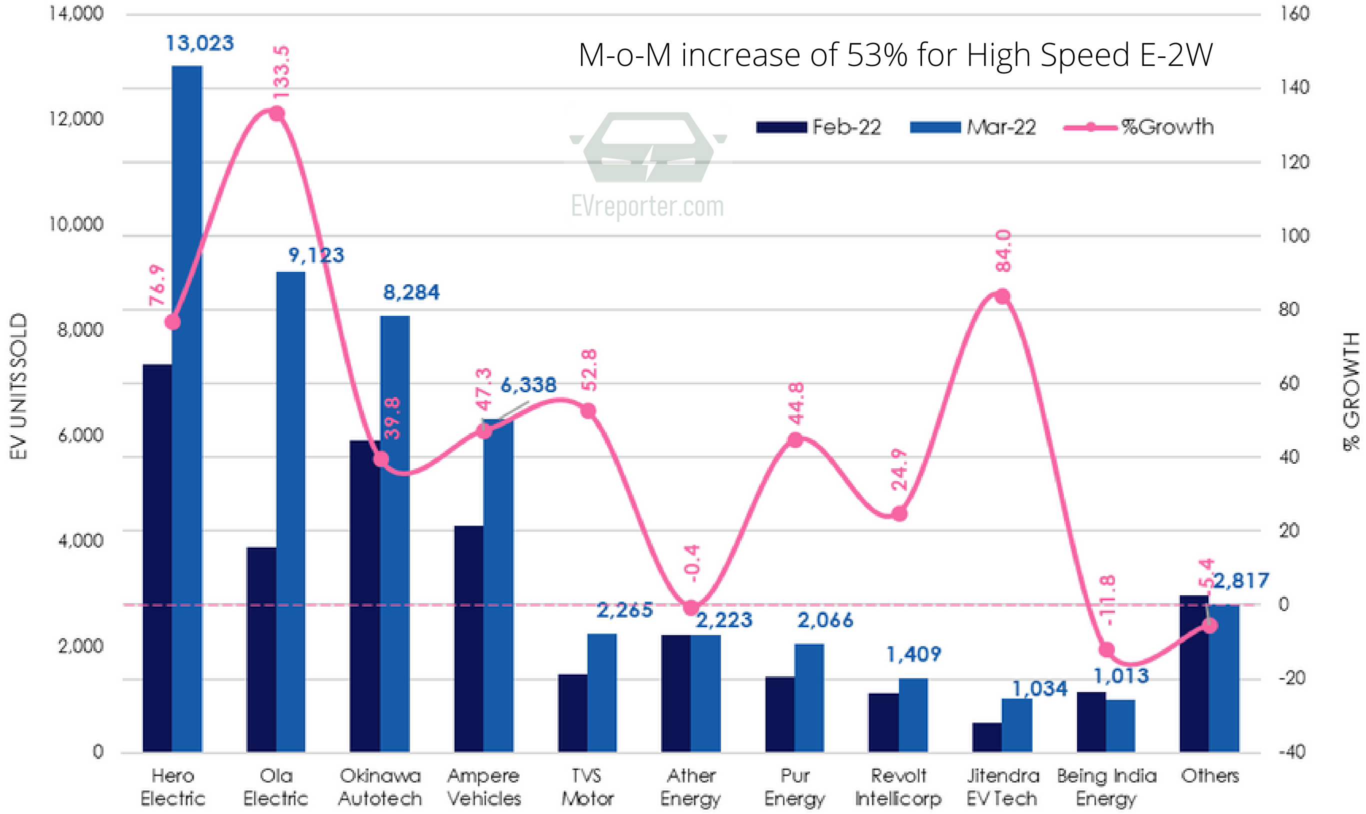
# EV Category-wise Sales Trend from Mar 2021 to Mar 2022



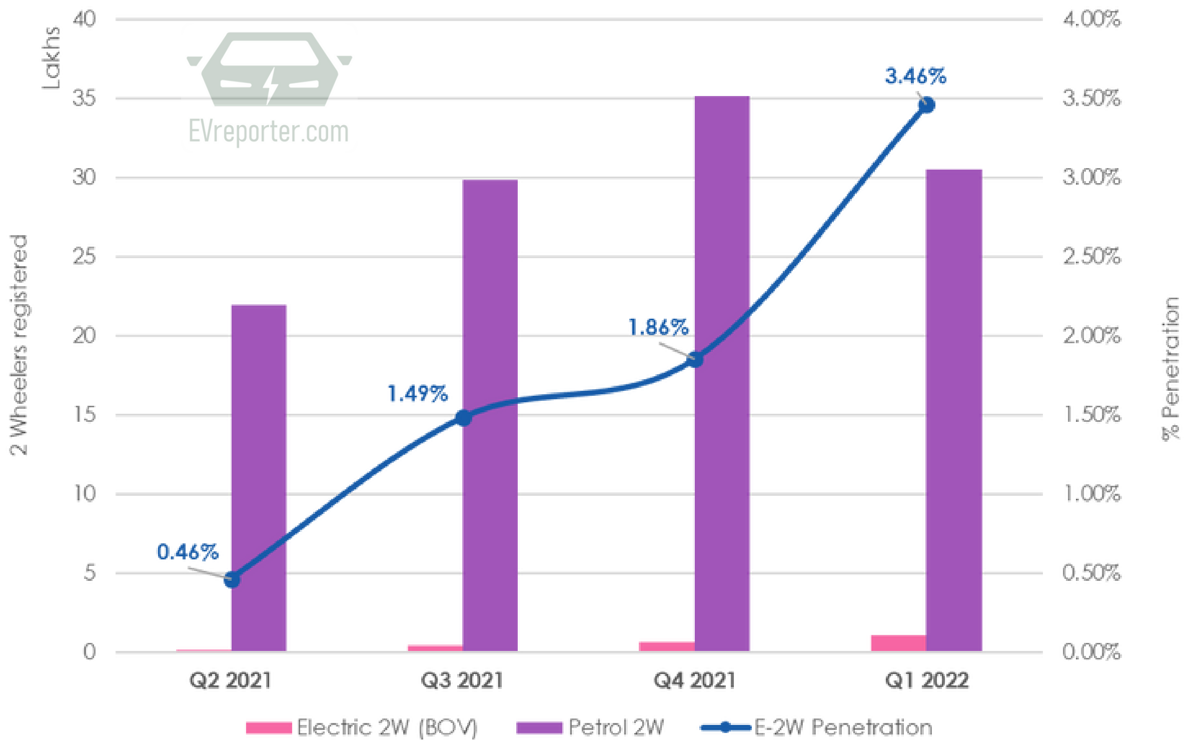

| | Mar-21 | Apr-21 | May-21 | Jun-21 | Jul-21 | Aug-21 | Sep-21 | Oct-21 | Nov-21 | Dec-21 | Jan-22 | Feb-22 | Mar-22 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2W | 10558 | 5132 | 1040 | 4073 | 13389 | 14911 | 16672 | 19264 | 22474 | 24732 | 27555 | 32416 | 49,595 |
| 3W Passenger | 11587 | 6968 | 1805 | 5147 | 9962 | 11366 | 14505 | 16340 | 16383 | 21208 | 17039 | 16540 | 20,725 |
| 3W Cargo | 2970 | 879 | 139 | 923 | 1582 | 1519 | 1825 | 1671 | 1632 | 2162 | 1893 | 2509 | 3,146 |
| 4W | 846 | 597 | 241 | 766 | 1063 | 999 | 1250 | 1320 | 1559 | 2548 | 3,020 | 2933 | 3566 |
| e-Bus | 95 | 155 | 84 | 70 | 44 | 80 | 79 | 84 | 34 | 221 | 126 | 133 | 76 |
| Others | 24 | 447 | 2 | 219 | 142 | 86 | 47 | 43 | 18 | 25 | 27 | 21 | 29 |

Source: Vahan Dashboard. Data as per 1397 out of 1605 RTOs across 33 out of 37 state/UTs

# High Speed E - 2 Wheeler Sales Trend by OEM, Mar 2022

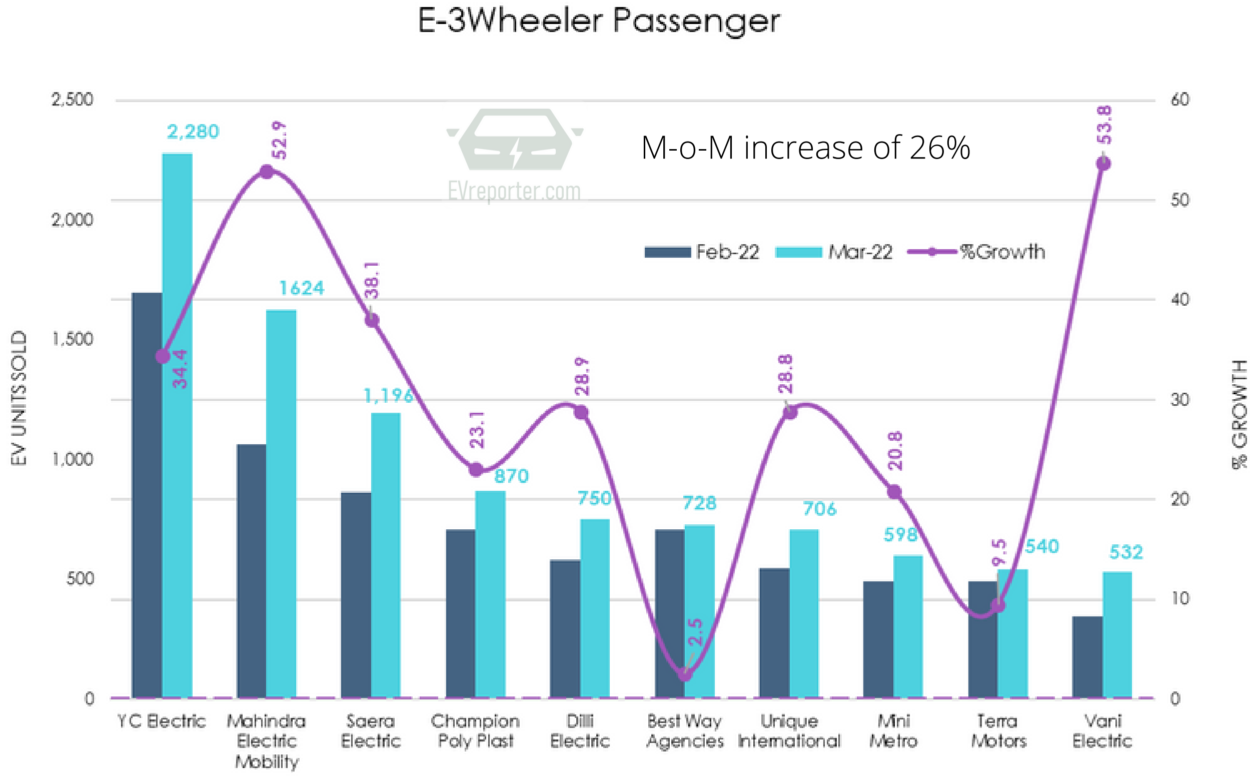


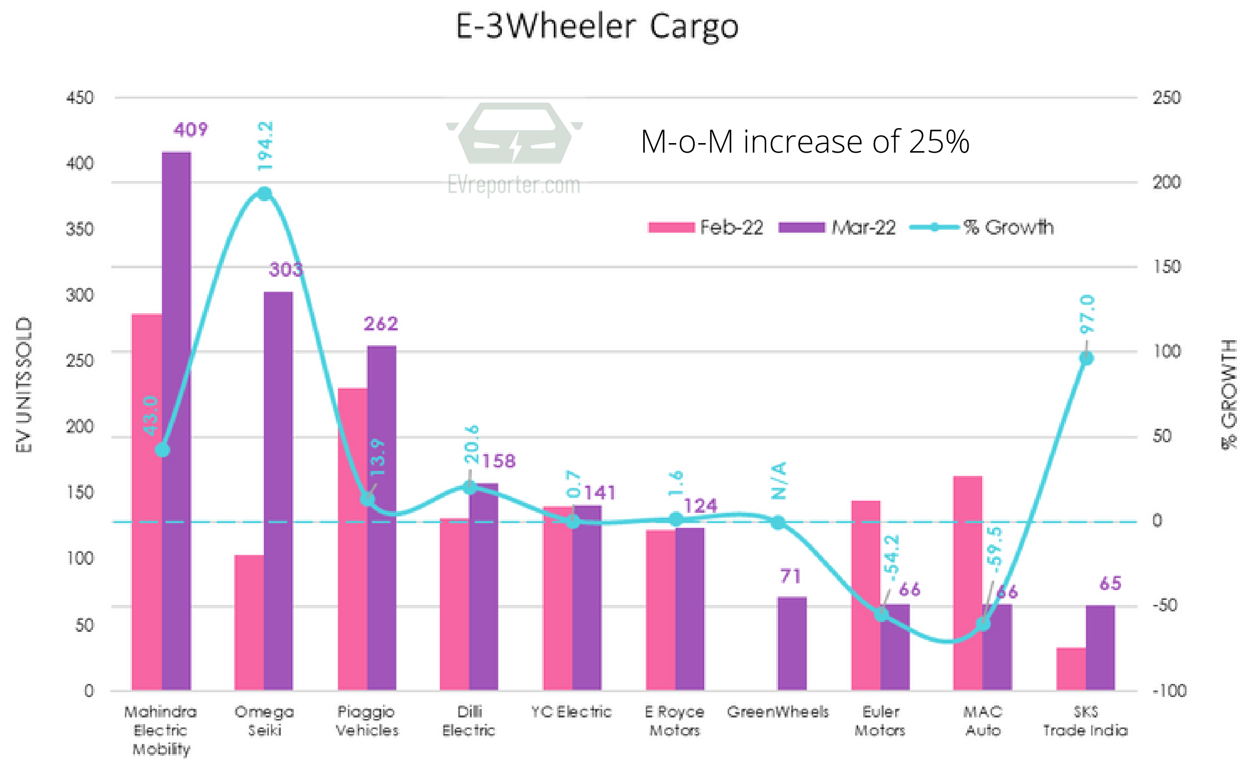

# 2 Wheeler Quarterly Sales Trend in India




Source: Vahan Dashboard. Data as per 1397 out of 1605 RTOs across 33 out of 37 state/UTs.
Note: Data excludes low-speed Electric 2Ws.

# Electric 3 Wheeler Sales Trend by OEM, Mar 2022




Note: For E-3W Passenger and Cargo vehicles, the top 10 OEMs contributed only 48% and 53% of the sales respectively, in March 2022. Source: Vahan Dashboard. Data as per 1397 out of 1605 RTOs across 33 out of 37 state/UTs. The aim of these graphs is to represent an overall trend of the new EV registrations in India.

# Manufacturer-wise Electric 4 Wheeler Sales performance

| | OEM Manufacturer | Mar-22 | Feb-22 | Difference | % Change | % Market Share Mar 2022 |
|---|---|---|---|---|---|---|
| 1 | Tata Motors | 3,387 | 2846 | 541 | 19 | 94.40% |
| 2 | MG Motors | 89 | 38 | 51 | 134 | 2.48% |
| 3 | Mahindra & Mahindra | 18 | 12 | 6 | 50 | 0.50% |
| 4 | Hyundai | 18 | 8 | 10 | 125 | 0.50% |
| 5 | BYD India | 17 | 12 | 5 | 42 | 0.47% |
| 6 | Audi | 15 | 7 | 8 | 114 | 0.42% |
| 7 | Others | 22 | 15 | 7 | 47 | 0.61% |

*Others include JLR, Mercedes Benz, Porsche, etc.*

Source: Vahan Dashboard, Company press releases. Data as per 1397 out of 1605 RTOs across 33 out of 37 state/UTs.

# Manufacturer-wise Electric Bus Sales performance

| | OEM Manufacturer | Mar-22 | Feb-22 | Difference | % Change | % Market Share Mar 2022 |
|---|---|---|---|---|---|---|
| 1 | JBM Auto Limited | 35 | 10 | 25 | 250 | 46.05% |
| 2 | PMI Electro Mobility | 19 | 52 | -33 | -63 | 25.00% |
| 3 | Olectra GreenTech | 18 | 69 | -51 | -74 | 23.68% |
| 4 | Tata Motors | 4 | 2 | 2 | 100 | 5.26% |
| | Total | 76 | 133 | | | 100.00% |


Source: Vahan Dashboard. Data as per 1397 out of 1605 RTOs across 33 out of 37 state/UTs.

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