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# Battery Pack Aadhaar System

## Digital Identity, Health & Safety Platform for EV Batteries in India


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# Topics



- Battery → EV → Aadhaar | Passport → **Battery Aadhaar**
- Battery Cell, Module, Pack & BMS | SoC, SoH, RuL
- Applications, Types & Parts of Batteries + **Architecture**
- Battery Material & Carbon Footprint
- Manufacturer Identifier (BMI) & Descriptor Section (BDS)

# Battery Aadhaar



- National digital system for tracking batteries
- Inspired by Aadhaar, but for batteries
- Focus on EV batteries and sustainability

# Battery Aadhaar



## Battery Aadhaar

Digital Identity System for Batteries in India


**Unique ID**
Each battery gets a unique digital identity

**Track History**
Monitor complete lifecycle and ownership

**Secure Data**
Encrypted and protected information

**Recycling**
Enable efficient battery recycling

# Why Do We Need Battery Aadhaar ?

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- EV batteries are expensive and safety-critical
- Difficult to track battery life and reuse today
- Recycling and disposal need proper data

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# Why Do We Need Battery Aadhaar ?

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## Why Battery Aadhaar is Needed?

The Problem of Missing Battery Identity

New Battery
No ID

Used Battery
No History

Damaged Battery
Safety Risk

Old Battery
No Recycle Info

### No Identity Tracking

Batteries have no unique ID, making it impossible to track origin, ownership, or usage history

### Safety Concerns

Damaged or degraded batteries cannot be identified, leading to potential safety hazards and accidents

### Poor Recycling

Without proper records, battery recycling becomes inefficient and environmental impact increases

Battery Aadhaar solves these problems with digital identity for every battery

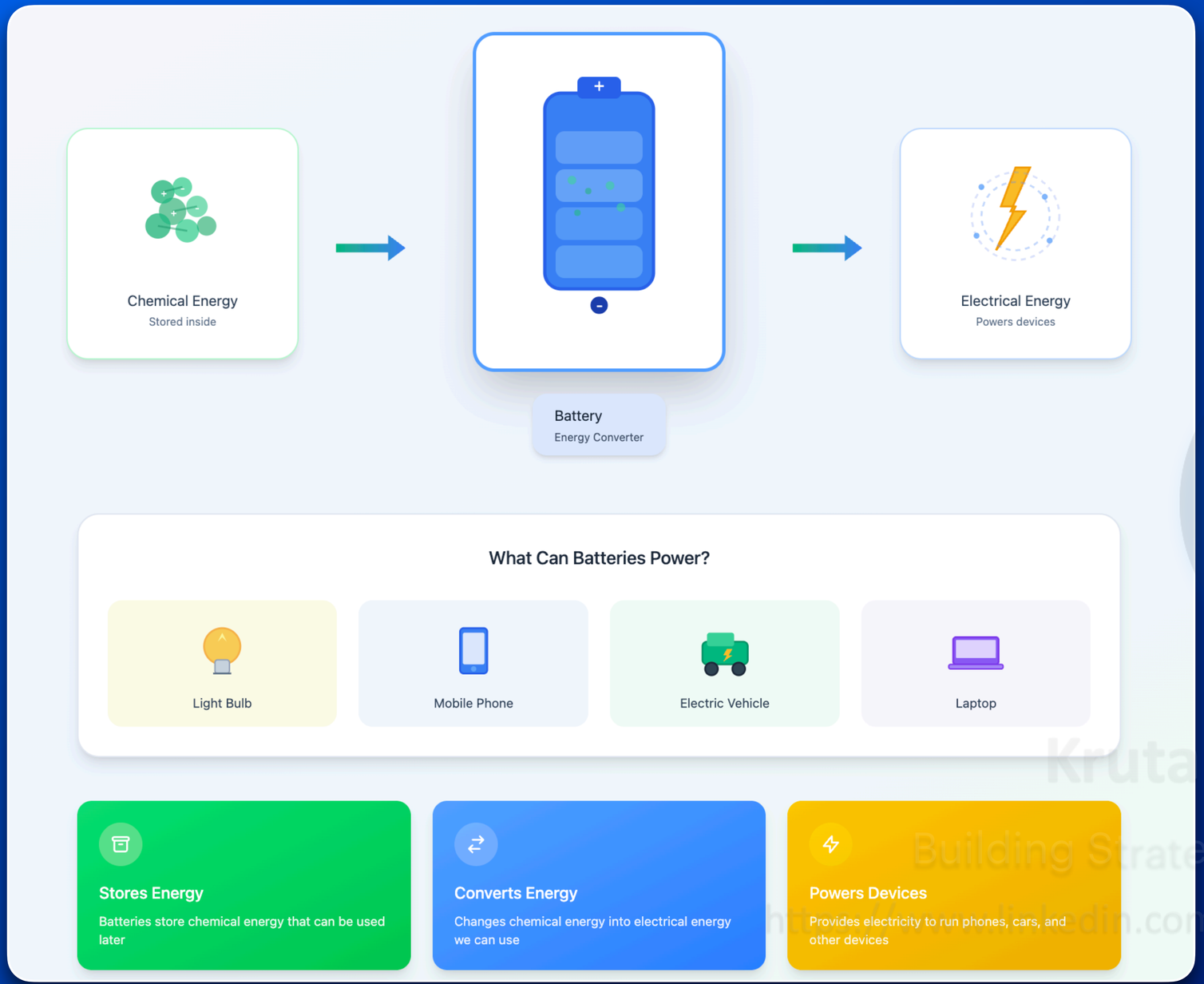
# What is a Battery?



- Device that stores chemical energy
- Converts chemical energy into electrical energy
- Used in EVs, mobiles, energy storage

# What is a Battery?





# Battery Cell, Module & Pack

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- **Cell**: smallest unit
- **Module**: group of cells
- **Pack**: complete usable battery

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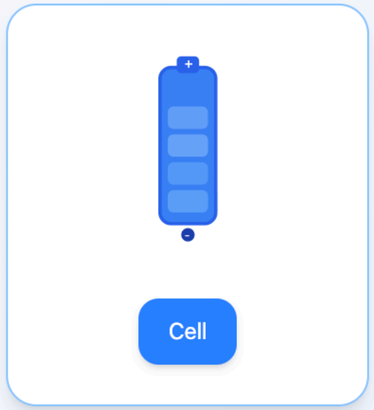
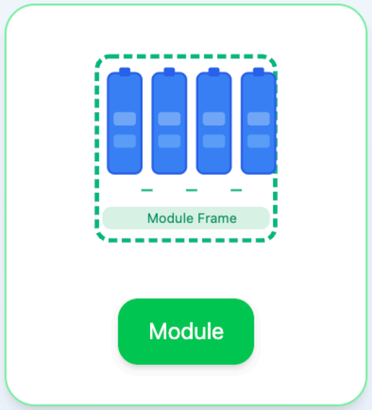
# Battery Structure

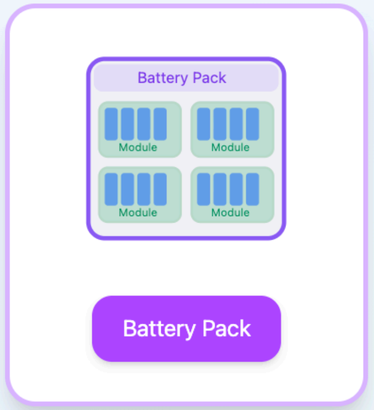





The smallest unit - stores energy




Multiple cells grouped together




Complete battery system with modules

### Cell

The basic building block. A single electrochemical unit that stores and provides energy.

### Module

Multiple cells connected together in a protective frame to increase voltage or capacity.

### Battery Pack

Complete system with multiple modules, protection circuits, and cooling for vehicles or devices.

### Real-World Example: Electric Vehicle

| 1 | 12-24 | 10-20 |
|---|---|---|
| Cell | Cells per Module | Modules in Pack |
| Small cylindrical unit | Grouped for efficiency | Powers the entire EV |

# State of Charge (SoC)



**SoC** = “**How much charge is left in the battery right now**”

- Indicates the current battery charge level in percentage (0%–100%).
- Similar to a fuel gauge in a petrol vehicle.
- Changes continuously during **charging** and **discharging**.

**SoC** = 80% → Battery is 80% charged.

**SoC is dynamic and changes continuously with charging and driving**

The Battery Management System (BMS) constantly monitors SoC to provide accurate range estimates and prevent battery damage from overcharging or deep discharge.

# State of Charge (SoC)

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**SoC = How much energy is left in the battery**

Expressed as a percentage (0% = Empty, 100% = Full)

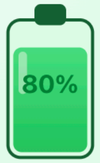
**Low**


⚠ Charge Soon
Limited driving range

**Medium**


✓ Adequate
Good for daily use

**High**




✓ Optimal
Full driving range

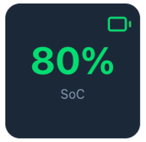
**Real-Time State of Charge**

Current SoC 80%


0% 25% 50% 75% 100%

Discharge -10% Charge +10%

Dashboard View




**Charging**
Increases SoC

**Driving**
Decreases SoC

**Capacity**
Total energy

**Monitor**
Always visible

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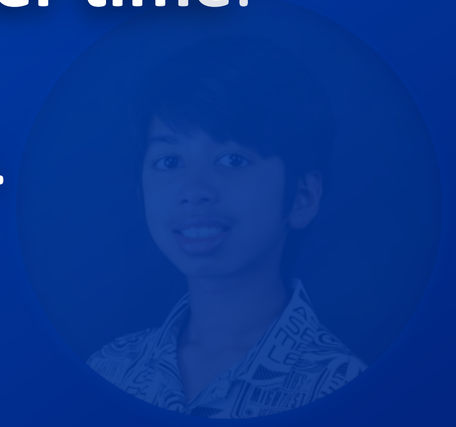
# State of Health (SoH)



**SoH** = “**How healthy the battery is compared to when it was new**”

- Shows how much the battery has **aged** or **degraded over time**.
- Compares current capacity to **original factory capacity**.
- Helps decide reuse, second-life, or replacement
- SoH decreases slowly over time and does not increase with charging



**SoH** = 85% → Battery can deliver only 85% of its original performance.

# State of Health (SoH)



## Battery Health Comparison


**New Battery**
100% Health

**Used Battery**
75% Health

## Battery Health Stages

**Healthy**
90–100%
Like new

**Aging**
70–89%
Reduced range

**Degraded**
<70%
Replacement or reuse needed

### Degradation

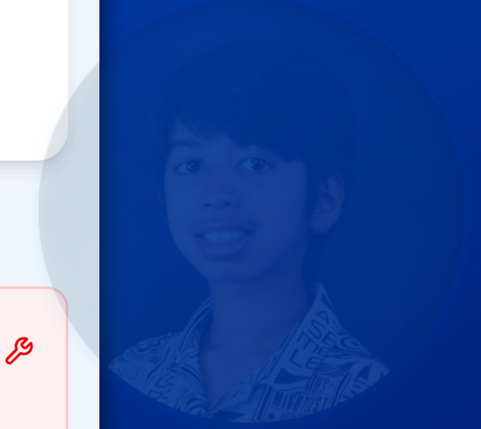
Battery capacity naturally decreases over time and charging cycles

### Aging

Age and usage patterns affect overall battery performance

### Maintenance

Proper care can help maintain battery health longer



# Remaining Useful Life (RUL)



**RUL** = “**How long the battery can still be used safely**”

- Estimates **remaining time** or **cycles** before battery reaches end-of-life.
- Calculated using usage patterns, SoH, and operating conditions.
- Critical for predictive maintenance and planning replacement.

**RUL** = 2 years → Battery is expected to be usable for 2 more years

# Remaining Useful Life (RUL)

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## Remaining Useful Life (RUL)

**RUL = How long the battery can continue to be safely used**

A prediction based on SoC, SoH, and usage history

### Battery Life Prediction

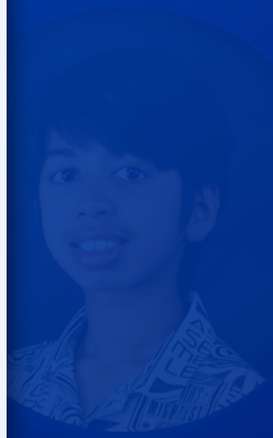
Estimated Remaining Life

**2.5 Years**

Remaining Cycles: 800

**Now**
Current State

**End of Life**
Replacement Needed



# Remaining Useful Life (RUL)



## Remaining Life Stages

### Long Life Remaining

Battery is in good condition with many years of use ahead

### Medium Life Remaining

Battery showing signs of aging, plan for replacement

### End-of-Life Approaching

Battery nearing end of useful life, replacement recommended soon

## How RUL is Predicted

### Analytics / AI

Machine learning algorithms analyze battery patterns

### Prediction

Forecasts future performance based on current health trends

### Time

Considers usage history, cycles, and aging effects

### Time-Based Estimation

RUL calculates expected remaining years or cycles before the battery reaches end-of-life threshold

### Gradual Decline

Battery capacity decreases over time, allowing predictive maintenance and replacement planning

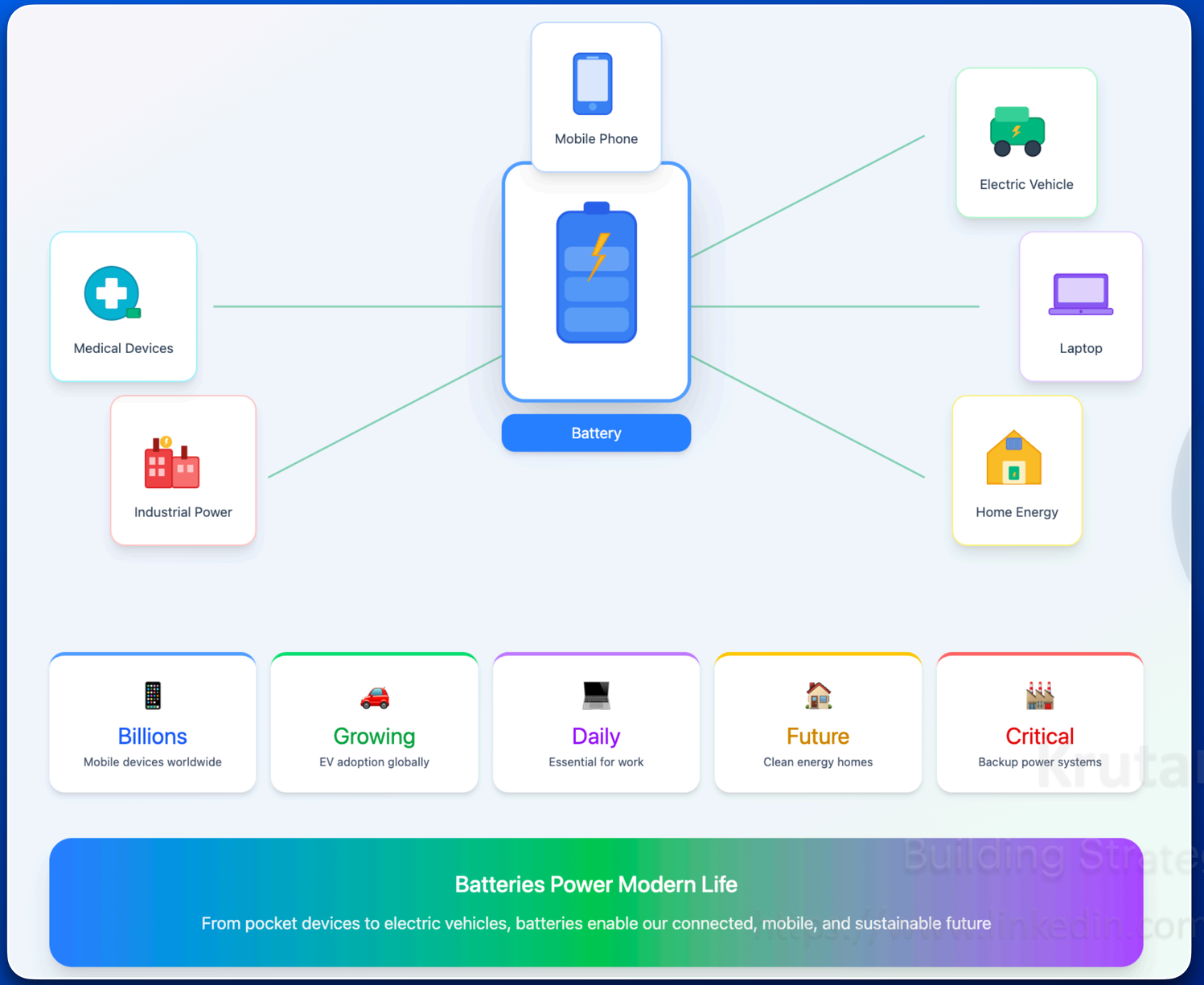
# Applications of Batteries



- Electric vehicles (2W, 3W, cars, buses)
- Home & grid energy storage
- Industrial backup systems

# Applications of Batteries





# Types of Batteries



- Lead Acid (old technology)
- Lithium-ion (modern & EV batteries)
- Different chemistries: LFP, NMC, NCA



An EV battery is a large, high-voltage energy system made of thousands of cells.

These cells are organized into modules, which are then assembled into a complete battery pack that powers the electric vehicle.

# Types of Batteries




## Lead Acid

Old Technology

Heavy, low energy density, used in traditional automotive

MODERN

## Lithium-Ion

Modern & EV Batteries

High energy density, lightweight, rechargeable

## Battery Chemistries

**LFP**
Lithium Iron Phosphate
Safe, long life

**NMC**
Nickel Manganese Cobalt
Balanced performance

**NCA**
Nickel Cobalt Aluminum
High energy density

Legacy | Modern Standard | Advanced Variants

# What is an EV Battery?



- Designed to power vehicle movement
- High energy and long life
- Requires safety and monitoring

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# What is an EV Battery?

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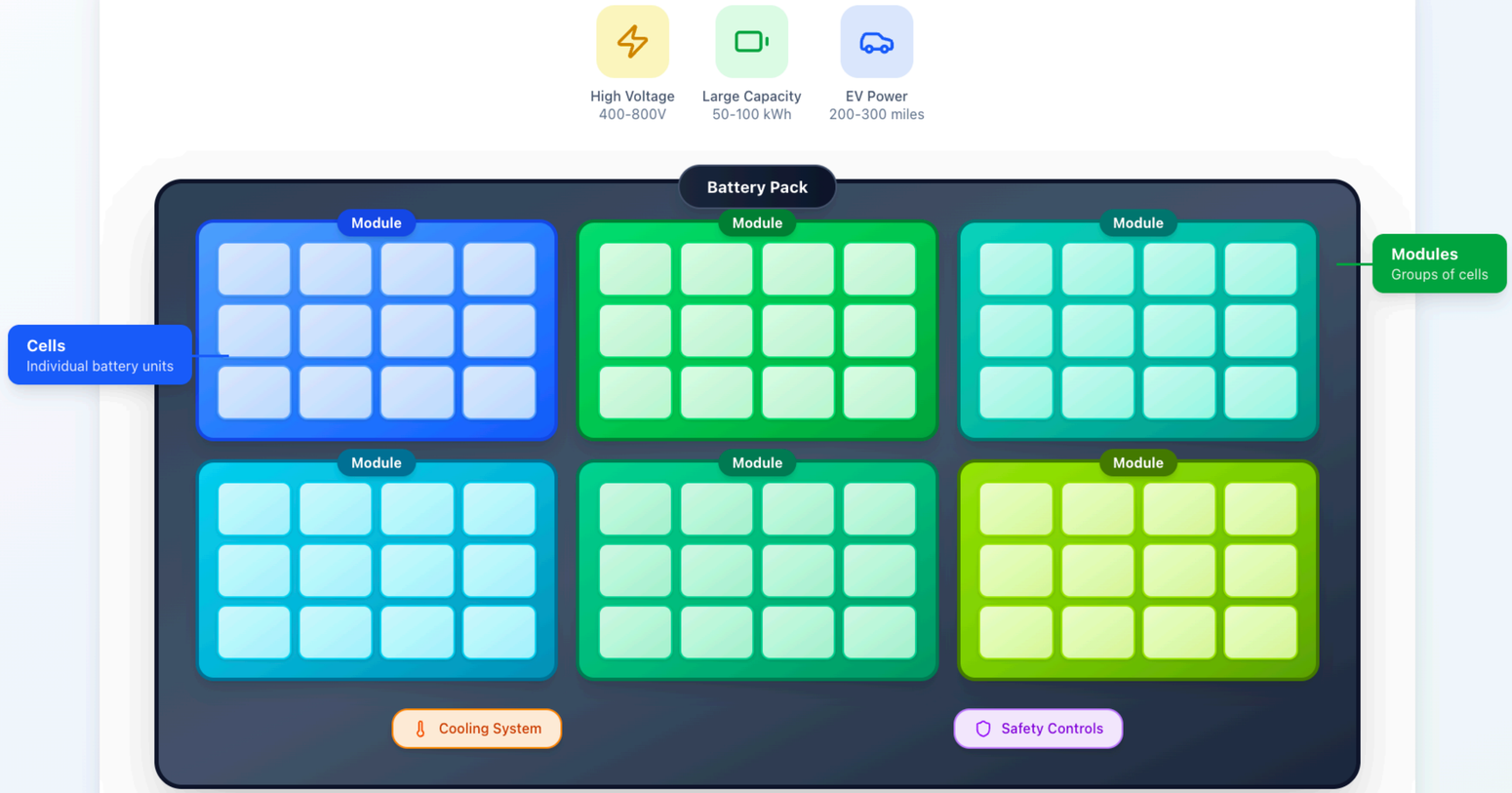
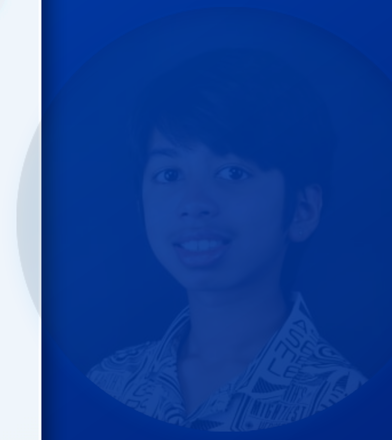



| 7,000+ | 20-30 | 1 |
|---|---|---|
| Cells | Modules | Battery Pack |
| Cylindrical or prismatic lithium-ion cells | Cells grouped into manageable modules | Complete integrated system |



# What is Aadhaar?



- Unique identity for people
- Stores essential personal information
- Helps in verification and services

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# What is Battery Aadhaar?

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- Unique **digital identity** for a battery
- Tracks battery from **birth** to **end-of-life**
- Stores **technical** and **lifecycle** data

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# What is Battery Aadhaar?



## Battery Aadhaar

Digital Identity for Batteries

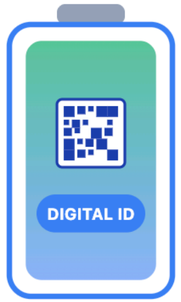
**Battery Aadhaar is a digital identity** that stores, tracks, and manages battery data across its entire lifecycle.

**National Digital Registry**
Centralized Battery Database

State of Charge
**SoC: 85%**

State of Health
**SoH: 92%**

Remaining Useful Life
**RUL: 3.2 Years**

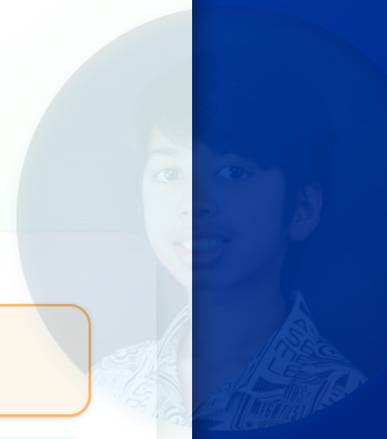



**Unique Battery ID**
Scannable QR Code

Battery Chemistry
**Li-ion NMC**

Manufacturing Details
**2024, India**

Usage History
**450 Cycles**



# Benefits Battery Aadhaar



## Battery Aadhaar Benefits

### Data Tracking

Real-time monitoring of battery performance and health

### Safety

Ensures battery safety standards and compliance

### Lifecycle

Tracks battery from manufacturing to recycling

### Sustainability

Promotes battery reuse and circular economy

## One System for Complete Battery Management

Battery Aadhaar connects battery data, safety protocols, lifecycle management, and sustainability initiatives into a unified digital ecosystem—enabling transparency, accountability, and efficient resource utilization.

# Battery Passport vs Battery Aadhaar

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- **Battery Passport** : European concept
- **Battery Aadhaar**: India-specific & simpler
- Works even without internet (offline data)

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# What is a Battery Management System - BMS ?



- The intelligent brain that keeps your EV battery safe and efficient
- Electronics inside battery pack
- Monitors **voltage**, **current**, **temperature**
- Protects battery from damage

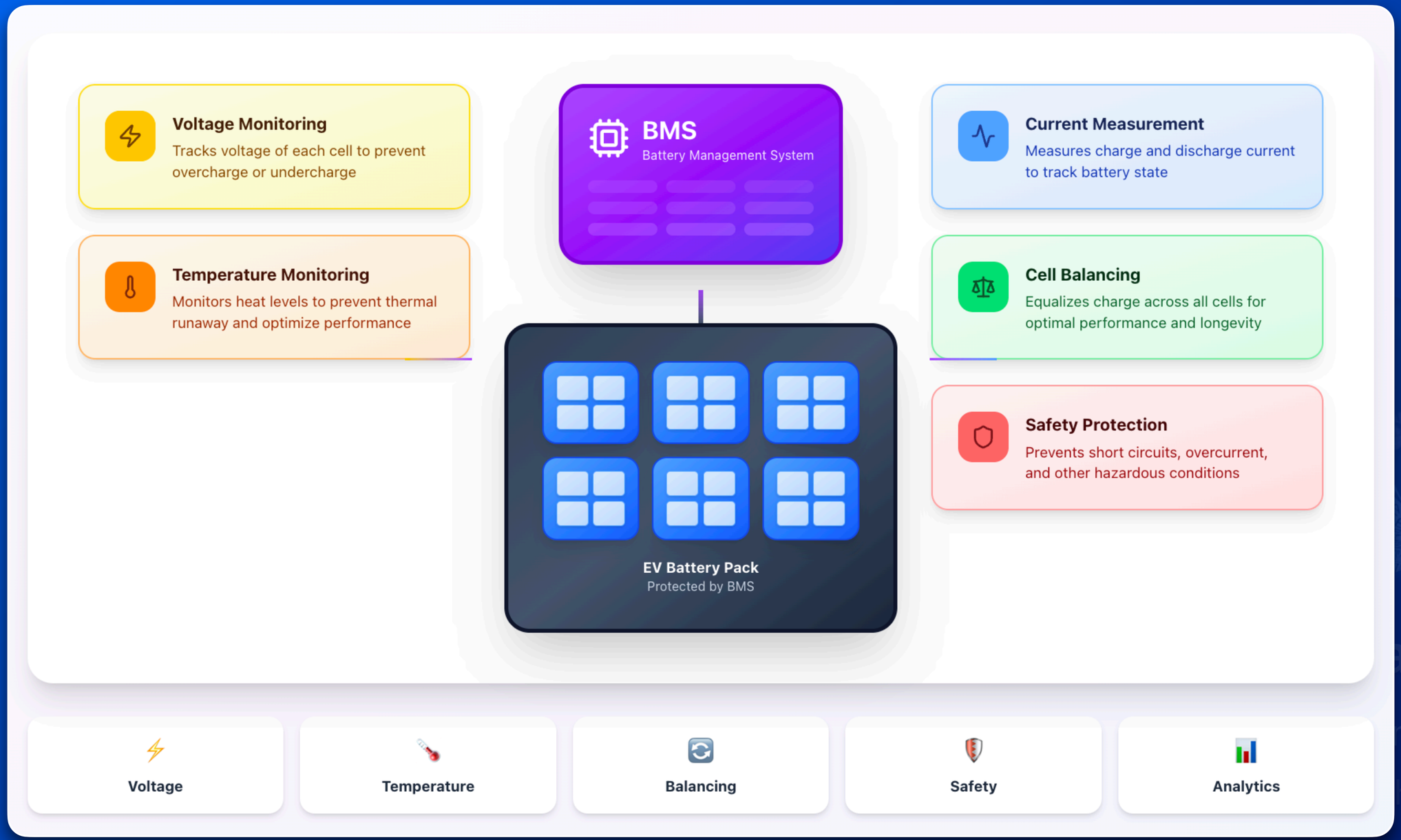
**The BMS is the brain of the EV battery. It monitors, protects, and controls the battery.**

Without a BMS, an EV battery cannot operate safely. It continuously analyzes thousands of data points per second to ensure optimal performance, prevent damage, and maximize battery life.

**Critical Safety Component**

# What is a Battery Management System - BMS ?





# How Battery Data is Generated ?

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- **Sensors** collect battery data
- **BMS** processes data
- Data used for **health** and **safety**

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# Static vs Dynamic Battery Data

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- **Static**: does not change (capacity, chemistry)
- **Dynamic**: changes over time (health, status)
- Battery Aadhaar stores both

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# Battery Aadhaar System Architecture

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- Physical battery
- QR code & Alphanumeric ID
- Central server (cloud)

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# Battery Lifecycle

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## Battery Aadhaar – Battery Lifecycle

End-to-end digital tracking of a battery from birth to recycling

**1 Manufacturing**

Battery is issued a unique Battery Aadhaar ID

*Chemistry, Manufacturer, Date, Country*

**2 Vehicle Integration**

Battery linked to vehicle VIN and owner

*OEM, Vehicle ID, BMS pairing*

**3 Usage & Monitoring**

SoC, SoH, temperature, cycles tracked

*Charging history, driving patterns*

**4 Health Evaluation**

AI-based SoH & RUL prediction

*Degradation, safety risk analysis*

**5 Second Life**

Battery reused for stationary storage

*Grid, solar, backup systems*

**6 Recycling & Disposal**

Materials recovered responsibly

*Compliance, sustainability reporting*

**Battery Aadhaar**
Unique Digital Identity

**Battery Aadhaar ensures full lifecycle visibility,** safety compliance, traceability, and sustainability across the EV ecosystem.

# Battery Aadhaar System Architecture

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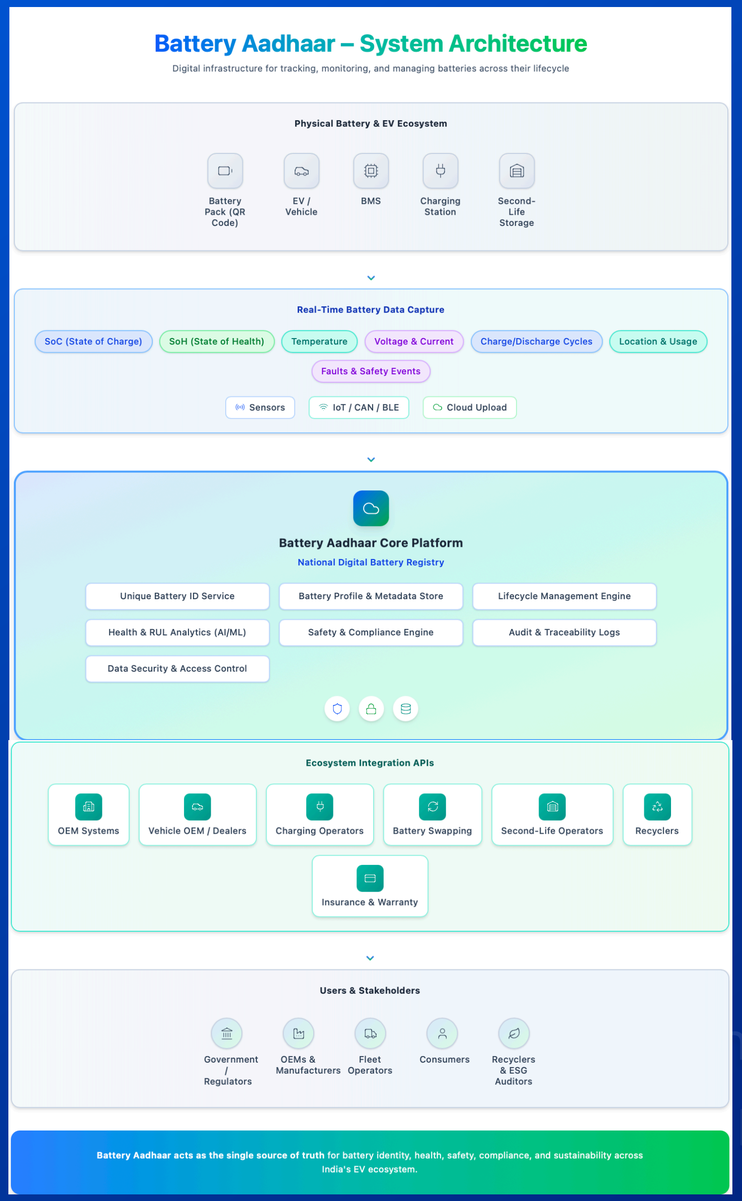
Physical Battery & EV Ecosystem

Real-Time Battery Data Capture

Battery Aadhaar Core Platform

Ecosystem Integration APIs

Users & Stakeholders



# Battery Aadhaar System Architecture

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## Battery Aadhaar – System Architecture

Digital infrastructure for tracking, monitoring, and managing batteries across their lifecycle

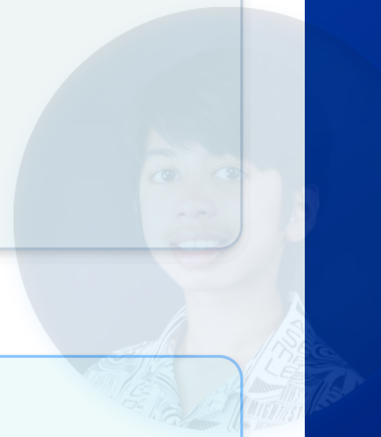
### Physical Battery & EV Ecosystem

- Battery Pack (QR Code)
- EV / Vehicle
- BMS
- Charging Station
- Second-Life Storage

### Real-Time Battery Data Capture

- SoC (State of Charge)
- SoH (State of Health)
- Temperature
- Voltage & Current
- Charge/Discharge Cycles
- Location & Usage
- Faults & Safety Events

- Sensors
- IoT / CAN / BLE
- Cloud Upload



# Battery Aadhaar System Architecture

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## Battery Aadhaar Core Platform

National Digital Battery Registry

- Unique Battery ID Service
- Battery Profile & Metadata Store
- Lifecycle Management Engine
- Health & RUL Analytics (AI/ML)
- Safety & Compliance Engine
- Audit & Traceability Logs
- Data Security & Access Control

## Ecosystem Integration APIs

- OEM Systems
- Vehicle OEM / Dealers
- Charging Operators
- Battery Swapping
- Second-Life Operators
- Recyclers
- Insurance & Warranty

# Battery Aadhaar System Architecture

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## Ecosystem Integration APIs

- OEM Systems
- Vehicle OEM / Dealers
- Charging Operators
- Battery Swapping
- Second-Life Operators
- Recyclers
- Insurance & Warranty

## Users & Stakeholders

- Government / Regulators
- OEMs & Manufacturers
- Fleet Operators
- Consumers
- Recyclers & ESG Auditors

**Battery Aadhaar acts as the single source of truth** for battery identity, health, safety, compliance, and sustainability across India's EV ecosystem.

# Three Parts of Battery Aadhaar



- **Alphanumeric Code** – visible on battery
- **QR Code** – scan for details
- **Server Data** – live updates

# Battery Manufacturer Identifier (BMI)

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- Identifies country and manufacturer
- First part of Battery Aadhaar number
- Similar to vehicle manufacturer code

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# Battery Descriptor Section (BDS)



- Basic battery specifications
- Capacity, voltage, chemistry
- Helps quick identification

# Battery Material & Carbon Footprint

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- Records materials used in battery
- Tracks carbon footprint
- Helps recycling and sustainability

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# Battery Dynamic Data (Live Data)



- Battery health (SoH)
- Battery status (in use, reused, recycled)
- Updated throughout life

# Why Battery Aadhaar is Important for Future?

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- Improves EV safety
- Enables second-life batteries
- Supports clean & circular economy

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# References



- Battery Pack Aadhaar

  https://morth.nic.in/sites/default/files/Battery%20Pack%20Aadhaar%20Guideline_30122025.pdf

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