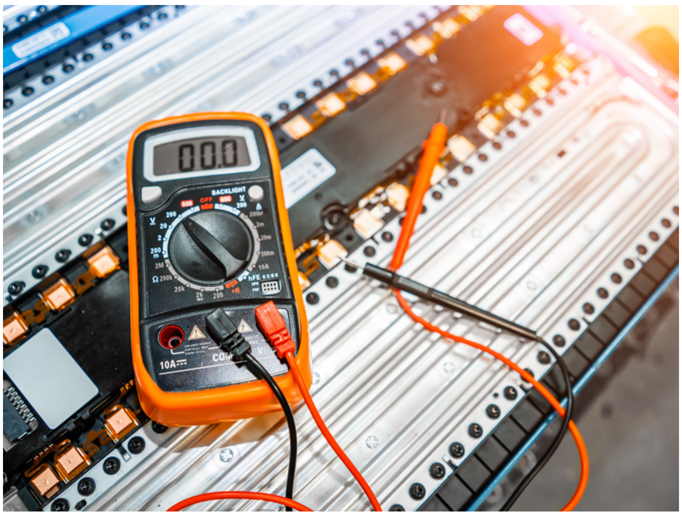
PERSPECTIVE

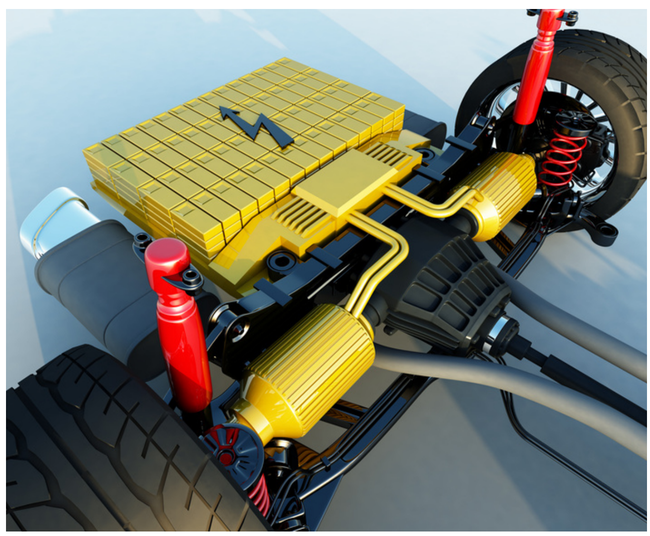
BATTERY TECHNOLOGY ROADMAP:

WHAT ARE SOME EMERGING EV BATTERY TECHNOLOGIES AND COMPOSITIONS?



With the vast consumption of fossil fuels and increased greenhouse gas emissions, drastic environmental impacts have happened which have led to an increased global demand for developing methods of harvesting and storing energy sustainably. Renewable energy sources, such as solar, hydro, and wind energy are the most promising solutions for addressing these concerns.

However, electricity produced from these sources must be efficiently stored to supply the world with energy on demand. This is where batteries come into the picture. When it comes to electric vehicles also, batteries form the crucial part. Any discussion of the future of electric vehicles ends up with a review of where battery technology, specifically battery range and recharge speeds, will be in the coming years.



A big leap is needed to increase the distances these batteries can power vehicles. To do so, battery technology researchers are focusing on immediate improvements, with an eye on a longer-term move to solid state batteries, which would replace the liquid part of a battery. So, what are some of the emerging EV battery technologies and compositions and what is the future roadmap. We asked our experts to answer the same..

DHRUV WARRIOR

RESEARCH ANALYST, COUNCIL ON ENERGY, ENVIRONMENT AND WATER (CEEW)

The deployment of electric vehicles (EVs) will define the mobility revolution of the 21st century. The recent emergence of light and small lithium-ion batteries has made some EVs cost-competitive with conventional vehicles. However, since batteries make up about fifty per cent of the value of an EV, the maturing of EV battery technologies will be critical for a complete transition to electrified transport. The new generation of batteries will have to improve the cost-effectiveness, safety, convenience and sustainability of EVs to entice the vast majority of regular vehicle buyers.

CEEW analysis suggests that research is increasingly focussed on reducing dependence on critical minerals and materials used for manufacturing of lithium-ion (Li-ion) batteries. For instance, cobalt is a necessary component of most EV batteries. But the market for cobalt is volatile and reserves are low, with most of the global cobalt resource concentrated in the Democratic Republic of Congo. Funding development of low cobalt battery-compositions like Nickel Manganese Cobalt Oxide 811 (NMC-811) would increase the resilience of the EV supply chain. Similarly, replacing graphite anodes with silicon has the potential to improve the battery's energy density. Batteries could potentially become more compact and offer better vehicle mileage.

We can also fast-track the development of new chemistries to provide functional alternatives to conventional Li-ion EV batteries. Lithium sulphur (Li-S) batteries, that replace cobalt with sulphur in the cathode, could reduce material costs and environmental impact. Alternatively, metal-air batteries forgo the cathode entirely. Instead, they use a metal anode which reacts with atmospheric oxygen to produce energy. Metal-air batteries have some of the highest theoretical energy densities and could make use of easily available metals like sodium, zinc or aluminium, but the technology is still in a nascent stage and requires significant R&D.

The structure of the battery is also a possible avenue for innovation. For instance, solid-state batteries (SSB), that consist of a solid electrolyte rather than liquid, minimise the risk of fire. They have a high charging rate and energy density compared to conventional EV batteries. Another potential breakthrough is the commercialisation of structural batteries, also called massless energy storage systems. Structural batteries store energy while also acting as load-bearing components integral to the vehicle's structure, negating the battery's additional weight. While structural batteries would greatly increase the driving range and efficiency of EVs, the associated increase in the cost and complexity of the battery recycling process should be evaluated.

As electric vehicles become more mainstream, the focus on battery technology R&D has also increased. Companies and academic institutions are increasingly building teams and targeting their R&D spending towards the improvement of existing technologies. It is imperative that India takes a leading role by participating in global research and encouraging collaboration between Indian and global institutions. By focussing on R&D, India can not only accelerate decarbonisation of its own transport sector, but also play a pivotal role in accelerating the deployment of EVs in other countries too.

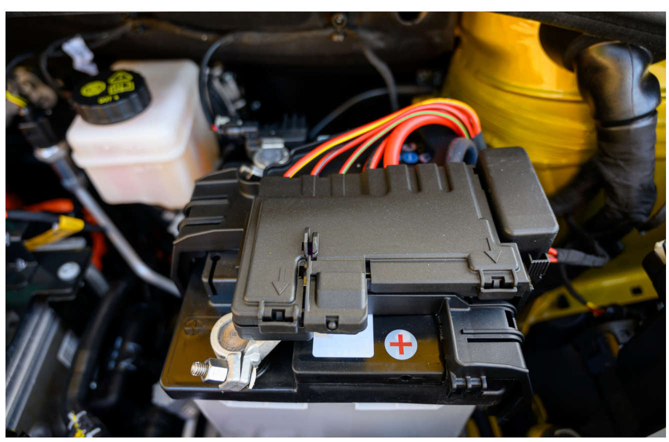
DR N S SURESH

RESEARCH SCIENTIST, CENTER FOR STUDY OF SCIENCE, TECHNOLOGY AND POLICY (CSTEP)

BHUPESH VERMA

SENIOR RESEARCH ANALYST, CENTER FOR STUDY OF SCIENCE, TECHNOLOGY AND POLICY (CSTEP)

The performance of an electric vehicle (EV) is largely dependent on a battery and its materials composition. Battery selection is based on performance characteristics, such as energy and power density, life cycle, safety, charging/discharging rate, cost, etc. Currently, the market is dominated by Lithium-ion batteries (LiBs). The most prominent material compositions in LiBs are Lithium Nickel Manganese Cobalt (LNMC), Lithium Nickel Manganese Oxide (LNMO), and Lithium Iron Phosphate (LFP) as cathode materials and graphite as anode material. Lithium and cobalt have lesser energy density. Also, these materials are scarce. Therefore, new material compositions are being tried to enhance the performance, environmental friendliness, and sustainability of batteries. The following Table provides the summary of performance indicators for various existing and emerging battery technologies.



PRABHAT KHARE
DIRECTOR, KK CONSULTANTS,
IIT ROORKEE GOLD MEDALIST

Material composition (Cathode/Anode)	Energy density* (Wh/kg)	Cycle life*	Cost* (INR/kWh)	Safety	Remarks
Existing					
LNMC/graphite	140–200	1,000–2,000	13,000–15,000	Less safe because of cobalt	Most proven but challenge with materials
LFP/graphite	90–140	2,000	17,000–24,000	Safe at high temperature (60–80°C)	Cheaper and F&P abundant
LMO/graphite	100–140	1,000–1,500	7,500–14000	Safe and stable at high temperature	Manganese abundant
Emerging					
LiS/graphite	450–600	1,500	15,000	Significantly safe	Lightweight, cheaper and abundant materials
LNMC/Silicon	205	5,000	12,000	Swelling issues	Silicon has 10 times higher energy density
Solid-state LiB	500	10,000	60,000	Significantly safe	Fast charging, amicable even in cold regions
Zinc-air	200–600	5,000	19,000	Significantly safe	Abundant
Al-air	8,100	3,000 km/ 100 kg	2,500	Significantly safe	Cheaper and abundant materials
Graphene-Al	80–225	250,000	7,500	Significantly safe	Fast charging; mass production is a challenge

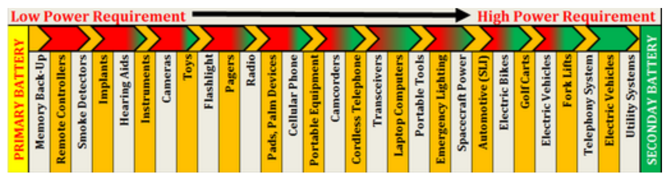
*approximately

As seen in the Table, emerging technologies have higher energy density (2–4 times) compared to traditional batteries. This leads to an increase in the life of the battery and run time, and minimises footprint size. Emerging batteries (except LiS) offer greater life cycle and can even be used for long-distance travel (over 300 km) per charge. Further, these batteries have enhanced safety characteristics and raw materials are widely available (including in India). Some emerging batteries have special features. Metal-air batteries do not require electricity for charging and require the replacement of metals (Aluminium/Zinc) for every cycle. Similarly, graphene-based batteries can be charged quickly (15 sec) and facilitate more cycles (but have low energy density). As for costs, emerging batteries are more feasible except for solid-state batteries (due to high equipment cost). Materials used in most emerging batteries are environmentally friendly, including when it comes to the afterlife. This indicates that emerging battery chemistries can play a crucial role in EVs alongside most proven traditional batteries.

India is targeting 30% of EV deployment by 2030. To meet this target, the Government of India announced plans for indigenous manufacturing with an earmarked production-linked incentive scheme of INR 18,000 Crore. The current composition of LiBs (Li, Co) would pose implications relating to materials availability, economics, and environment. Therefore, it is imperative to utilise domestically available materials such as Aluminium, Sulphur, Iron, Phosphorus, etc. The economies of scale through indigenous plants would pave a path for further cost reduction and sustainable battery manufacturing.

> **EMERGING BATTERIES (EXCEPT LIS) OFFER GREATER LIFE CYCLE AND CAN EVEN BE USED FOR LONG-DISTANCE TRAVEL (OVER 300 KM) PER CHARGE.**

The research on batteries had started in the early 1800 and was evolving with time at a very slow pace till the electronics revolution happened around 1960 making these batteries part of daily lives which brought the drastic changes in the development of battery technologies. While historically, the batteries were classified as primary (non-rechargeable) or secondary (rechargeable), yet with time and applications, this classification has vanished. However, one must understand the basic difference between the two as explained graphically below – shift happens from primary batteries to secondary batteries as the power needs go up with repeated requirements.



The current family of battery technologies have a wide range, many of them are already available commercially, while many others are still in the development stages. With time, many of these technologies will evolve and come out of the laboratory, and compete for their survival. We will look at some of them now.

Present Day Commonly Used Batteries:

1. **Lead Acid Battery:** They are the most commonly used batteries which got very early success and hence were used in diverse multiple applications. However, due to various inherent issues including their weight & safety, they are now only found in a very specific application like SLI or the home inverters.

2. **Lithium-Ion Battery:** They are the most commonly used batteries in present times yet despite pushing their chemistry to its limits, they still have limitation in delivering a driving range to a BEV (on full charge) as comparable to that of ICEVs (on full tank), leave aside issued of extended charging or recouping time

3. **Lithium Polymer Battery:** Despite having similar energy densities as that of LIBs and also having advantages like form flexibility, ruggedness, being safer they could not find much success except in restricted applications of niche markets.