Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

On behalf of:
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
of the Federal Republic of Germany

Deloitte.

Battery Ecosystem: A Global Overview, Gap Analysis in Indian context, and Way Forward for Ecosystem Development

Workshop presentation

13 May 2022

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
World Resources Institute
icct The International Council on Clean Transportation
International Transport Forum
SLOCAT Partnership
Agora Verkehrswende
REN21

CONTENTS

Climate concern, COP26, and India's net-zero commitment…

Climate change – a growing global challenge…

- **19 of the top 20 warmest years** on the planet have occurred in the 21st century itself
- ★ **2015: COP15** – first time every country entered into a **legally binding commitment** to reduce emission and to limit global warming to **well below 2 degrees** and aim for **1.5 degrees**
- ★ **2021: COP26** – secured **near-global net zero**, **NDCs from 153 countries with India being one of them**

"Glaciers are melting, sea levels are rising, cloud forests are dying, and wildlife is scrambling to keep pace." - Nat Geo

India's "Panchamrita" to counter global warming and climate change…

1| Reaching **non-fossil energy** capacity of 500 gigawatt by 2030

2| Meeting 50 per cent of energy requirements from **renewable energy** by 2030

3| Reducing projected **carbon emission** by one billion tonnes by 2030

4| Reducing **economy's carbon intensity** by less than 45 percent by 2030

5| Achieving **net zero** by 2070

Battery technology – Driving decarbonization and global energy transition

Growing environment concerns have led to the rapid adoption of...

Electric Vehicles (EVs)

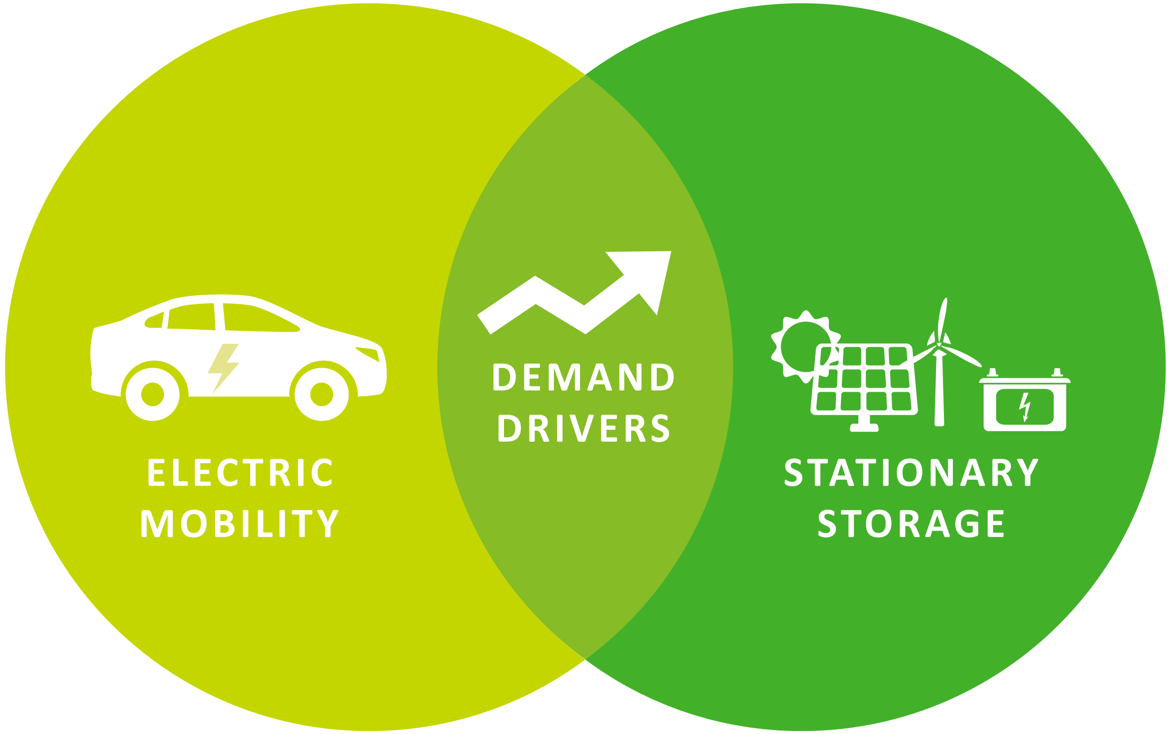
Renewable Energy (RE)

...and the characteristics of batteries makes them the best fit to use in EVs and provide grid support from intermittent RE

- Transportation industry has **huge carbon footprint** and there is a dire need to replace polluting ICE vehicles
- **High energy and power density** of batteries makes them the most ideal candidate to replace ICE vehicles

- Renewables have been adopted worldwide to replace polluting thermal power plants
- However, power from RE plants is intermittent and there is need for a solution to **firm the RE power**
- Battery storage acts as such **flexibility solution**

Battery storage industry has grown at **~25% CAGR** in the last decade owing to two major demand drivers:



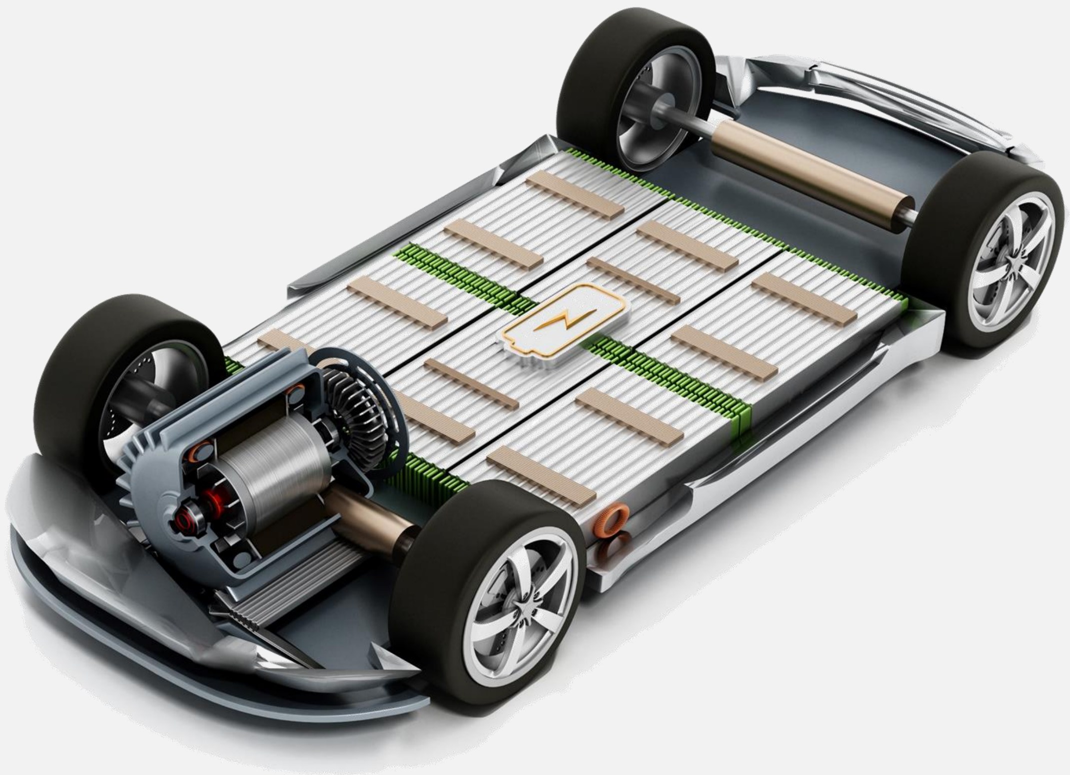
With India aiming ambitious net-zero goals, **creating an enabling ecosystem for batteries** becomes **pivotal**

Brief description of the study around traction batteries

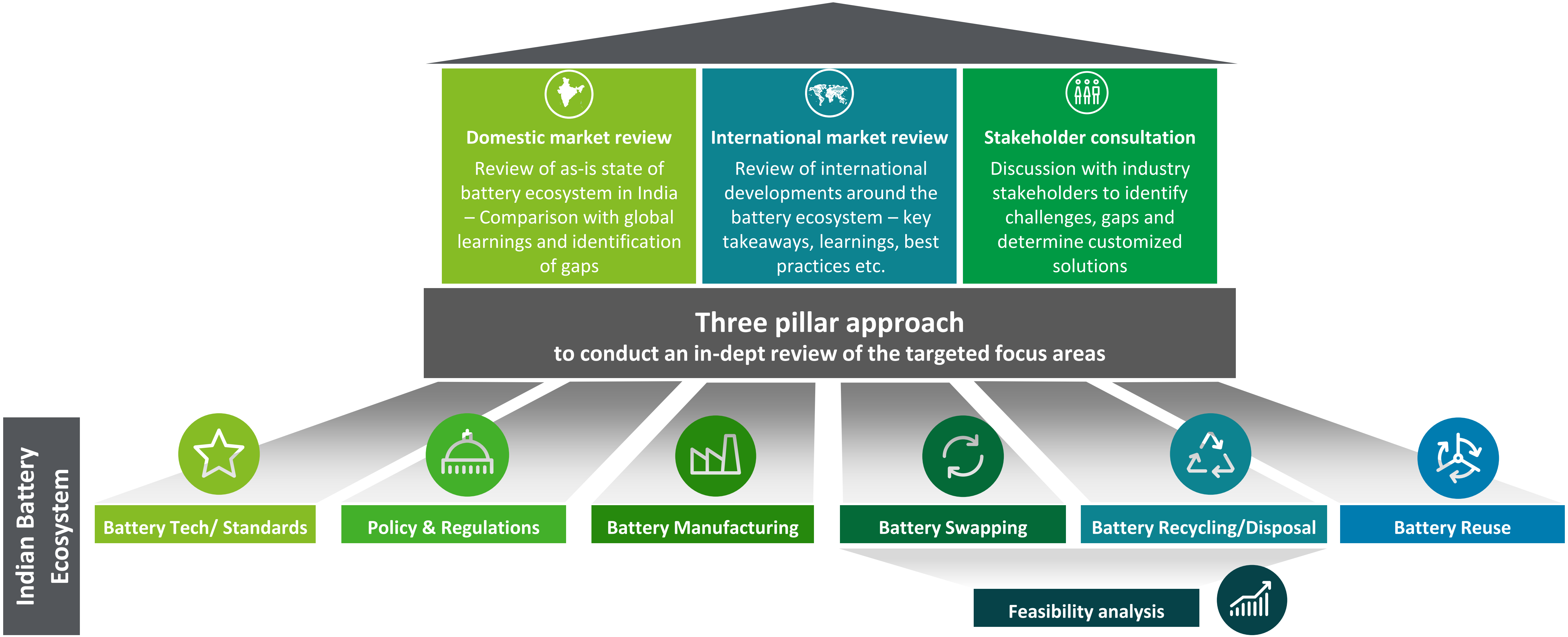
The study aims to provide a global overview and perform gap analysis in the Indian context and suggest a way forward for battery ecosystem development looking into:

- ✓ **Value chain** for **traction batteries** and current scenario of sourcing, manufacturing, assembling, reuse, and recycling in India and globally
- ✓ **Battery standards** in India, key gaps and ways to bridge them
- ✓ Policies, Regulatory, technical and logistical **barriers** to the **battery swapping**, disposal, recycling and reuse
- ✓ **Financial and economic analysis** of battery swapping and battery recycling businesses

This study is unique as it focuses on the complete battery ecosystem



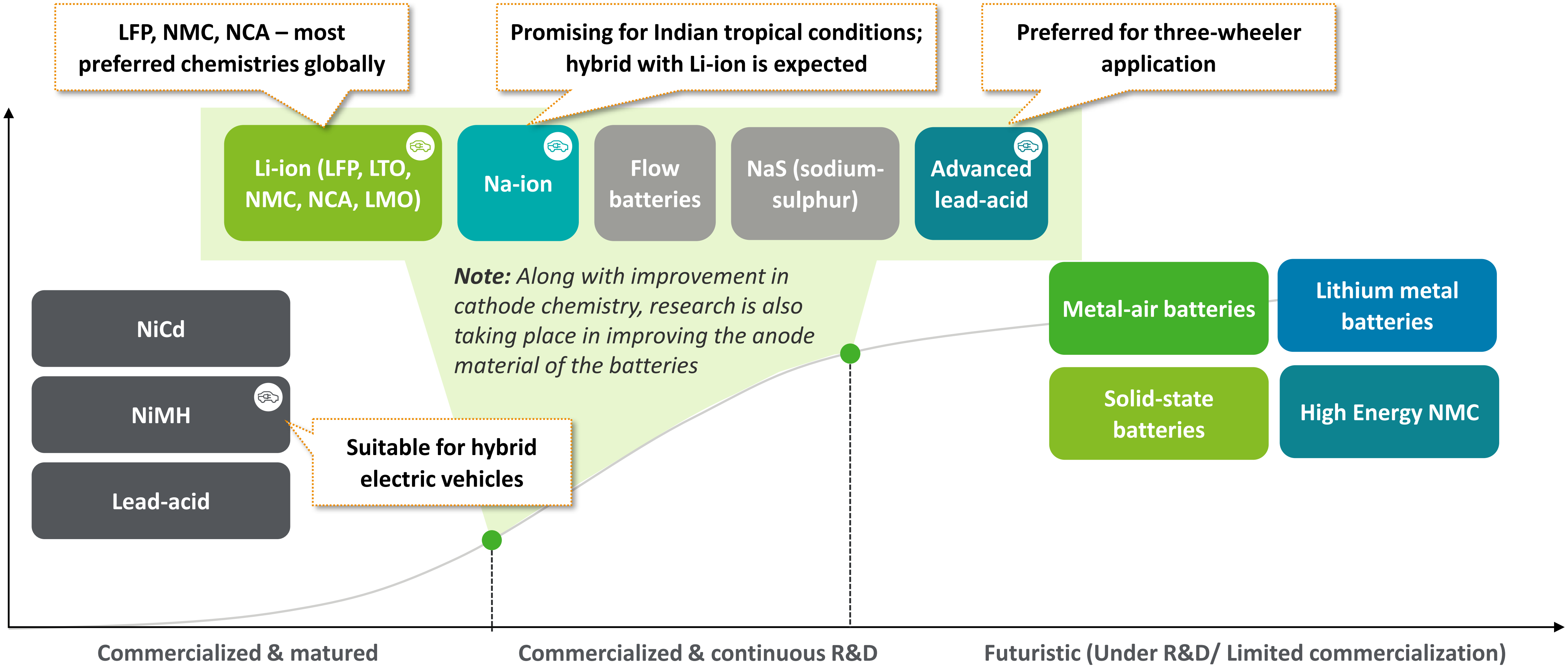
Approach to the assignment



Key study findings

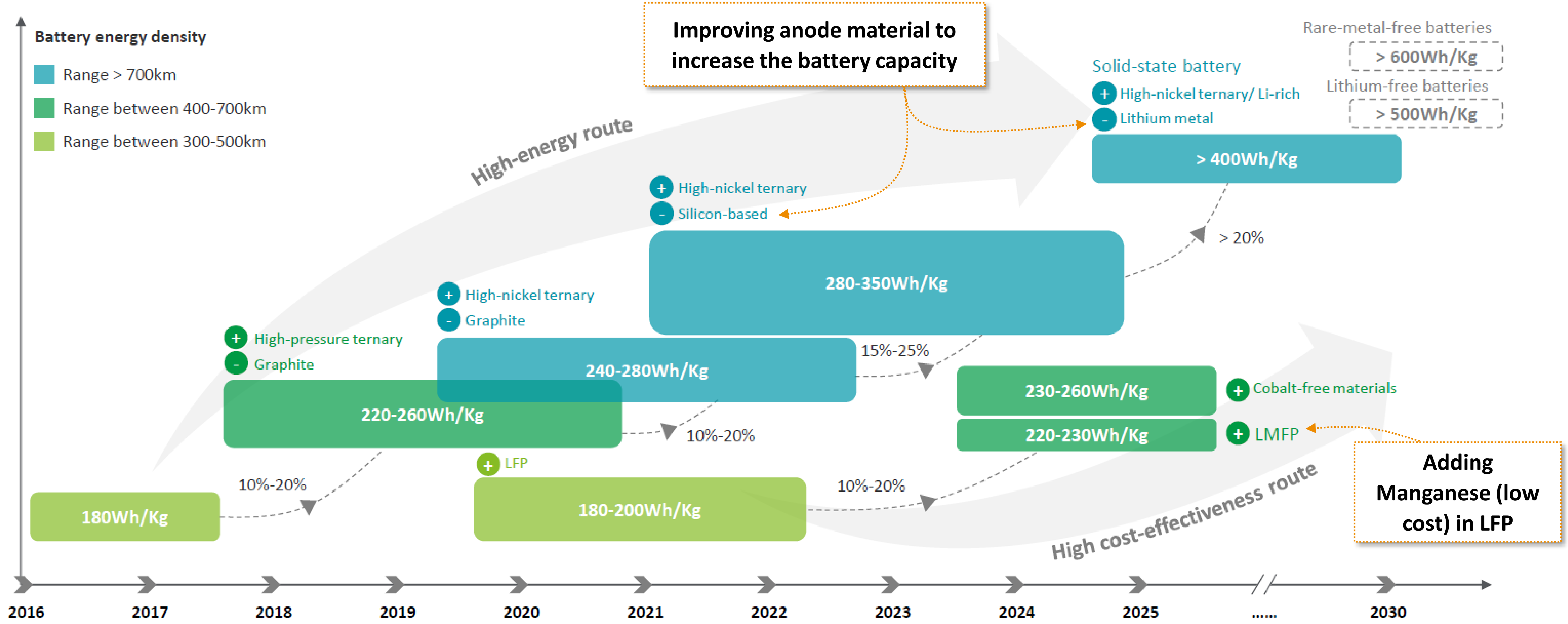
1 | Battery Technology

Lithium-ion is here to stay in the Indian EV market – for at least this decade…



Development of lithium batteries could be **restricted by the shortage of lithium resources**, **sodium ion** batteries have shown potentials as an alternative

Energy density improvement in Li-ion chemistries will remain the priority for global OEMs…



Source: Deloitte analysis

Given India's tropical conditions, chemistries with **high thermal runaway** temperature such as **LFP** are more likely get adopted in the Indian EV industry owing to safety concerns

Key study findings

2 | Battery Standards

Standards & organizations covered in the study

Organizations: IEC International Electrotechnical Commission, ISO, CENELEC, GB, UL

Electric Vehicles

Uses

Battery Technology

- Lead Acid
- Lithium-ion
- Nickel Metal Hydride
- Nickel Cadmium

Governed By

★ Focus area

Standards

- General
- Safety
- Performance
- Transportation
- Recycling
- Abuse Testing
- Communication

While India has notified domestic versions of the international battery standards, it currently completely lacks in covering the recycling activity of batteries

Mapping Indian standards with global:

Chemistry	Standards			
	Performance and Lifecycle	Safety	Transportation	Recycling
Lead Acid	✓	✓	✓	✗
Lithium-ion	✓	✓	✗	✗
Nickel Metal Hydride	✓	✓	✓	✗
Nickel Cadmium	✓	✓	✓	✗

Even though Indian standards are present for certain aspects of the **battery ecosystem, testing parameters, additional tests** could be included in existing standards apart from developing newer standards for comprehensively capturing the battery ecosystem.

Key recommendations (1/2)

Considering the growing battery industry, India needs to develop its own **standards for battery recycling**. International standards that can be referred for the same are:

Lead acid:

- EN 61429:1996, IEC 61429:1995, J3071, J2984

Lithium-ion:

- J3071, J2984

NiMH:

- EN 61429:1996, IEC 61429:1995, J3071, J2984

NiCd:

- EN 61429:1996, IEC 61429:1995, J3071, J2984

For lead-acid and Ni chemistries, measurement of rated capacity should be done at varying levels of charge / discharge rates to determine performance under different operating conditions

Lead acid and Ni chemistries:

- SAE standards

For Li-ion batteries, Indian standards lack mechanical tests such as drop, penetration and saltwater immersion which can be taken from IEC 62660-2

Key recommendations (2/2)

For Li-ion, aspects such as thermal shock test, thermal runaway, thermal cycling, dewing, emissions, salt spray, and flammability could be referred from UL and SAE standards

QC/T standards include requirements for components viz. **vehicle charging battery enclosure** and **swapping battery enclosure** which can be adopted in India to promote uptake of battery swapping business

Battery should be able to deliver a proper **cranking power** is in case the vehicle is idle for a long time. This is applicable for HEVs. Reference from the same can be taken from IEC and ISO standards.

Key study findings

3 | Policy and Regulatory Landscape

Approach for global study & key findings

Value chain covered:

Mining › Battery manufacturing › Battery swapping › R&D › Reuse & recycle

Economies covered:

Key takeaways:

- **National level policy** and **regulatory initiatives** are effective ways to promote battery industry
- **Subsidies & incentives** are essential for kick-starting a new industry
- Continuous focus on **Research, development, capacity building** for overall development
- **Demand creation** must remain in focus for creating a suitable ecosystem for battery

Notable measures adopted globally to promote battery ecosystem

USA released a **National blueprint for lithium batteries** which provides for a **ten-year plan** to guide investments in the domestic **lithium-ion supply chain**. (*National blueprint for lithium batteries 2021–2030, 2021*)

China notified the **national standards for battery swap safety requirements** for EVs to **improve the level of safety** during battery swapping. *(National standard for battery swap safety requirements for EVs, 2021)*

South Korea has launched a government led initiative to **commercialize lithium sulfur, solid state & lithium metal batteries** will be commercialized by 2025, 2027 and 2028 respectively (*K-Battery Strategy, 2021*)

Australia has offered recyclers a **rebate per kg** to **collect, sort and process end-of-life batteries**. Major **battery manufacturers** were also encouraged to participate in the scheme to improve the rate of recycling *(Battery Stewardship Scheme, 2019)*

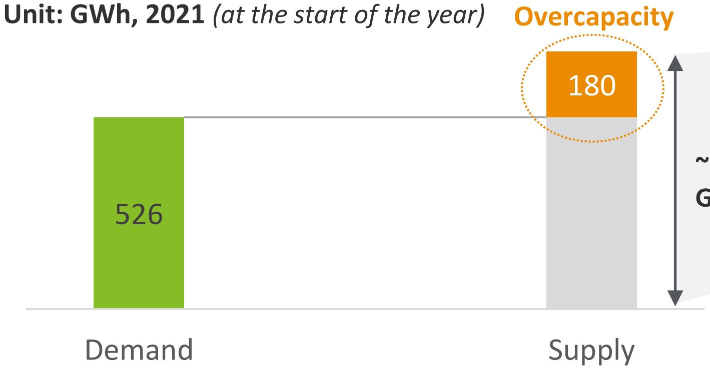
Key study findings

4 | Battery Manufacturing

Battery manufacturing – Global & Indian market overview

Global market overview

Aggressive expansion in recent years has currently led to a situation of oversupply in the global Li-ion battery industry…



Source: S&P Global Market Intelligence

79% contribution (558 GWh) (2021)

- **Why China?**
  - Upstream chain dominance (low input cost)
  - Cheap skilled labor, rental, electricity
  - High demand

★ **Setting up a facility in China gives a manufacturer location advantage of almost $6-7/kWh**

India market overview – Present & Future

Upstream — Midstream — Downstream

Localization level:	Mining	Refining	Active	Cell manufacturing	Pack manufacturing
2022	LOW	NIL	LOW	NIL	HIGH
2027	LOW	MEDIUM	MEDIUM	HIGH	HIGH

★ ACC PLI Scheme (Mar 2022)

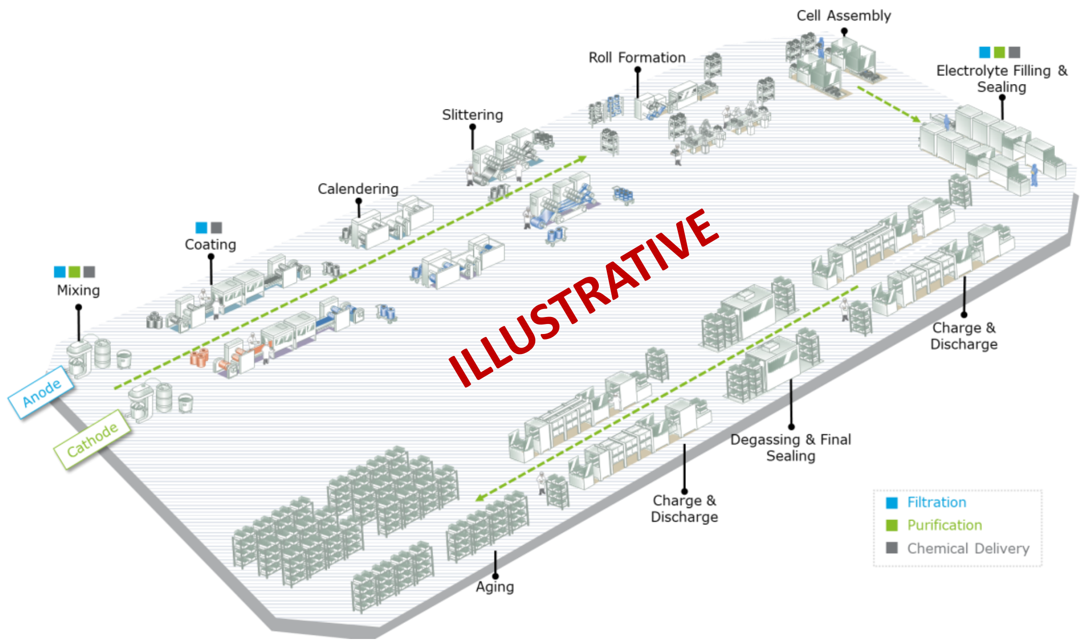
Key takeaways

- India could become an **export hub** for battery cells by 2027
- High **upstream & midstream expansion** could be witnessed in the next 5 years
- **Business model shift** from "global technology partner dependency" to "self or domestic reliance"

xx Localization level

Setting up a cell manufacturing in India

Expected expenditure…



Capex

1,000 – 1,500 Cr per GWh (Total capex)	
Plant & equipment	INR 900 – 1400 Cr/GWh
Building & surroundings	INR 60 – 80 Cr/GWh
Land requirement	5-8 Acre/ GWh

Opex

INR 500 – 800 Cr* (Annual opex)	
Power requirement	45-55 MUs/ GWh/ year
Water requirement	7000-9000 liter/ GWh/ day
Manpower requirement	750 nos. /GWh

** For 1 GWh*

Note: The capex and opex figures will vary based on technology transfer cost, battery chemistry, plant location etc.; the above figures are for a hybrid (LFP & NMC) manufacturing plant

Clearances required…

1 Environment and Forest Clearance

- Screening
- Scoping
- Public Consultation
- Appraisal

2 Other Statutory Clearances and Approvals

- Permission for land use
- Water & Air Pollution Control Act – NOC
- Import/ export code numbers
- Authorization for waste generation

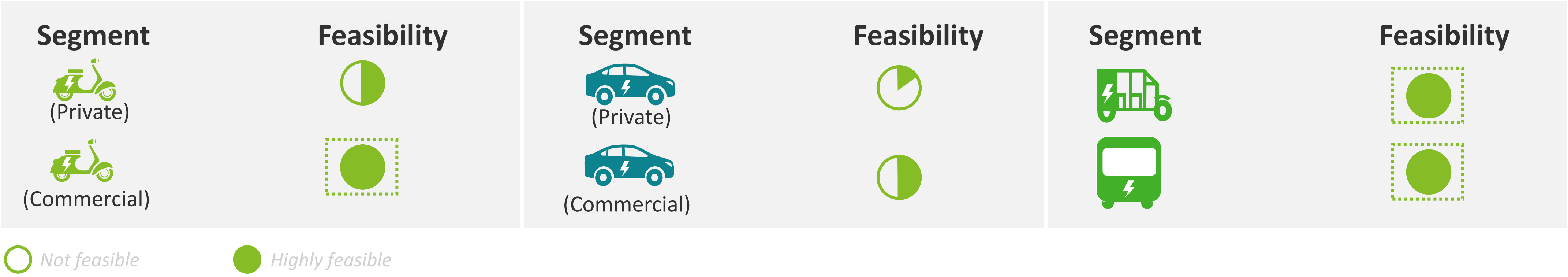
Note: Comprehensive list of approvals/ clearances along with concerned agency is provided in the report

Key study findings

5 | Battery Swapping

Battery swapping in India – An overview

A time-saving alternative to charging but not feasible for all…



Business models – Present & future…

Three types:

- **Fleet operator driven**
- **Battery Swapping services provider driven**
- **OEM driven**

Payment models…

Two types:

- **Pay per use/ pay-as-you-go**
  user pays for the energy charges corresponding to the battery capacity which is used for running
- **Battery as a service**
  user signs up for a battery rental plan in which it pays monthly fees in return for access to a battery swapping on regular basis

Setting up a battery swapping station – Financial analysis output

Key model inputs

- The model was developed for a swapping operator having **20 swapping** stations with **15 batteries in each** swapping station
- The batteries are **modular in nature** to cater to both E-2Ws and E-3Ws (through stacking)
- Users can either pay based on **usage (INR/kWh)** or a **fixed rate per swap (INR/swap)**

Particulars	Value
Batteries per user	1.5
Battery Size	1.5 kWh
Battery cost	INR 35,000
Investment per station	INR 9 lacs
Utilization (cycles per day)	4 (Y1) to ~12 (Y10)
Battery charging time	1.5 hours
Fixed swapping rate	INR 50/swap
Usage based swapping rate	INR 35/kWh
Area required per station	150 sq. feet
Manpower per station	2 nos.

Note: *All inputs are verified from market players*

Key model outputs*

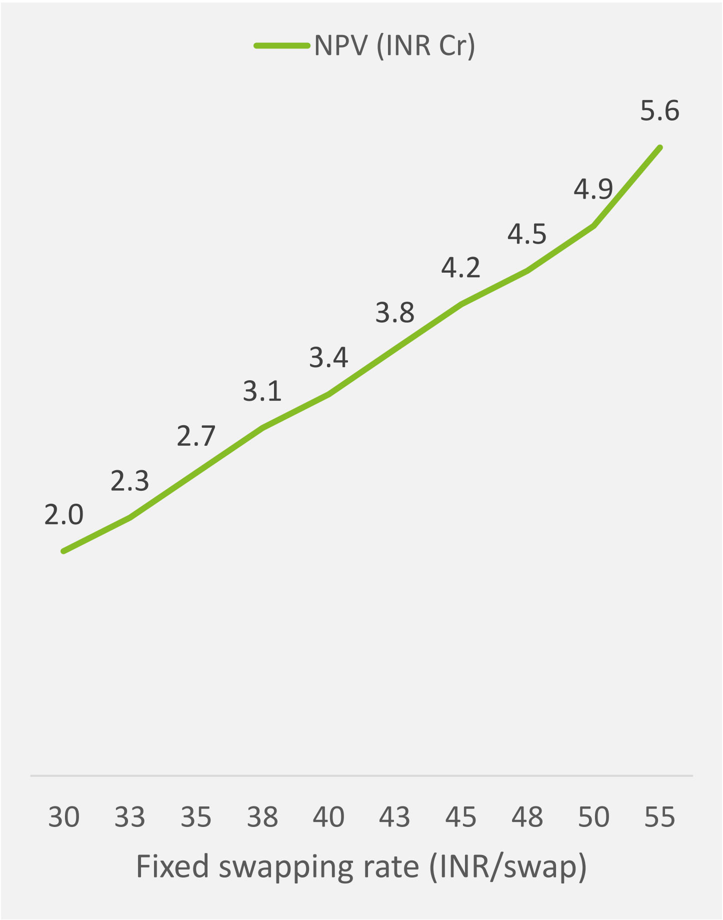
#	Output	Value
1	Total CAPEX	INR 5.7 Cr
2	NPV	INR 4.9 Cr
3	IRR	32.28%
4	Avg. Operating Margin	27%
5	Emission Savings (NOx)	48.37 tonnes

** Assuming 30% users opt for fixed swapping rate and remaining opt for usage basis swapping rate*

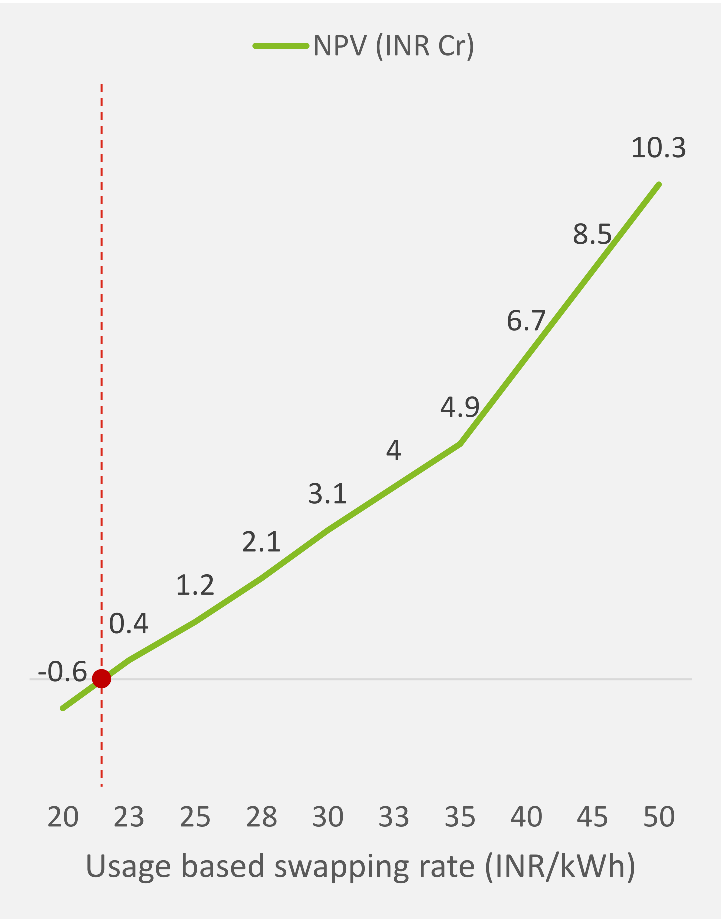
Sensitivity analysis of battery swapping stations

NPV vis-à-vis…

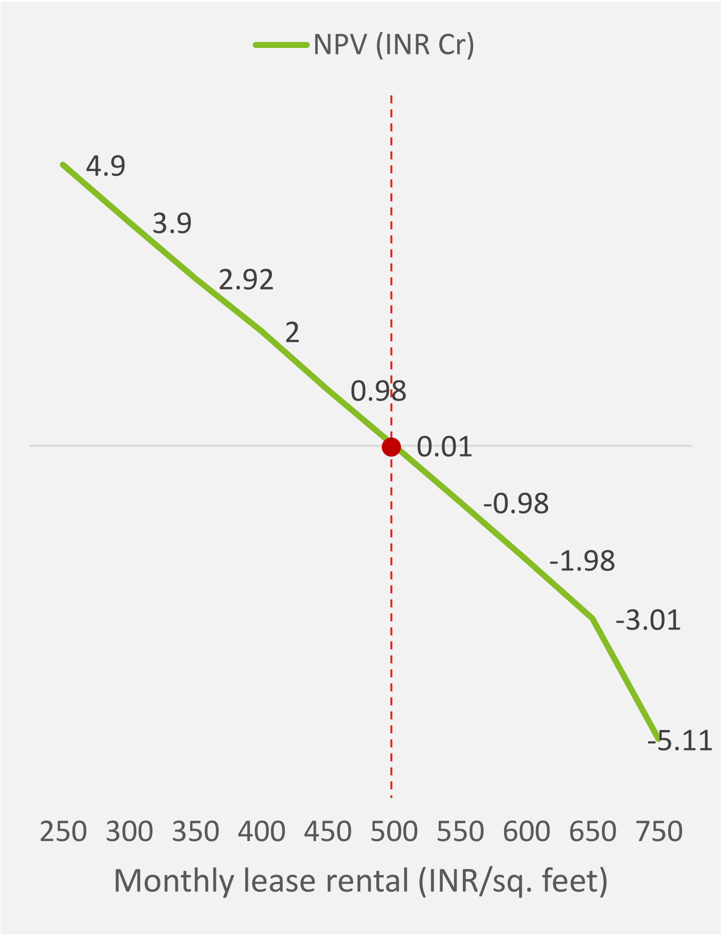
Fixed swapping rate



Usage based swapping rate



Monthly lease rental



Key study findings

6 | Battery Recycling

Recycling of Li-ion batteries – Technology overview

Globally, there are three prominent battery recycling technologies

Three types:

TECHNOLOGY	3 Li 6.94	28 Ni 58.69	27 Co 58.93	25 Mn 54.93	6 C 12.01	Suitable technologies
PYRO	✓ (Potentially economical)	✓ (Economical)	✓ (Economical)	✓ (Potentially economical)	✗ (Not extracted)	Lithium-ion, Nickel Metal Hydride, Lead Acid
HYDRO	✓ (Potentially economical)	✓ (Economical)	✓ (Economical)	✓ (Economical)	✓ (Potentially economical)	Lithium-ion, Nickel Metal Hydride
DIRECT	✓ (Economical)	✓ (Economical)	✓ (Economical)	✓ (Economical)	✓ (Potentially economical)	Lithium-ion

Economical | Potentially economical | Not extracted

Hydrometallurgy – Technology of choice

- Basis technology readiness, process complexity, recovered material quality & quantity, energy usage, toxic material containment, capital cost, and battery presorting requirements our study concluded that **Hydrometallurgy is the best fit for recycling lithium-ion batteries** which are the mainstay of the EV industry
- **Recyclers in India** are foraying with Hydrometallurgy as the technology of choice for recycling lithium-ion batteries

Setting up a battery recycling facility – Financial analysis output

Key model inputs

- The model was developed for a 10,000 MTPA **hydrometallurgical or pyrometallurgical** processes
- Assumptions were collected through **primary interactions** and **secondary research**

Particulars	HYDROMETALLURGY	PYROMETALLURGY
CAPEX*	INR 163 Cr	INR 285 Cr
Electricity Consumption	0.035 kWh/kg spent battery	1.3 kWh/kg spent battery
Transportation Cost	INR 30/kg spent battery	INR 30/kg spent battery
Battery purchase cost	INR 135/kg spent battery	INR 135/kg spent battery
Capacity Utilization	50% in 1st year with YoY increase of 10% up to 95% from 6th year onwards	50% in 1st year with YoY increase of 10% up to 95% from 6th year onwards

*Note: * Excluding Land cost; #: Considering 0% grant*

Key model outputs#

1. Hydrometallurgy

1	NPV	INR 420 Cr
2	IRR	32.8%
3	Avg. Operating Margin	26.5%
4	Emission Savings (GHG CO2 eq.)	260.8 thousand tonnes

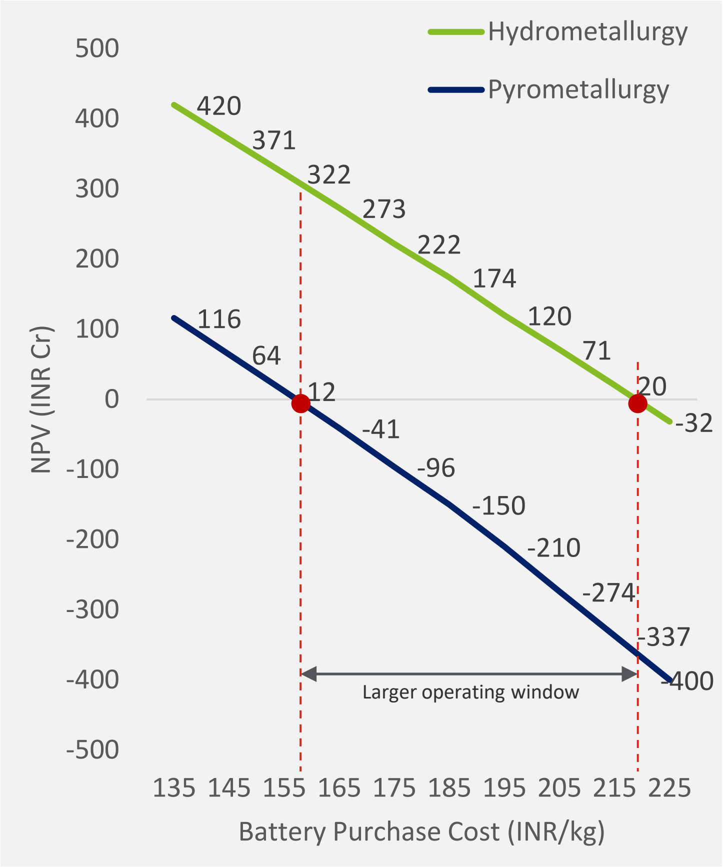
2. Pyrometallurgy

1	NPV	INR 116 Cr
2	IRR	15.8%
3	Avg. Operating Margin	14.5%
4	Emission Savings (GHG CO2 eq.)	124.8 thousand tonnes

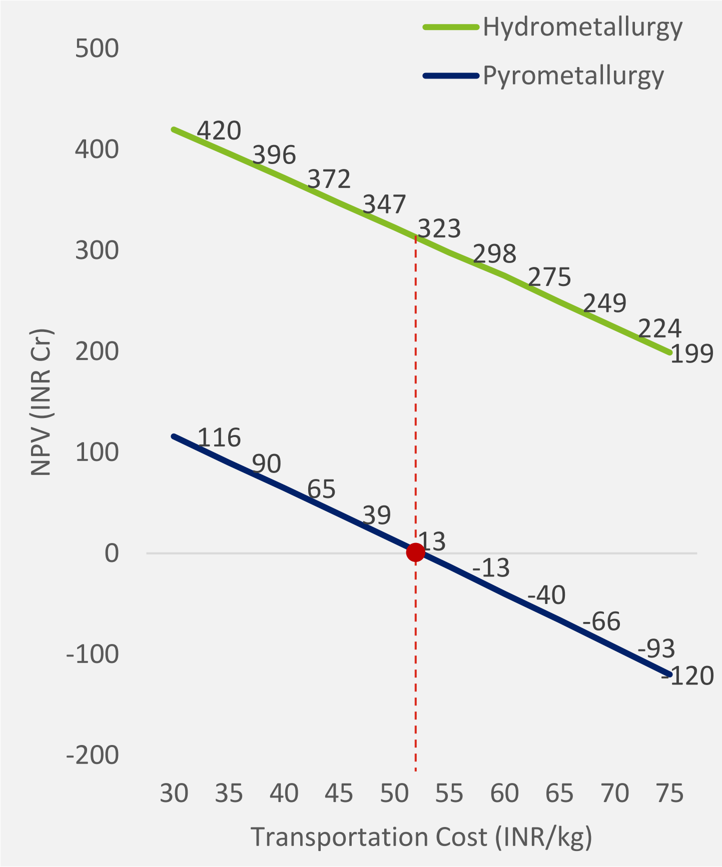
Sensitivity analysis of battery recycling facility

NPV vis-à-vis…

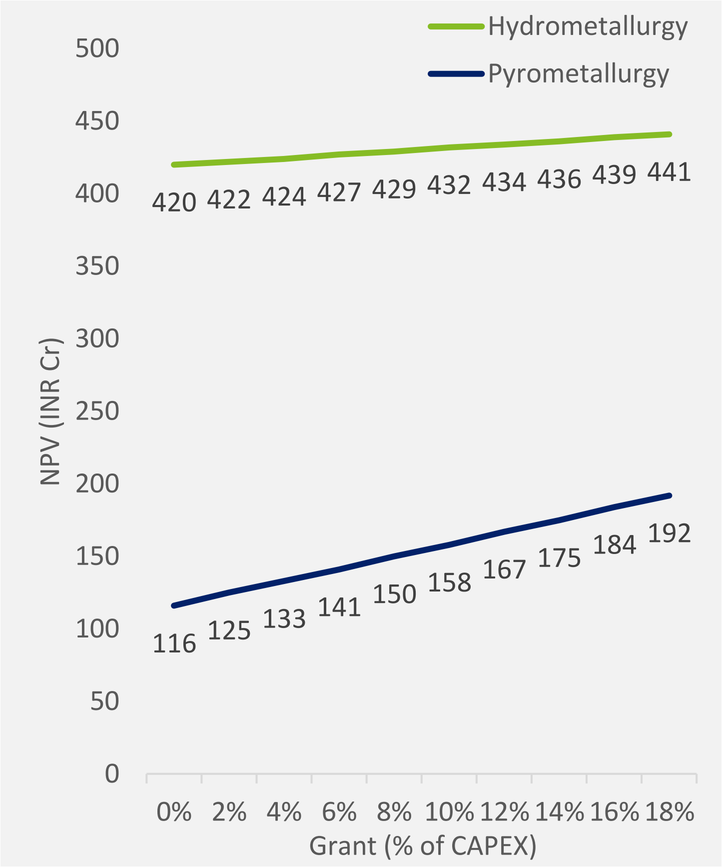
Battery Purchase Cost



Transportation Cost



Grant



Key recommendations

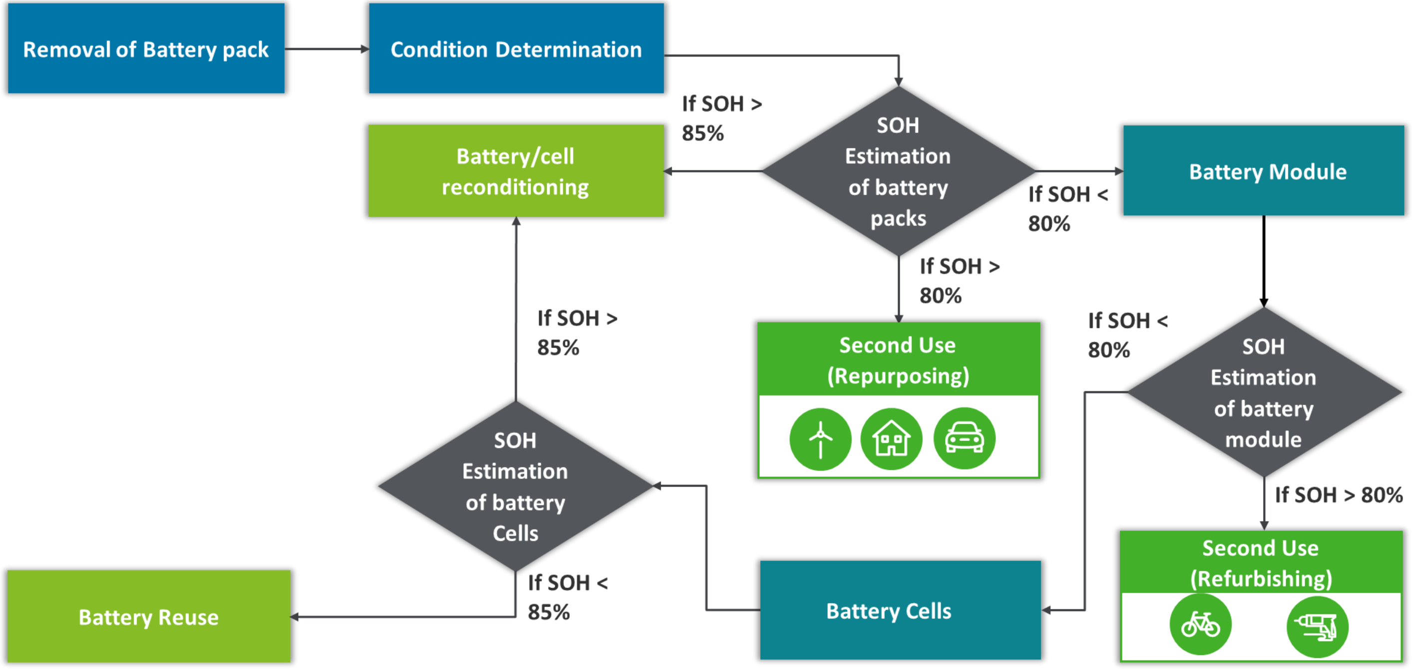
- **Encouraging design** for recycling practices with battery manufacturers in close collaboration with recycling industry
- **Institutionalization of recovery rates** from recycling processes in Battery Waste Management Rules; higher for matured technologies and lower for newer upcoming technologies
- **Development of battery reuse register** for keeping track of batteries in circulation after their first life and ensuring they are recycled after their second use along with a repository for battery EoL configurations
- **Development of national level not for profit battery collection schemes** could be introduced to formalize the channels for EV battery collection and proper disposal
- **Responsible battery disposal should be attributed to vehicle OEMs** having significant reach through their service centers which could act as collection centers

Key study findings

7 | Battery Reuse

Li-ion battery reuse – Overview

Battery reuse – Decision chart...



Methods/ processes

Reconditioning: Replacement of dead cells or packs to reuse the assembly as an EV battery

Refurbishing: Opening the battery, replacing degraded parts, reassembling, etc.

Repurposing: Replacement of some cells or packs, but only used in stationary applications

Reusing: The individual cells are reused in a wide variety of applications

Major Applications...

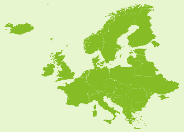
- Reuse in EVs
- Grid scale energy storage
- Renewable Energy
- Backup power/ UPS
- EV Charging

Li-ion battery reuse – Challenges

Challenges in Indian Battery Reuse Ecosystem

Type	Details
Market Side Challenges	• Unproven performance, reliability, and safety of reused batteries • Complexity of repurposing non-standardized battery packs • Declining prices of new battery packs
Policy Side Challenges	• Inclination towards Battery recycling • Presence of the unorganized players in the ecosystem

The key enablers and incentives to ensure growth of reuse ecosystem in the following countries were reviewed.



European Union

South Korea

USA

Key recommendations

The lack of guidelines and management rules for battery reuse needs to be addressed. The guidelines for battery reuse and associated standards should be drafted and included in individual state EV policies.

The growth of infrastructure for battery reuse and use of such applications which will increase the demand of repurposed batteries should be promoted by **rolling out appropriate subsidies**

OEMs must include onboard diagnostic to accurately track the capacity, and various characteristics to determine the viability of battery for reuse

R&D should be directed towards **examining battery degradation, newer technologies of battery reuse, SOH estimation etc.** in different processes for improved battery management

THANK YOU!