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Battery Pack Aadhaar System

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

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Battery Pack Aadhaar System

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



Krutarth S Karkala

Under the guidance of - **Ashwini Sudarshana** | Building Strategic Thinking Skills

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09 October 2025 | https://www.linkedin.com/in/krutarthskarkala

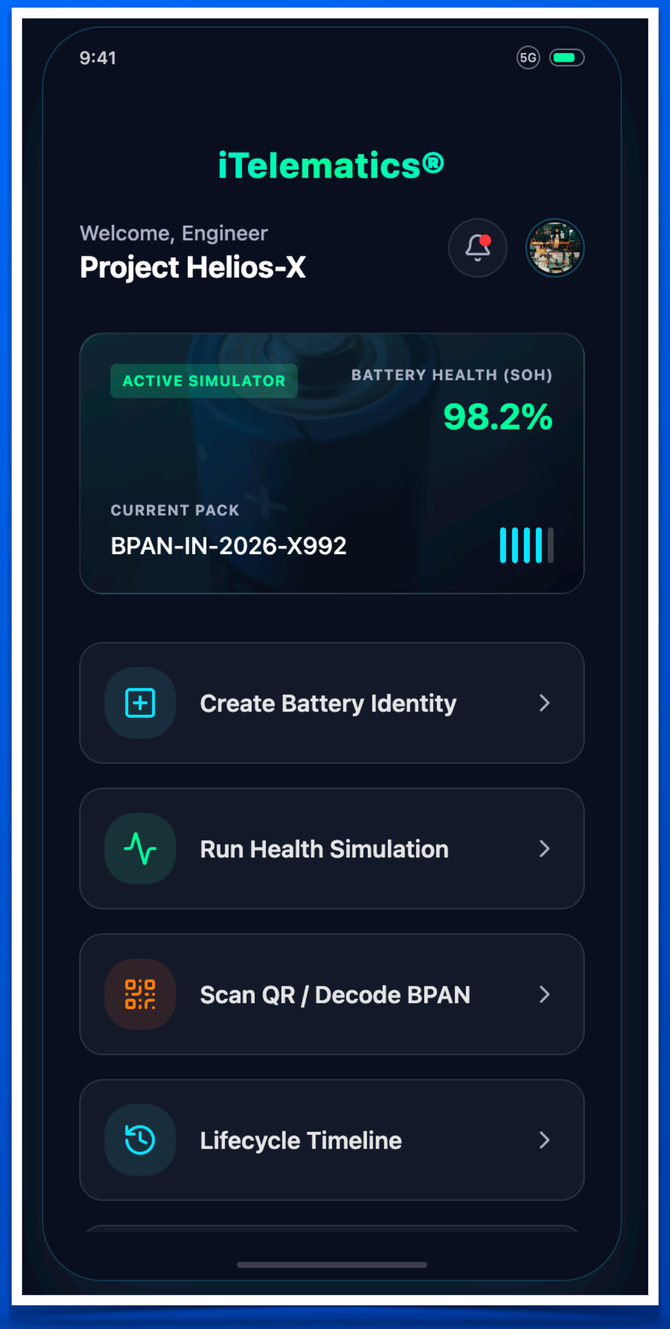
Topics

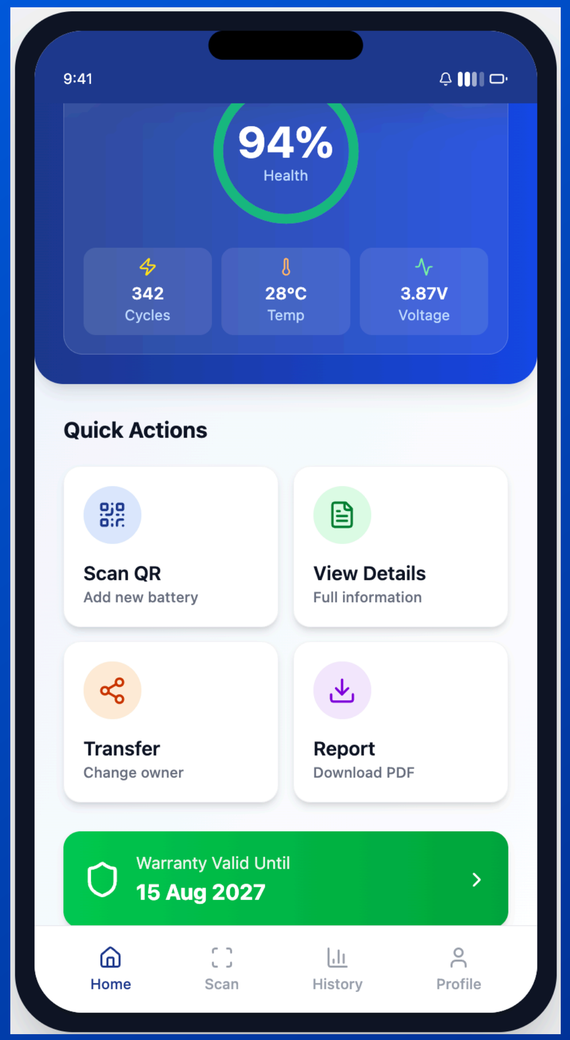
- Battery → EV → Aadhaar | Passport → **Battery Aadhaar**
- Battery Cell, Module, Pack & BMS | SoC, SoH, RuL
- Applications, Types & Parts of Batteries + **Architecture**
- Battery Material & Carbon Footprint
- Manufacturer Identifier (BMI) & Descriptor Section (BDS)

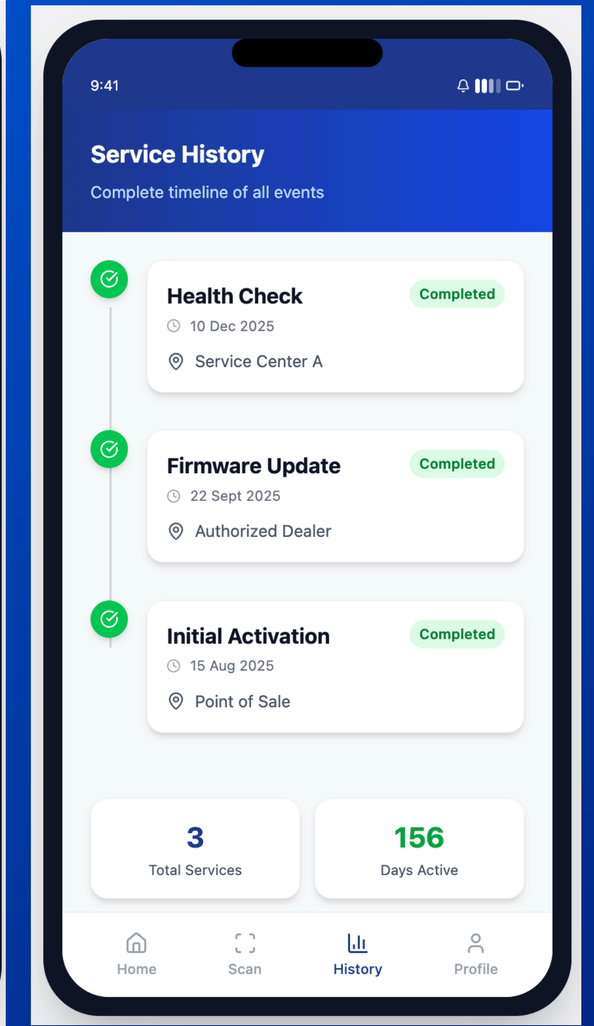


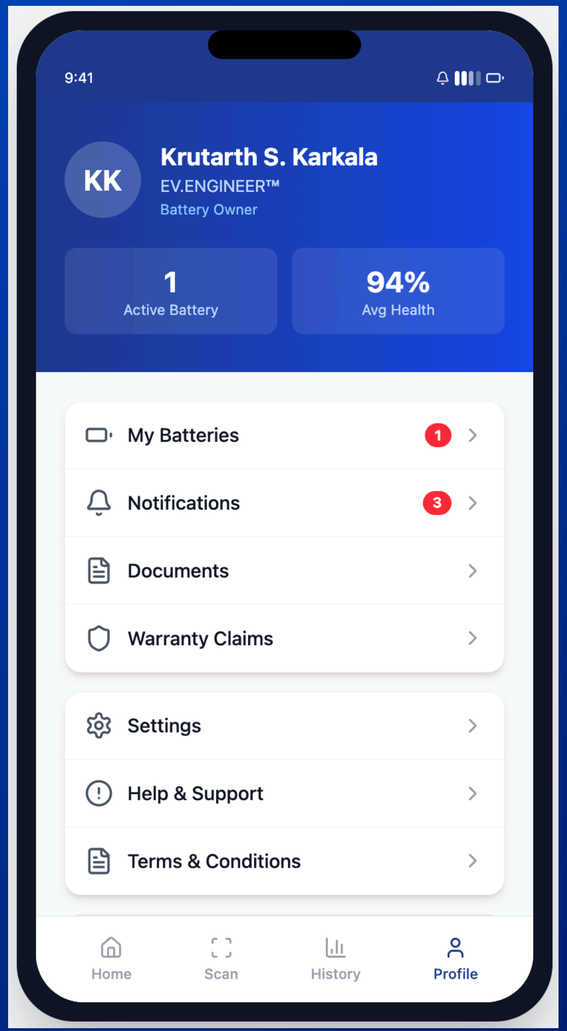
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Battery Pack Aadhaar System









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https://tweak-stand-28567793.figma.site/

Battery Aadhaar

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



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Battery Aadhaar

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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



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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

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What is a Battery?

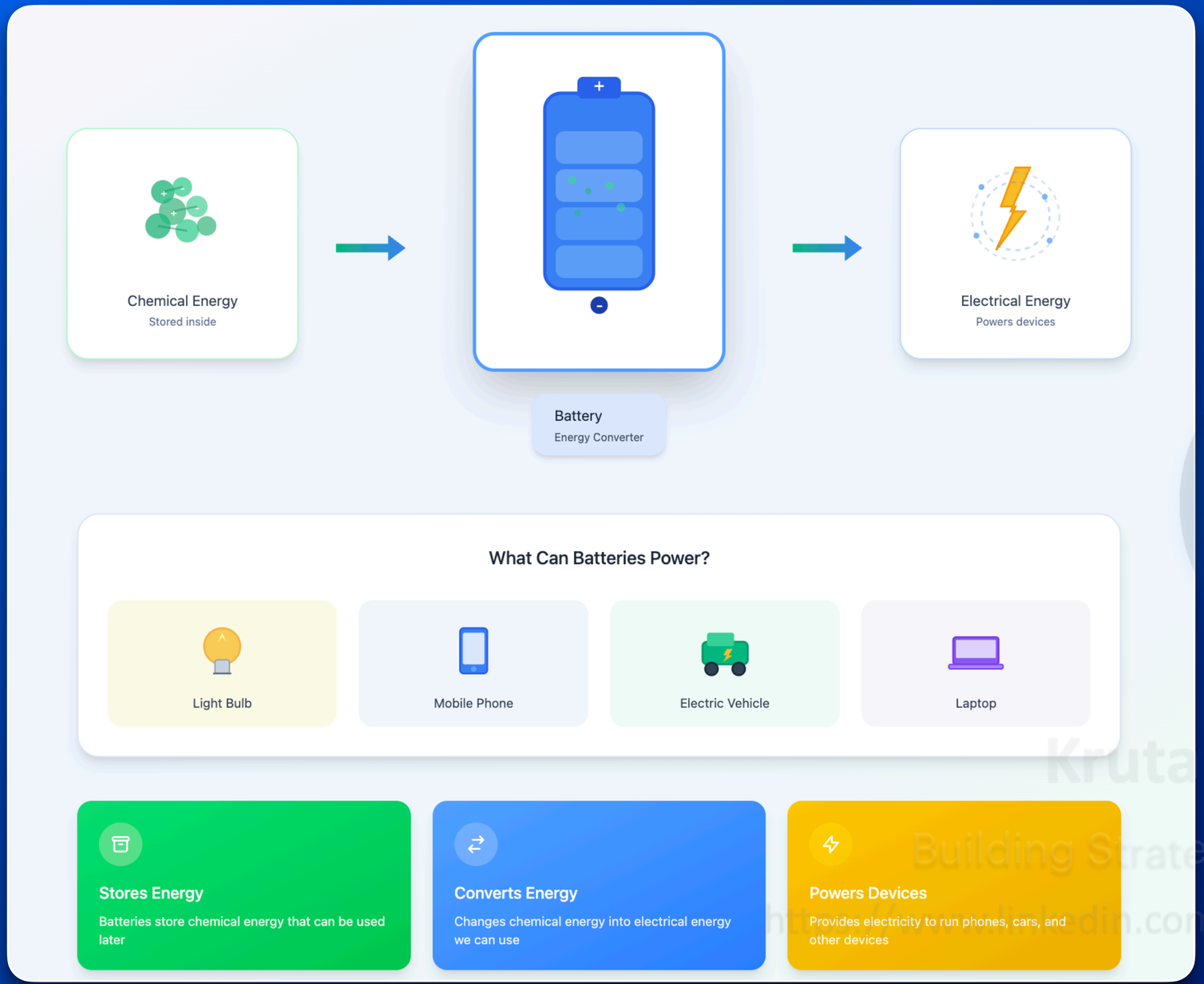
- Device that stores chemical energy
- Converts chemical energy into electrical energy
- Used in EVs, mobiles, energy storage



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What is a Battery?

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Battery Cell, Module & Pack

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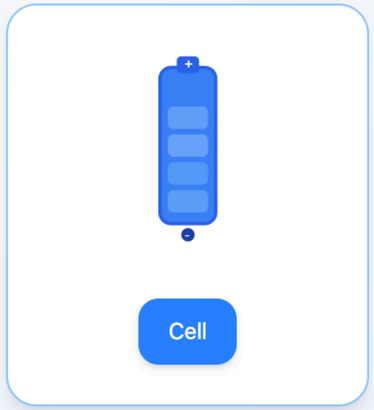
- **Cell**: smallest unit
- **Module**: group of cells
- **Pack**: complete usable battery



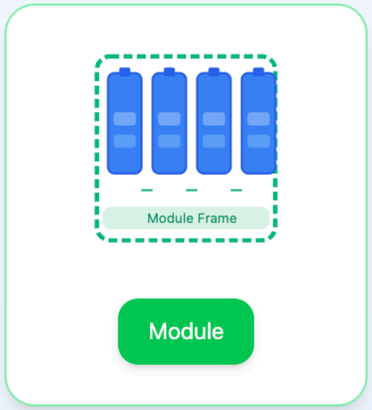
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Battery Structure

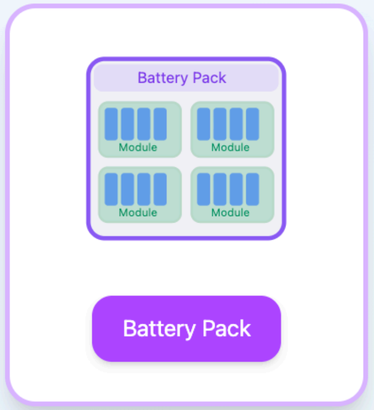
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The smallest unit - stores energy



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

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State of Charge (SoC)

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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.

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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



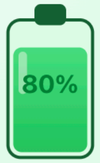
⚠ Charge Soon
Limited driving range

Medium



✓ Adequate
Good for daily use

High



✓ Optimal
Full driving range

Real-Time State of Charge

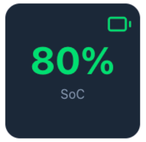
Current SoC 80%



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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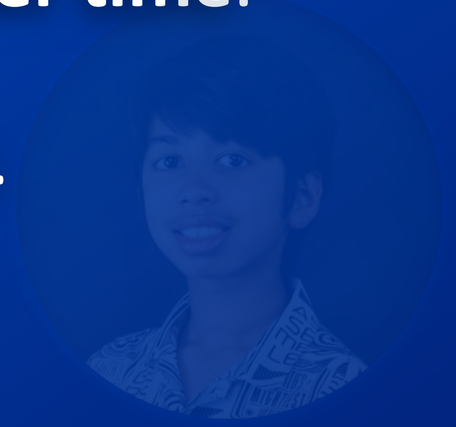
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State of Health (SoH)

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.

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State of Health (SoH)

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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

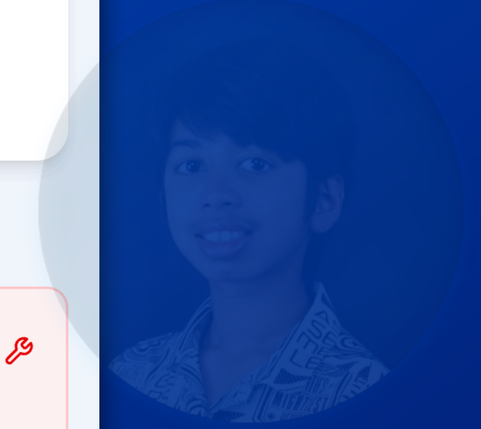
Battery capacity naturally decreases over time and charging cycles

Aging

Age and usage patterns affect overall battery performance

Maintenance

Proper care can help maintain battery health longer



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Remaining Useful Life (RUL)

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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



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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

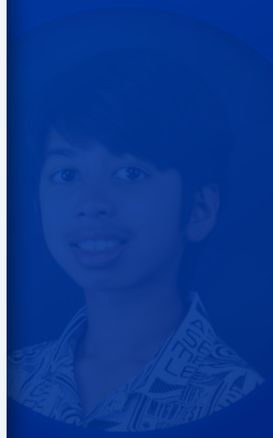
2.5 Years

Remaining Cycles: 800



Now
Current State

End of Life
Replacement Needed



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Remaining Useful Life (RUL)

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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

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Applications of Batteries

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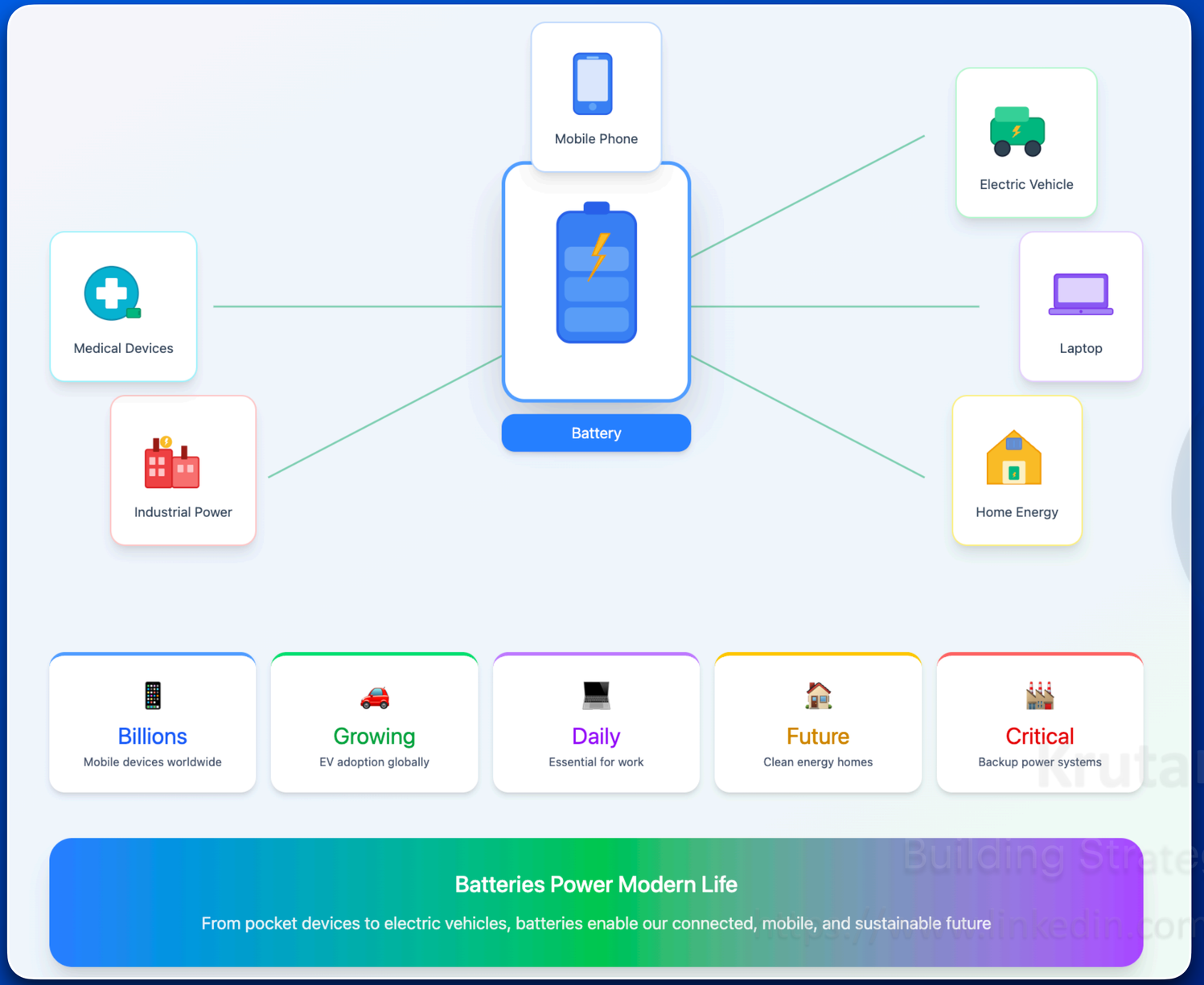
- Electric vehicles (2W, 3W, cars, buses)
- Home & grid energy storage
- Industrial backup systems



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Applications of Batteries

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Types of Batteries

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



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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

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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

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What is an EV Battery?

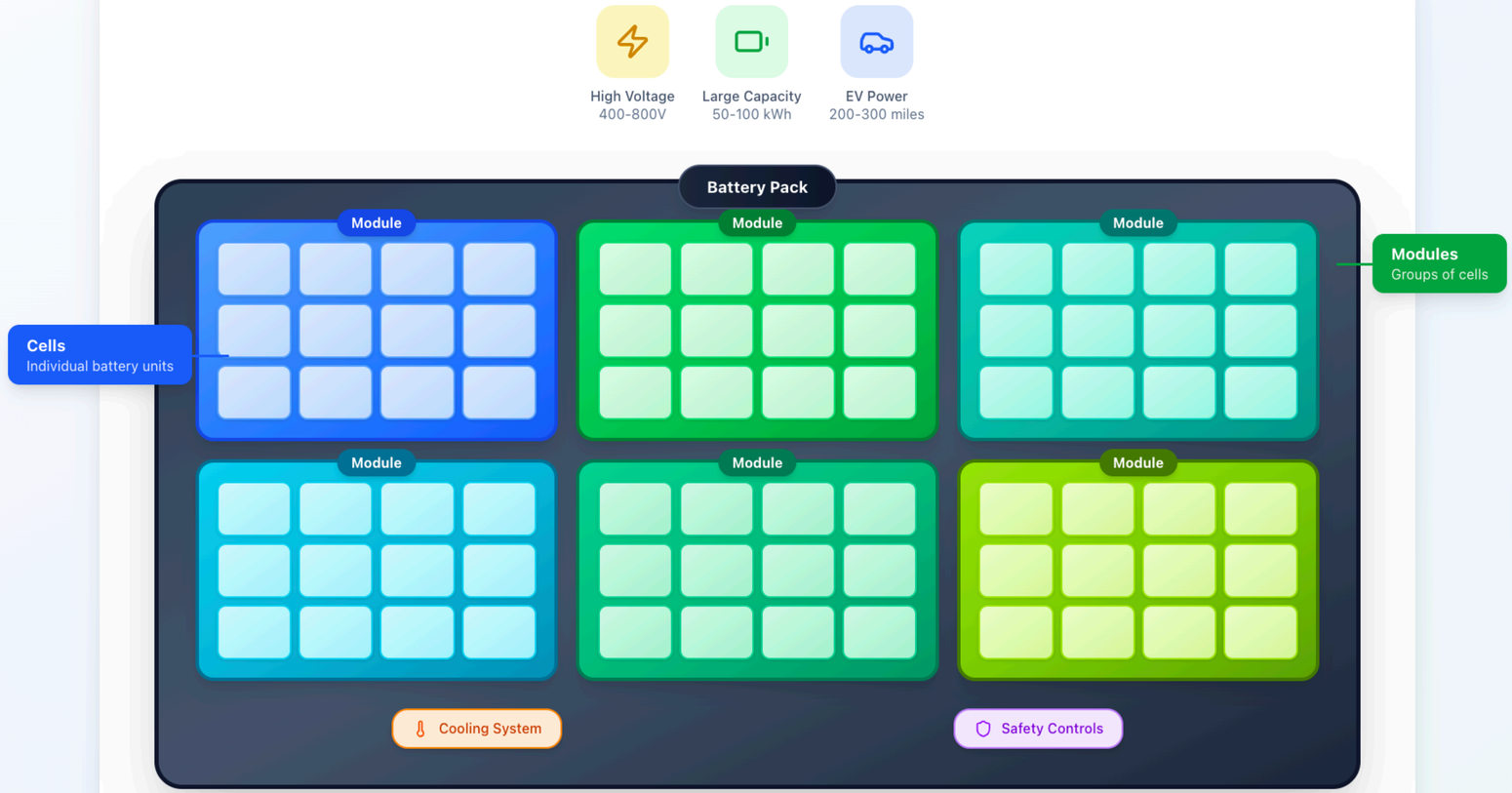
- Designed to power vehicle movement
- High energy and long life
- Requires safety and monitoring



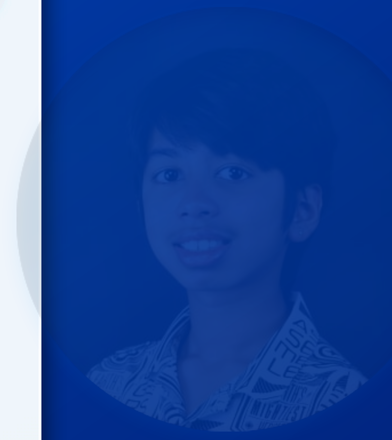
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What is an EV Battery?

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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



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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?

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Battery Aadhaar

Digital Identity for Batteries

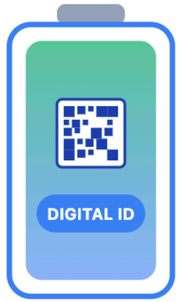
Battery Aadhaar is a digital identity that stores, tracks, and manages battery data across its entire lifecycle.

National Digital Registry
Centralized Battery Database

State of Charge
SoC: 85%

State of Health
SoH: 92%

Remaining Useful Life
RUL: 3.2 Years

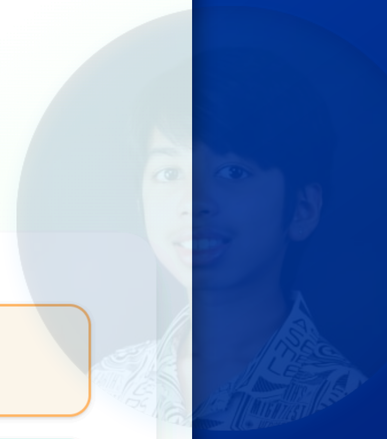


Unique Battery ID
Scannable QR Code

Battery Chemistry
Li-ion NMC

Manufacturing Details
2024, India

Usage History
450 Cycles



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Benefits Battery Aadhaar

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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.

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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 ?

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- 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.

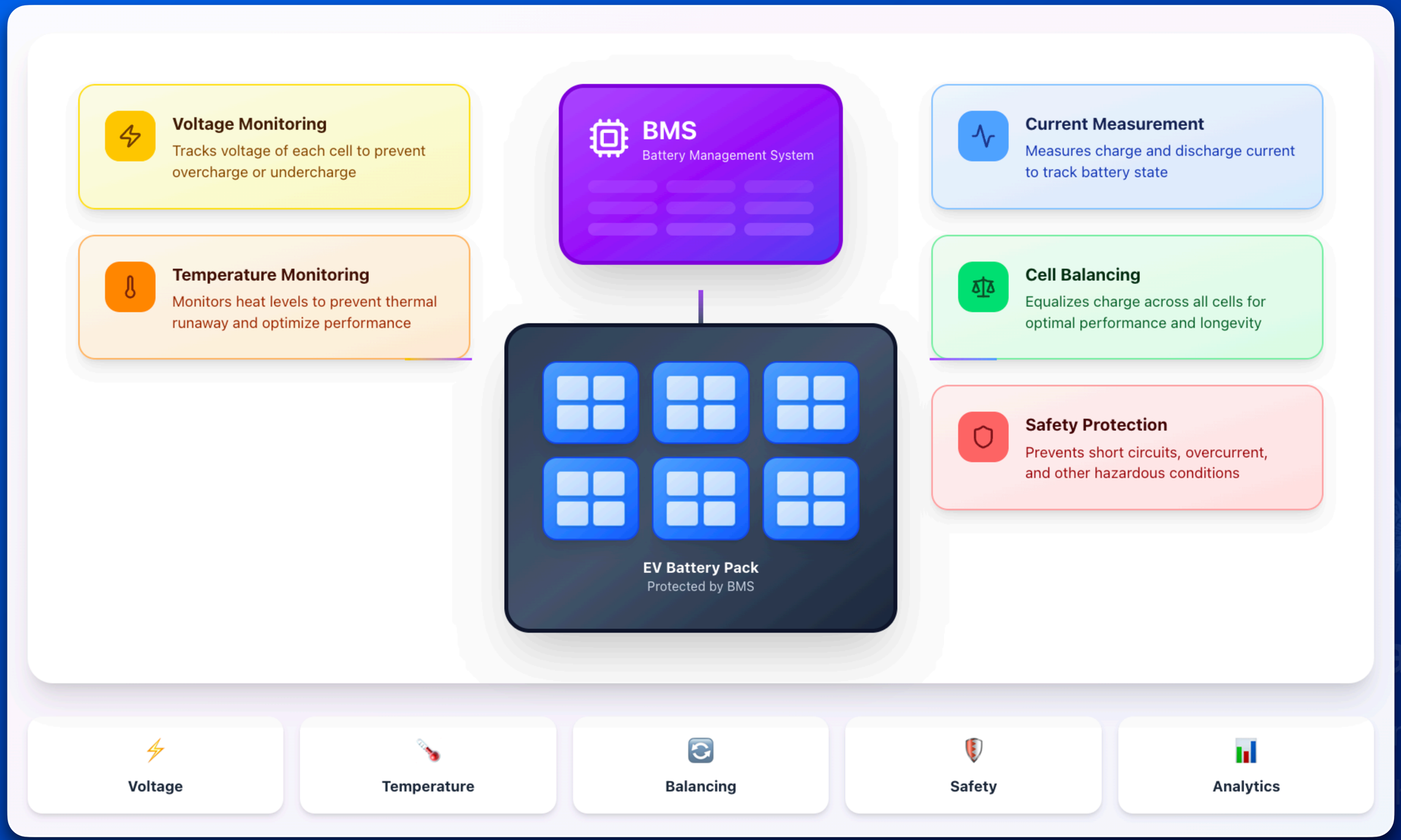
Without a BMS, an EV battery cannot operate safely. It continuously analyzes thousands of data points per second to ensure optimal performance, prevent damage, and maximize battery life.

Critical Safety Component

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What is a Battery Management System - BMS ?

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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)

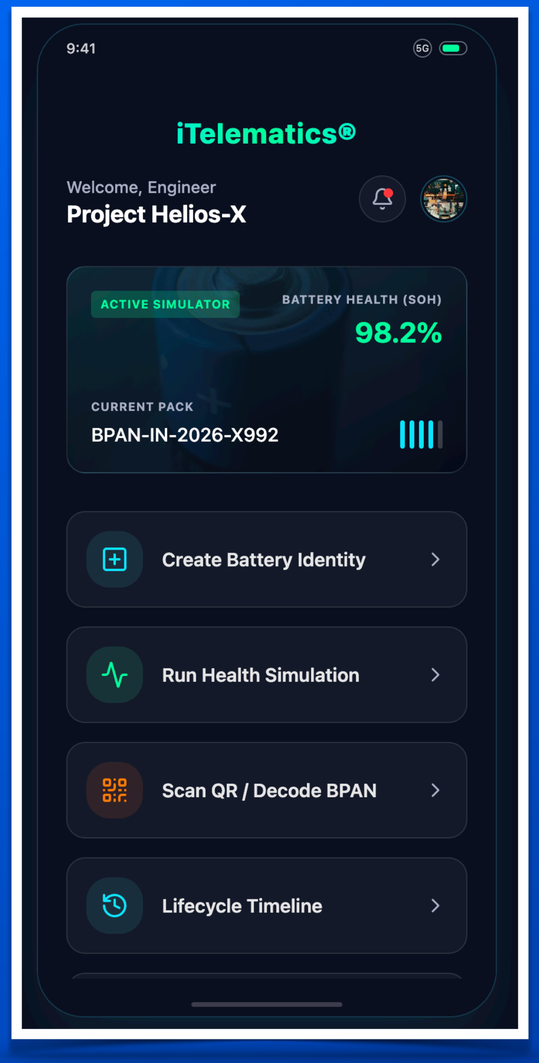


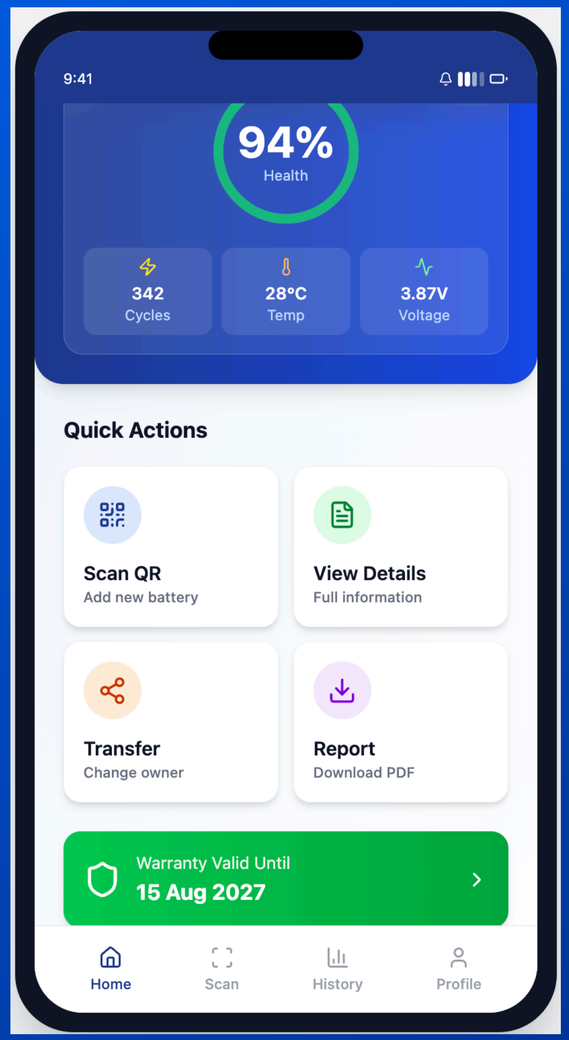
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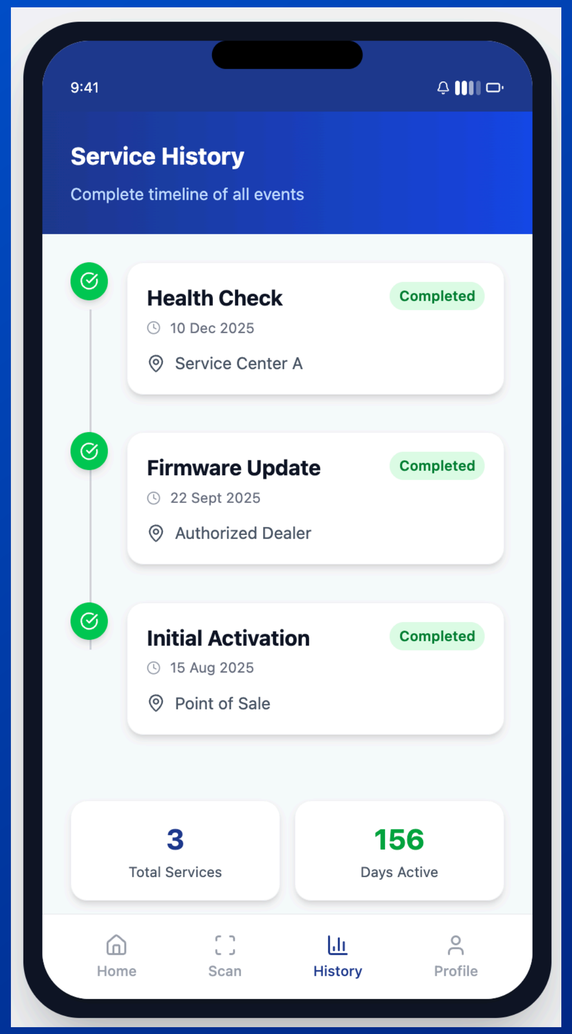
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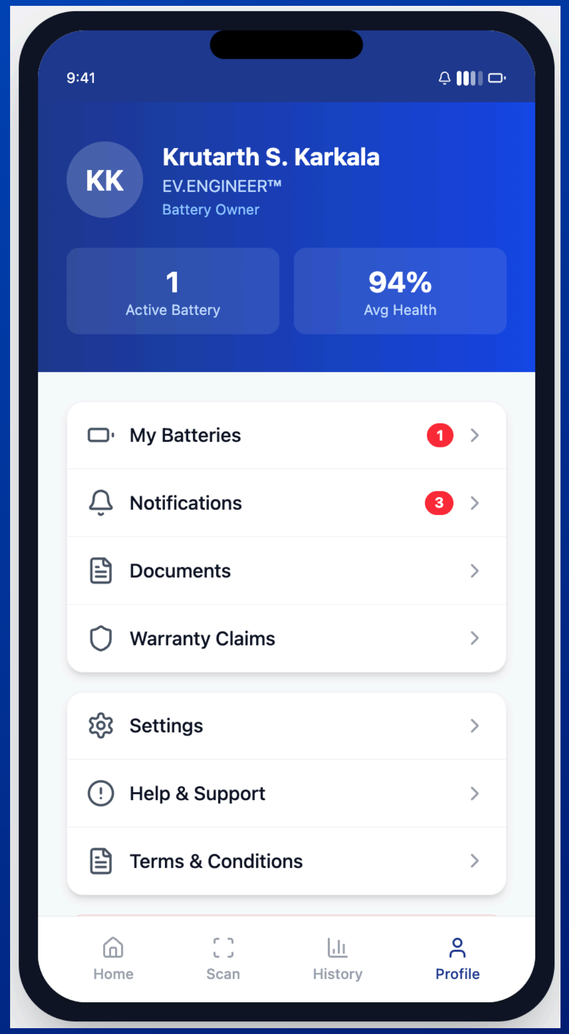
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https://tweak-stand-28567793.figma.site/

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.



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Battery Aadhaar System Architecture

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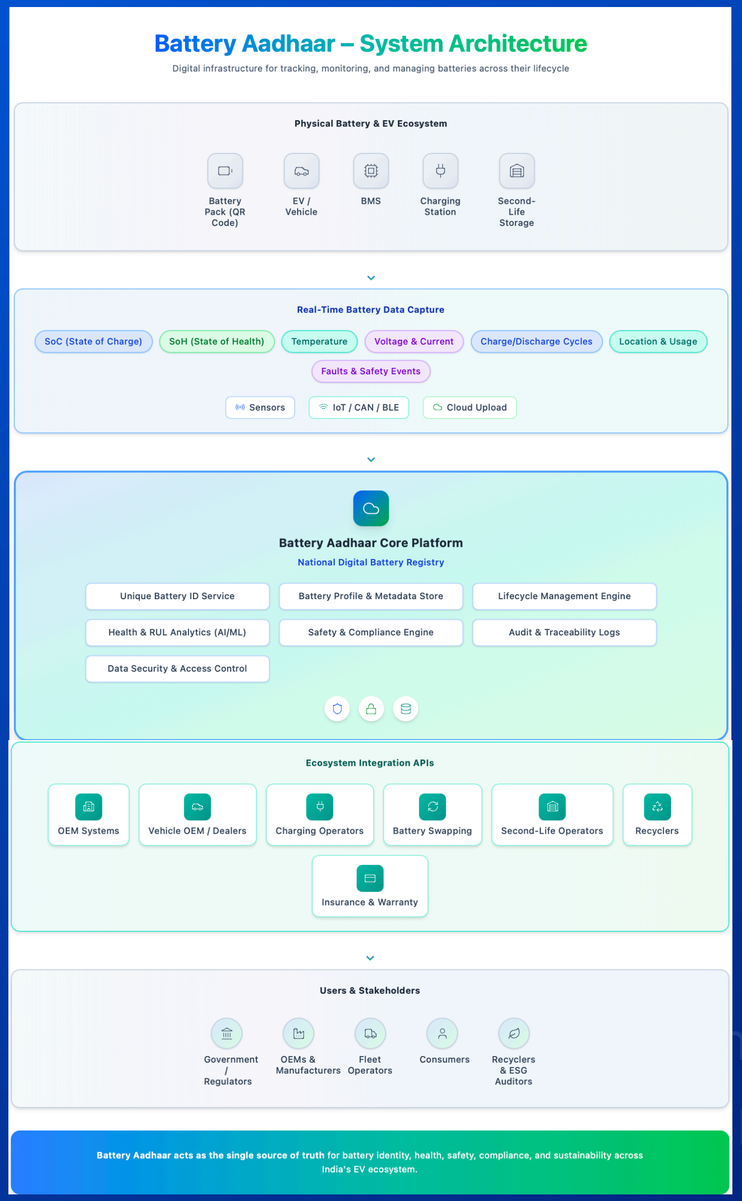
Physical Battery & EV Ecosystem

Real-Time Battery Data Capture

Battery Aadhaar Core Platform

Ecosystem Integration APIs

Users & Stakeholders



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Battery Aadhaar System Architecture

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Battery Aadhaar – System Architecture

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

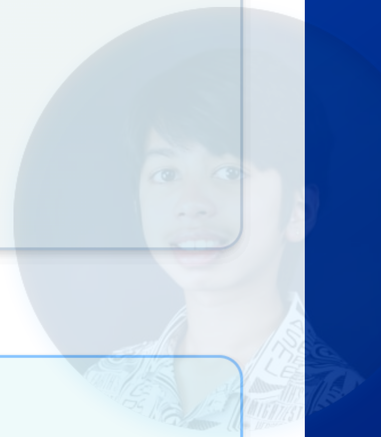
Physical Battery & EV Ecosystem

- 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



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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

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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.

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Three Parts of Battery Aadhaar

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



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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)

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



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Battery Material & Carbon Footprint

KRUTARTH.in™

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



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Battery Dynamic Data (Live Data)

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



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Why Battery Aadhaar is Important for Future?

KRUTARTH.in™

- 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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Thank you



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