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The Case for Sodium-Ion Technology – Rethinking Battery Strategy in India

Mains: *GS III – Science & Technology*

Why in News?

In recent days, the Sodium-ion batteries present a promising alternative to Lithium-ion batteries.

What are batteries?

- **Battery** – It is an electrochemical device that stores chemical energy and converts it into electrical energy to power devices.
- **Components** – It consists of one or more cells—containing an anode, cathode, and electrolyte—that produce electric current through chemical reactions.
- **Cells vs. Battery** – While a "cell" is the basic unit, a "battery" historically refers to multiple cells connected in series or parallel to increase voltage or capacity.
- **Types of Batteries**
    - **Primary Batteries** – Non-rechargeable, single-use batteries (e.g., alkaline).
    - **Secondary Batteries** – Rechargeable batteries (e.g., Lithium-ion, Nickel-metal hydride).

What are the issues with lithium-ion batteries?

- **Dominance of Lithium-Ion Batteries –** Among various battery chemistries such as lead-acid and nickel-cadmium, lithium-ion batteries have emerged as the dominant global technology.
- Their dominance is driven by high energy density, low self-discharge rates, and long cycle life.
- Sustained global investment over two decades has improved lithium-ion performance, manufacturing efficiency, and scale.
- By 2024, global lithium-ion manufacturing capacity reached nearly 2.5 times annual demand.
- Battery costs declined sharply from around $1,100 per kWh in the early 2010s to about $108 per kWh in 2025 due to economies of scale.
- **Structural Challenges of Lithium-Ion Technology –** Lithium-ion batteries are highly resource-intensive and depend on critical minerals such as lithium, cobalt, nickel, and graphite.
- The availability of these minerals is unevenly distributed across a limited number of countries.

- Refining and processing capacities are even more geographically concentrated.
- These factors create vulnerabilities related to supply security, price volatility, and geopolitical risk.
- Rising global battery demand is likely to intensify these constraints, necessitating alternative technologies.
- **India's Battery Manufacturing Ambitions and Constraints –** India has taken steps to build domestic battery manufacturing capacity through the Production Linked Incentive scheme for Advanced Chemistry Cells launched in 2021.
- Around 40 GWh of battery manufacturing capacity has been allocated under the scheme so far.
- Actual deployment remains limited, with just over 1 GWh commissioned to date.
- India's upstream ecosystem, including raw material extraction, mineral processing, and active material manufacturing, remains underdeveloped.
- Domestic lithium reserves are limited and not yet commercially viable.
- As a result, India's dependence on imports for lithium-ion batteries is likely to continue.

How sodium-ion batteries serve as an alternative?

- **Energy security** – Sodium-ion batteries present a promising alternative that can reduce material risk and enhance energy security.
- **Adjustable specific energy** – Sodium-ion batteries have lower specific energy than lithium-ion batteries due to sodium's higher atomic mass.
- However, this energy density gap can be narrowed by reducing the mass of other cell components.

__Specific energy__ is defined as the energy per unit mass.

- Layered transition-metal oxide sodium-ion cathodes already demonstrate higher specific energy than other sodium-based chemistries.
- These sodium-ion batteries are approaching the specific energy of lithium iron phosphate batteries.
- Although volumetric energy density remains lower, ongoing optimisation is expected to reduce this gap further.
- **Safety Advantages –** Safety represents a major advantage of sodium-ion batteries over lithium-ion batteries.
- Studies show that sodium-ion cells exhibit significantly lower peak temperatures during thermal runaway events.
- Lithium-ion batteries are classified as dangerous goods and must be transported at a limited state of charge.
- These restrictions increase logistical complexity and costs due to safety risks associated with copper current collectors.
- Sodium-ion batteries use aluminium current collectors on both electrodes, avoiding such risks.
- Sodium-ion cells can be safely stored and transported at zero volts without performance degradation.

- **Manufacturing Compatibility –** Sodium-ion batteries are largely compatible with existing lithium-ion manufacturing infrastructure.
- Lithium-ion production lines can be adapted to sodium-ion manufacturing with relatively minor modifications.
- The main process difference lies in stricter moisture control during cell preparation.
- While sodium-ion cells require deeper vacuum drying, these challenges are expected to reduce with advancements in manufacturing techniques.
- This compatibility lowers capital investment barriers and enables manufacturers to hedge against supply risks.
- **Lower Material Risk and Supply Chain Resilience –** Sodium is derived from abundantly available resources such as soda ash, which are geographically widespread.
- Several sodium-ion chemistries eliminate the need for critical minerals like cobalt, nickel, and copper.
- Aluminium current collectors used in sodium-ion batteries are cheaper, lighter, and more widely available than copper.
- These features reduce exposure to commodity price volatility and improve supply chain resilience for India.
- **Strategic Importance –** Sodium-ion batteries are not merely experimental but are emerging as commercially viable technologies.
- Cost projections indicate that sodium-ion batteries could become cheaper than lithium-ion batteries by 2035.
- Around *70 GWh* of sodium-ion manufacturing capacity is already operational globally as of 2025.
- Global capacity is expected to scale up to nearly *400 GWh by 2030*.
- Early engagement with sodium-ion technology is therefore strategically important for India.

What lies ahead?

- Public support for battery infrastructure should explicitly include sodium-ion chemistries.
- Incentive frameworks should encourage flexibility so that battery plants can manufacture both lithium-ion and sodium-ion cells.
- Standards, safety codes, and certification pathways must be updated to include sodium-ion batteries.
- EV manufacturers should be encouraged to type-test and approve vehicle platforms using sodium-ion batteries.
- Targeted public funding for R&D, pilot projects, and early deployment should focus on grid storage and small EV segments.
- India's growing reliance on batteries makes energy storage a strategic concern for economic and energy security.
- Continued dependence on lithium-ion batteries exposes structural vulnerabilities linked to critical minerals and imports.
- Sodium-ion batteries offer safety, material availability, manufacturing compatibility, and supply resilience advantages.
- By aligning industrial policy, regulation, and market incentives, India can build a

future-ready battery ecosystem in which sodium-ion technology plays a central role.

Reference

The Hindu| Sodium ion Batteries