EXECUTIVE SUMMARY

STATE OF RESEARCH AND DEVELOPMENT IN ELECTRIC VEHICLE BATTERY TECHNOLOGY

WRI-INDIA.ORG
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Today, lithium-ion (Li-ion) batteries have established themselves as the leading storage technology for transportation applications. There are multiple Li-ion technologies with different types of chemistries, each with its distinct performance characteristics, depending on the application requirements and vehicle size.

Energy storage for electric vehicles (EVs) is a continually evolving set of technologies owing to the introduction of next-generation chemistries (such as lithium-sulfur batteries, solid-state batteries, inorganic liquid electrolytes, high-voltage cathodes, and silicon and lithium metal anodes) and the gradually declining use of older chemistries.

Stronger collaboration must be established between industry and academia if advanced technologies are to be developed in India. A healthy network of incubation centers and centers of excellence (CoEs) can help bridge the gap between industry and academia and stimulate the creation of a new start-up ecosystem in the field of clean energy technologies.

Infrastructure for recycling Li-ion batteries must be set up in parallel with the development of Gigafactories and other battery-industry-related efforts, as recycling may become an important source of raw materials in the future.

Introduction

The target set in the Paris Agreement—to limit the global average temperature rise to well below 1.5°C above pre-industrial levels—is difficult to achieve with reasonably accessible technologies today, even when very stringent and ambitious abatement strategies are assumed. Hence, rapid technological advancement in the future is considered vital for bringing us closer to the targets. As transportation is one of the toughest sectors in which to achieve deep carbon emission reductions, a thorough understanding of technological solutions is imperative for us to put far-reaching solutions on the table, based on sound judgment and credible research. In particular, the electric mobility transition within the transportation sector is seen as a core pillar of deep decarbonization. Existing long-term strategies globally have typically identified it as a key priority, given that the transition can potentially enable renewable power to become a major low-cost transportation fuel in the future.

Although our electricity grid is currently dominated by fossil fuels, India has ambitious renewable energy plans that could significantly decarbonize the grid in the long term. This could enable EVs to decarbonize the transportation sector substantially in the future, unlike its contribution today, which is moderated by a fossil-fuel-dominated grid. India acknowledges the merits of this transition from internal combustion engine vehicles to EVs and has introduced several national- and state-level policies and incentives to promote it. Electric mobility, apart from addressing climate change concerns, will also help reduce India's oil import bill and enable it to move in the direction of energy independence and self-reliance.
Guidelines for registration of OEMs (original equipment manufacturers) and vehicle models under FAME India scheme approved

Notification for extension of Phase I up to March 31, 2018
Ministry of Heavy Industry and Public Enterprises & DHI

Notification to modify the scheme to amend electrical range targets for plug-in hybrid electric vehicle (PHEV) and battery electric vehicle (BEV) buses and specify new demand incentives for electric buses
Ministry of Heavy Industry and Public Enterprises & DHI

Notification to modify the scheme to include L5 category is included in the Retrofitment category under vehicles eligible to obtain demand incentives specified for the newly added category of vehicles
Ministry of Heavy Industry and Public Enterprises & DHI

Notification to modify FAME to include low-speed electric three-wheelers (with maximum speed not exceeding 25 km/hour) under vehicles eligible to obtain demand incentives, as well as to specify demand incentives for low-speed three-wheelers
Ministry of Heavy Industry and Public Enterprises & DHI

Notification for extension of FAME Phase I up to September 30, 2017
Ministry of Heavy Industry and Public Enterprises & DHI

Notes: ACC = Advance Chemistry Cell; FAME II = Faster Adoption and Manufacturing of Electric Vehicles in India Phase II; MoEF = Ministry of Environment, Forest and Climate Change; MoRTH = Ministry of Road Transport and Highways; PLI = Production-Linked Incentive.

Source: WRI India authors
The Union Cabinet approves the plan to set up a National Mission on Transformative Mobility and Battery Storage
Ministry of Heavy Industry and Public Enterprises & NITI Aayog

The Union Cabinet approves INR 10,000 crore programme under the FAME II scheme to be effective from April 1, 2019
Ministry of Heavy Industry and Public Enterprises & NITI Aayog

NITI Aayog released handbook to guide EV charging infrastructure in India

Government extends the deadline of FAME II up to March 31, 2024

Government approves Rs 18,100 crore PLI scheme for promoting ACC battery manufacturing

2018
FAME Phase I extended up to March 31, 2019 or until notification of FAME II, whichever is earlier
Ministry of Heavy Industry and Public Enterprises & Department of Heavy Industries (DHI)

Notification for extension of FAME Phase I up to September 30, 2018
Ministry of Heavy Industry and Public Enterprises & DHI

2020
MoRTH allows sale and registration of electric vehicles without batteries based on the type approval certificate issued by the test agency

Draft of Battery Waste Management Rules, 2020 from MoEF

The Union Cabinet approves the creation of a Phased Manufacturing Programme (PMP) to be executed between 2019–20 and 2023–24
Ministry of Heavy Industry and Public Enterprises & NITI Aayog

2021
The Union Cabinet approves the creation of a Phased Manufacturing Programme (PMP) to be executed between 2019–20 and 2023–24
Ministry of Heavy Industry and Public Enterprises & NITI Aayog

NITI Aayog released handbook to guide EV charging infrastructure in India

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Government approves Rs 18,100 crore PLI scheme for promoting ACC battery manufacturing

2019

About the report

This report presents a snapshot of commercially available EV battery technologies today as well as the state of R&D in EV battery technologies. It also provides recommendations on how to strengthen industry–academia collaboration to promote uptake of these technologies.

Through this study, we attempted to fundamentally improve our understanding of technological solutions for EV batteries in India. Many promising developments are occurring around the world, with researchers engaged in different areas such as reducing battery cost, increasing energy density, and improving durability and lifetime. In this paper, we explore battery designs, chemistries, and cell formats, and assess their potential in making the transition to EVs economically feasible in a resource-secure way for India. The report focuses on the current commercially available battery technologies as well as on battery research aimed at developing alternative technologies. The study explores the research and development (R&D) landscape for these batteries and investigates how the R&D community can work collaboratively and effectively with industry to address the challenges associated with the manufacture and uptake of battery technologies.

Key conclusions

Several policies and initiatives have been introduced by the Indian government in to speed up the adoption of EVs in the country. These efforts span various central ministries, including the Department of Heavy Industries (DHI), NITI Aayog, Ministry of Power (MoP), Ministry of Urban Development (MoUD), Ministry of Road Transportation and Highways (MoRTH) and the Department of Science and Technology (DST). Most notably, the FAME II scheme (DHI), which gives subsidies for EVs, and the Production Linked Incentive scheme (NITI Aayog), which subsidizes the setting up of Li-ion cell-manufacturing Gigafactories, are aimed at fast-tracking the transformation in the transportation sector.

Several state governments, including early movers such as Karnataka, Maharashtra, Telangana, Uttar Pradesh, Kerala, Uttarakhand, and Delhi, have also taken steps to further developments in this space. These state-led initiatives include various activities such as providing incentives and concessions to EV battery-manufacturing/assembly enterprises, providing funding for setting up of CoEs for R&D, incubation centers for clean energy startups, tax exemptions for EVs, promotion of skill development activities, and setting up of charging infrastructure. These initiatives are in different stages of planning, and some of them have already been launched. The picture varies from state to state.

Several existing and next-generation energy storage technologies are suitable for application to EVs in the current context. Currently, Li-ion batteries are clearly the leading technology for transportation applications. Li-ion batteries encapsulate multiple chemistries such as nickel manganese cobalt (NMC), lithium iron phosphate (LFP), and lithium titanium oxide (LTO), which are used depending on the application requirements and vehicle size. However, this is a continually evolving landscape due to the introduction of next-generation chemistries and the gradually declining use of older chemistries. In this paper, we have presented a comparative technical evaluation of the performance of the old and new battery chemistries. In the battery development space, the trend has been toward maximizing the energy density of battery packs, which has led to rapid progress in the development of lithium-sulfur (LiS) batteries, solid-state batteries (inorganic and gel/polymer type), inorganic liquid electrolytes, high-voltage cathodes (>4.5 V), and silicon and lithium metal anodes. A high energy density (both volumetric—how much energy a battery contains compared to its volume—and gravimetric—how much energy a battery contains compared to its weight) is critical for transportation applications. Li-ion batteries are the preferred choice as they have high volumetric as well as gravimetric energy density. Due to ongoing R&D activities, a number of new technologies with higher energy density are also making inroads in the EV sector (see Figure 2).
Notes:

a. PEM Fuel Cell system includes tank + stack + boost convertor. Values calculated for system designed for car with 500 km range and tanks storing 5 kg hydrogen at 700 bars.

b. In Li-ion batteries, the system-level energy density is approximately 40 percent lower than the cell-level energy density due to the weight of the battery management system (BMS), thermal management, electrical connectors, and other components.

c. LCP = Lithium Cobalt Phosphate, LNP = Lithium Nickel Phosphate.

d. Expected performance in 2025.

e. Al-air system includes weight/volume of stack, electrolyte storage tanks, and pumps. There are no known commercial prototypes of the Li-air battery.

f. Thicker coatings and larger active material particles enhance energy density at the cost of power density.

Evolution of energy density from the year 2005 and projections up to 2025 are shown by increasing bubble sizes. A large increment in the energy density of Li-ion batteries is expected with the entry of solid-state batteries using lithium metal anode and high-voltage cathodes. (Top right) The relationship between the weight and volume of an energy storage system (ESS) and the energy density is shown. This chart is prepared with available data and predictions as of 2019.

Source: Customized Energy Solutions (CES) analysis.
The existing Li-ion chemistries are expected to continue to develop via the introduction of new electrode materials and electrolytes. Alternative chemistries such as Al-air and lithium-sulfur (LiS) batteries will also continue to improve via materials, cell design, and system design improvements. PEM fuel cell technology will also continue to benefit in terms of energy density via improvements in hydrogen storage technologies.

In addition to batteries, Polymer Electrolyte Membrane fuel cells powered by hydrogen could be a suitable solution for heavy vehicles, including trucks, small boats, and airplanes requiring constant power and very long driving ranges. However, their eventual adoption will largely depend on the cost reductions in the technology and on the availability of hydrogen fuel. In this report, we have tried to present a balanced view of this complex landscape of technologies, noting the impressive features of the advanced technologies that will be a part of the future while pointing out the challenges to their commercialization and widespread adoption.

**Table 1 | Technology Development Roadmap for Next-Generation Storage for Transportation Applications**

<table>
<thead>
<tr>
<th>STORAGE TECHNOLOGY</th>
<th>TECHNOLOGY ROADMAP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2020</strong></td>
<td><strong>2025</strong></td>
</tr>
<tr>
<td>Solid-state batteries</td>
<td>Thin-film batteries (TFBs) are at lab scale. Polymer/gel electrolyte SSBs are at commercial prototype scale.</td>
</tr>
<tr>
<td>Li-S</td>
<td>Pouch cells with high energy density (450+ Wh/kg). Low cycle life (200+ cycles). Small-scale production.</td>
</tr>
<tr>
<td>Metal-air</td>
<td>Li-air is in lab-scale prototype. Al-air is a fully developed system, but manufacturing is at very small scale.</td>
</tr>
<tr>
<td>Na-ion</td>
<td>Na-ion battery in the advanced prototype stage.</td>
</tr>
<tr>
<td>Fuel cell</td>
<td>Technological challenges like new composite membranes and Pt-free electrocatalysts are being pursued. Production, availability, and the cost of hydrogen are also the limiting factors.</td>
</tr>
</tbody>
</table>

*Source: Customized Energy Solutions (CES) authors.*

In response to the growing need for advanced electrochemical energy storage systems, the global R&D community has set up various mechanisms to focus its efforts. Within this paper, we examine the R&D programs operating in the United States, Europe, Japan, China, and Australia. In most areas, the starting point for research activities is the declaration of a broad vision for vehicle electrification by the central government agencies. Following this, specific goals and milestones are outlined by the relevant government bodies, with timelines assigned to the various objectives. This builds the framework for setting up appropriate funding schemes, incubation centers and testing facilities, consortia and associations, and more recently, specialized research centers. Within this paper, we present an overview of the activities underway in the various regions of the world, to identify measures that have been shown to be effective in stimulating rapid advances in battery technology.
<table>
<thead>
<tr>
<th>TYPE</th>
<th>NAME</th>
<th>REGION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government Programs</td>
<td>□ Advanced Research Projects Agency for Energy (ARPA-E)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>□ Small Business Innovation Research (SBIR)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>□ Battery500 (based out of PNNL)</td>
<td>United States</td>
</tr>
<tr>
<td>Incubation centers</td>
<td>□ Cyclotron Road (LBNL)</td>
<td>United States</td>
</tr>
<tr>
<td></td>
<td>□ Innovation Crossroads (UCB)</td>
<td>United States</td>
</tr>
<tr>
<td></td>
<td>□ Chain reaction Innovations (ANL)</td>
<td>United States</td>
</tr>
<tr>
<td></td>
<td>□ Los Angeles Cleantech Incubator (LACI)</td>
<td>United States</td>
</tr>
<tr>
<td>Consortia</td>
<td>□ New York Battery Energy Storage Technology (NY-BEST)</td>
<td>United States</td>
</tr>
<tr>
<td></td>
<td>□ U.S. Advanced Battery Consortium (USABC)</td>
<td>United States</td>
</tr>
<tr>
<td>Battery materials research</td>
<td>□ Joint Centre for Energy Storage Research (JCESR)</td>
<td>United States</td>
</tr>
<tr>
<td>centers</td>
<td>□ Centre for Energy Research (UCSD)</td>
<td>United States</td>
</tr>
<tr>
<td></td>
<td>□ University of Maryland Energy Research Center (UMERC)</td>
<td>United States</td>
</tr>
<tr>
<td>Government programs</td>
<td>□ Horizon Funding under European Union (EU)</td>
<td>Europe</td>
</tr>
<tr>
<td></td>
<td>□ LAVOISIER 2020 Programme</td>
<td>Europe</td>
</tr>
<tr>
<td>Incubation centers</td>
<td>□ InnoEnergy (Netherlands, France, Germany, Sweden, Spain)</td>
<td>Europe</td>
</tr>
<tr>
<td>Consortia and associations</td>
<td>□ Faraday Institute</td>
<td>Europe</td>
</tr>
<tr>
<td></td>
<td>□ UK Battery Industrialization Center (UKBIC)</td>
<td>Europe</td>
</tr>
<tr>
<td></td>
<td>□ Energy Storage–Henry Royce Institute</td>
<td>Europe</td>
</tr>
<tr>
<td>Battery materials research</td>
<td>□ Fraunhofer ISIT and ISE</td>
<td>Europe</td>
</tr>
<tr>
<td>centers</td>
<td>□ Helmholtz-Zentrum Dresden Rossendorf (HZDR)</td>
<td>Europe</td>
</tr>
<tr>
<td></td>
<td>□ Helmholtz Institute Ulm (HIU)</td>
<td>Europe</td>
</tr>
<tr>
<td></td>
<td>□ EnergyVille (supported by VITO)</td>
<td>Europe</td>
</tr>
<tr>
<td>Government programs</td>
<td>Advanced Low Carbon Technology Research and Development Program-Special</td>
<td>Japan</td>
</tr>
<tr>
<td></td>
<td>ly Promoted Research for Innovative Next Generation Batteries (ALCA-SPRING)</td>
<td></td>
</tr>
<tr>
<td>Government programs</td>
<td>Storage projects by Australian Renewable Energy Agency (ARENA)</td>
<td>Australia</td>
</tr>
<tr>
<td>Government programs</td>
<td>2nd Energy Master Plan</td>
<td>Korea</td>
</tr>
</tbody>
</table>

Way forward

Raw materials account for more than 50 percent of the total cost of cells, and a robust supply chain is critical to ensure the cost competitiveness of the end product. With this objective, in this report, we present a detailed analysis of the requirements of eight key raw materials (Li, Mn, Ni, Co, Cu, Al, Gr, and Ti), separator, and electrolyte in metric tons (1 metric ton = 1,000 kg) normalized for 1 GWh of Li-ion cell manufacturing. India has existing reserves of Mn, Ni, Cu, and Al. For these ores, an attempt should be made to produce high-value battery components that local and international cell-manufacturing companies can use. These key raw materials and components are MnSO₄, NiSO₄, copper foil current collector, and aluminum foil current collector. In the case of graphite, existing reserves should be evaluated for availability of large-flake graphite content, which is directly applicable as anode material. Synthetic graphite produced from coke is finding increased use as an alternative anode material. Even if the reserves are inadequate, facilities for processing ore and producing a high-value product for Li-ion batteries can be set up locally. India has no reserves of the other raw materials (Co and Li), and for these, adequate arrangements for procuring ores or concentrates from other countries should be made.

Localized processing of lithium concentrates is beneficial for the battery industry from a reliability and purity perspective. Purity of lithium raw materials such as Li₂CO₃ and LiOH is crucial for achieving long cycle life. In addition, it is suggested that infrastructure for recycling Li-ion batteries should be set up in parallel with the development of Gigafactories and other battery-industry-related efforts. Recycled batteries from EVs will become a prominent source of raw materials via “urban mining.” The initial setups could be in the form of pilot plants for recycling small volumes of Li-ion batteries. These can be great tools for skill development and for recycling process optimization. Refurbishment centers could also be established prior to recycling to enable second life use in stationary applications.
### Figure 3 | Availability of Reserves of Key Raw Materials and Annual Production in India for Supporting Li-Ion Manufacturing

<table>
<thead>
<tr>
<th></th>
<th>NICKEL</th>
<th>MANGANESE</th>
<th>COBALT</th>
<th>COPPER</th>
<th>ALUMINUM</th>
<th>GRAPHITE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing Reserves&lt;sup&gt;a&lt;/sup&gt; (million tons)</td>
<td>1.3</td>
<td>151.8</td>
<td>0.052</td>
<td>12.16</td>
<td>824.28</td>
<td>22.68</td>
</tr>
<tr>
<td>Annual Production&lt;sup&gt;a&lt;/sup&gt; (million tons)</td>
<td>Nil</td>
<td>0.79</td>
<td>Nil</td>
<td>0.787</td>
<td>2.9</td>
<td>0.037</td>
</tr>
<tr>
<td>Average Cost ($/ton)</td>
<td>15790</td>
<td>2471</td>
<td>38411</td>
<td>6775</td>
<td>1896</td>
<td>1300</td>
</tr>
<tr>
<td>Battery Component</td>
<td>Cathode</td>
<td>Cathode</td>
<td>Cathode</td>
<td>Anode current collector</td>
<td>Cathode current collector, Cell casing</td>
<td>Anode, Conductive additive</td>
</tr>
<tr>
<td>Main other uses</td>
<td>Special alloys/ super alloys</td>
<td>Steel and iron-making industries (93%)</td>
<td>Special alloys/ super alloys</td>
<td>Electrical and tele-</td>
<td>Electrical sector (48%), Automobile and transport (15%)</td>
<td>Crucible and Pencil industry (76%)</td>
</tr>
</tbody>
</table>

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*Source: Indian Minerals Handbook 2017*

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**Notes:**

- **a.** Reserves + remaining resources
- **b.** Annual production from domestic ore production and imported ores and concentrates.
- **c.** Most Nickel is produced as a by product of other refining. Country’s entire demand is met through import. High purity nickel for battery applications is produced in a refining factory in Goa (NiCoMet).
- **d.** Main mineral of Mn is pyrolusite. India is one of the major importers of manganese ore in the world. Principals producers of Mn ore are MOIL Ltd, The Sandur Manganese & Iron ores Ltd, Manglal Rungta, Orissa Manganese and Minerals Ltd.
- **e.** Cobalt is extracted as a by product of copper, nickel, zinc or precious metals. The demand for cobalt is usually met through imports. NiCoMet Industries Ltd. Gujarat is among leading producers of cobalt.
- **f.** Hindustan Copper Limited is the only vertically integrated company involved in mining to refine copper. HindalCo Industries Ltd and Vedanta Ltd rely on imported copper concentrates.
- **g.** India is one of the largest producers of Al in the world. Four major primary producers are National Aluminium Co. Ltd, Bharat Aluminium Co Ltd, and Vedanta Aluminium Ltd.
- **h.** India produces both types of natural graphite, crystalline (flaky) graphite and amorphous graphite. Synthetic or artificial graphite is manufactured on a large scale in electric furnaces.
A strong and mutually beneficial collaboration between industry and academia is needed to develop advanced technologies in India. Currently, the framework for taking lab-scale technologies (Technology Readiness Level, TRL = 1–4) to commercial prototype stage (TRL = 5–7) is fragmented and ineffective. Convergence with MRL (Manufacturing Readiness Levels) is also needed within this framework. As a result, many of the innovations created in universities and research institutes are not able to move to the next stage of the development phase. A healthy network of incubation centers and COEs can help bridge the gap between industry and academia and foster the creation of a new start-up ecosystem in the field of clean energy technologies. Central and state governments need to take measures to help create a favorable environment for India to be able to attract next-generation technologies from the global R&D community as well. In many parts of the world, technologies have been developed up to TRL = 5–6, which are ready for pilot plant manufacturing or in some cases for scaled-up manufacturing. Clear objectives regarding performance requirements combined with a robust infrastructure for testing, and adequate incentives can pave the way for the fast growth of the indigenous manufacturing industry. We suggest that acquiring technologies for recycling batteries should also be given prominence along with the actual storage technologies. Skill development in the space of Li-ion cell manufacturing will be critical for supporting large-scale manufacturing. In this respect, pilot plants for cell manufacturing can play a crucial role. These can be set up at a miniscule cost compared to a Gigafactory, and they serve multiple purposes: training and skill development in manufacturing, test-beds for optimizing the manufacturing process, and test-beds for testing new chemistries that have shown promise at the lab scale. Such small-scale setups can build a level of confidence in early entrepreneurs and interested industry stakeholders.

Figure 4  | Interrelationship between the Various Components of the Battery Development Ecosystem

<table>
<thead>
<tr>
<th>Development phase</th>
<th>Participants</th>
<th>TRL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular Simulations</td>
<td>A</td>
<td>1-2</td>
</tr>
<tr>
<td>Materials R&amp;D</td>
<td>A</td>
<td>1-3</td>
</tr>
<tr>
<td>Cell Fabrication and Testing</td>
<td>A, I</td>
<td>4</td>
</tr>
<tr>
<td>Commercial Cell Prototyping</td>
<td>I</td>
<td>5</td>
</tr>
<tr>
<td>Module Design and BMS</td>
<td>I, E</td>
<td>5</td>
</tr>
<tr>
<td>Module Testing</td>
<td>I, E</td>
<td>5</td>
</tr>
<tr>
<td>Field Testing and Validation</td>
<td>I, E</td>
<td>6-7</td>
</tr>
<tr>
<td>Pilot Plant for Manufacturing</td>
<td>I, E</td>
<td>7-8</td>
</tr>
<tr>
<td>Scale-up Manufacturing</td>
<td>E</td>
<td>8-9</td>
</tr>
<tr>
<td>Recycling</td>
<td>A, I, E</td>
<td>1-9</td>
</tr>
</tbody>
</table>

a. A = academic institutions, national research laboratories
l = Energy storage focused incubation centers, testing facilities
E = Enterprises, battery manufacturing companies, car OEM
b. Technology Readiness Level

Source: Source: Customized Energy Solutions (CES) and WRI India authors.
Recommendations for enhancing the Feedback Mechanism between Industry and R&D Community

- Develop research labs and implement projects in institute campuses: Electrochemical testing facilities at academic institutes in energy-related R&D centers need a major upgrade if they are to attract international funding for research activities. Faculty and researchers working on such projects could be given incentives in the form of funded 1–3 year stints at internationally renowned research centers and should be provided with adequate resources to promote ongoing and future activities through all media platforms.

- Commercial prototyping centers within universities: Selected institutes should be equipped with facilities for commercial prototyping and testing to demonstrate the performance of new developed materials in commercial size cells (TRL = 5). These types of demonstrations are key to attracting the interest of industry, which can then take the technology further.

- Technology incubators and field-testing centers: Field-testing centers should be established where real application testing of commercial prototypes (TRL = 5–6) can be evaluated. Such centers can serve as a good meeting point for technology developers and potential manufacturing partners. Technology incubators are a good medium for grooming PhD and postdoctoral researchers in the commercialization of technologies. The translation of technological inventions in institutions (TRL = 2–4) to commercial prototyping (TRL = 5–6) is one of the main objectives of technology incubators.

- Skill development programs and knowledge sharing on energy storage and EVs: Institutions or private companies should conduct capacity-building training programs and provide current market trends on different technologies and different policies/guidelines.

- Development of research labs focusing on recycling: IITs and CSIR labs need to focus on recycling activities, and they should work closely with battery industries.

Source: Customized Energy Solutions (CES) and WRI India authors.

Figure 5 | Bridging the Gap between Academia and Industry

Educational Institutions
- Development of new chemistries
- Proof of concept demonstration via lab scale prototypes
- Industry-Academia close collaboration
- Patents, IP & Research Papers

Incubator
- Address industry R&D needs
- Device fabrication: Demonstrate commercial viability
- Controlled testing to improve product design
- Thermal management, SOC management, battery sizing

Industry
- Pilot scale production leading to scale-up
- Indigenous development of technologies
- Product customization for Indian customers
- Local job creation
- Foreign investment

Source: Customized Energy Solutions (CES) and WRI India authors.
ABOUT WRI

World Resources Institute, India (WRI India) inspired by and associated with World Resources Institute. WRI India has the capacity to convene key stakeholders, and forge strategic partnerships with governments, business, foundations, civil society organizations, institutes and NGOs, to scale-up solutions that can bring game-changing results for the sustainable management of natural resources in India.

Our Challenge

Natural resources are at the foundation of economic opportunity and human well-being. But today, we are depleting Earth’s resources at rates that are not sustainable, endangering economies and people’s lives. People depend on clean water, fertile land, healthy forests, and a stable climate. Livable cities and clean energy are essential for a sustainable planet. We must address these urgent, global challenges this decade.

Our Vision

We envision an equitable and prosperous planet driven by the wise management of natural resources. We aspire to create a world where the actions of government, business, and communities combine to eliminate poverty and sustain the natural environment for all people.

Our Approach

COUNT IT
We start with data. We conduct independent research and draw on the latest technology to develop new insights and recommendations. Our rigorous analysis identifies risks, unveils opportunities, and informs smart strategies. We focus our efforts on influential and emerging economies where the future of sustainability will be determined.

CHANGE IT
We use our research to influence government policies, business strategies, and civil society action. We test projects with communities, companies, and government agencies to build a strong evidence base. Then, we work with partners to deliver change on the ground that alleviates poverty and strengthens society. We hold ourselves accountable to ensure our outcomes will be bold and enduring.

SCALE IT
We don’t think small. Once tested, we work with partners to adopt and expand our efforts regionally and globally. We engage with decision-makers to carry out our ideas and elevate our impact. We measure success through government and business actions that improve people’s lives and sustain a healthy environment.

PHOTO CREDITS

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