On behalf of:
Federal Ministry
for the Environment, Climate Action,
Nature Conservation and Nuclear Safety

of the Federal Republic of Germany

IKI INTERNATIONAL CLIMATE INITIATIVE

giz Deutsche Gesellschaft
für Internationale
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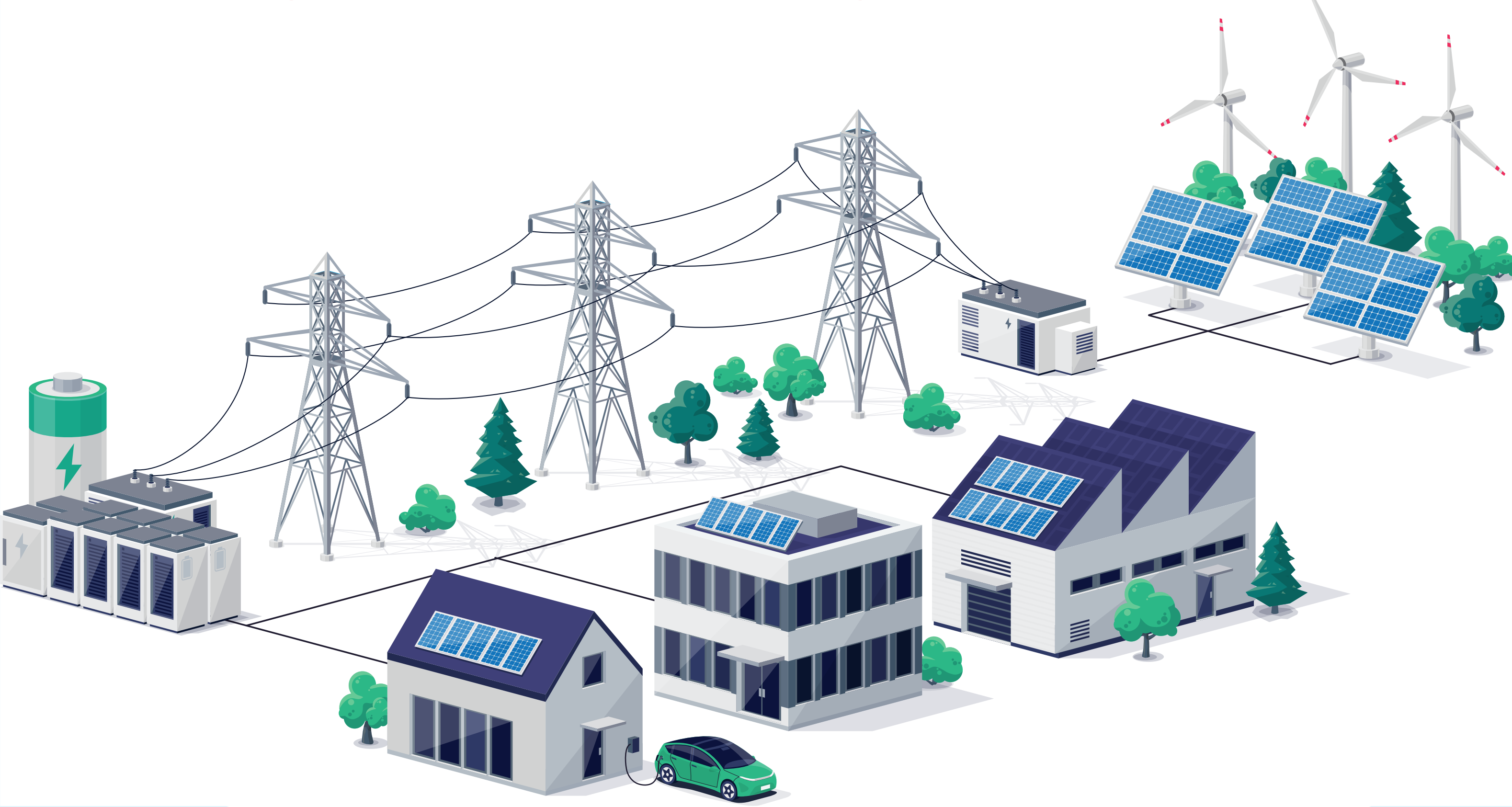
*Creating Innovative Solutions for a Sustainable Future*

सत्यमेव जयते

नवीन एवं
नवीकरणीय ऊर्जा मंत्रालय
MINISTRY OF
**NEW AND
RENEWABLE ENERGY**

# SKILL GAP ASSESSMENT IN BATTERY ENERGY STORAGE SECTOR IN INDIA



**Strategic Partner**

SCGJ
SKILL COUNCIL FOR GREEN JOBS
ISO 9001 : 2015 CERTIFIED

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WRI INDIA

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# ACKNOWLEDGEMENTS

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Given the high relevance of addressing skill gaps in the BESS ecosystem in the country, this study was initiated. We hope that the findings and recommendations of this study will support industry and policymakers in India in making informed decisions.

# List of
# ABBREVIATIONS

| | |
|---|---|
| **AC** | Alternating current |
| **ACC** | Advanced Chemistry Cell |
| **AEMO** | Australian Energy Market Operator |
| **AI** | Artificial intelligence |
| **BEE** | Bureau of Energy Efficiency |
| **BESS** | Battery energy storage system |
| **BMS** | Battery management system |
| **BMWK** | Germany's Federal Ministry for Economic Affairs and Climate Action |
| **BWCP** | Battery Workforce Challenge Program |
| **BWI** | Battery Workforce Initiative |
| **C&I** | Commercial and industrial |
| **CDTs** | Centres for Doctoral Training |
| **CEA** | Central Electricity Authority |
| **CERC** | Central Electricity Regulatory Commission |
| **CIRT** | Central Institute of Road Transport |
| **CPD** | Continuing professional development |
| **DC** | Direct current |
| **DER** | Distributed energy resources |
| **DES** | Distributed energy systems |
| **DISCOMs** | Distribution companies |
| **DOE** | US Department of Energy |
| **DOL** | US Department of Labor |
| **DSM** | Demand-side management |
| **EPSRC** | Engineering and Physical Sciences Research Council |
| **ESO** | Energy storage obligation |
| **ESS** | Energy storage system |
| **EV** | Electric vehicle |
| **FAT** | Factory acceptance test |
| **FGDs** | Focus group discussions |
| **FTE** | Full-time equivalent |
| **GIZ** | Deutsche Gesellschaft für Internationale Zusammenarbeit |
| **GTAM** | Green-term ahead market |
| **GW** | Gigawatt |
| **GWh** | Gigawatt hour |
| **HSE** | Health and safety executive |
| **HVAC** | Heating, ventilation, and air conditioning |
| **HVRT** | High-voltage ride through |
| **IESA** | India Energy Storage Alliance |
| **IIT** | Indian Institute of Technology |
| **IKI** | International Climate Initiative |
| **ITI** | Industrial Training Institute |

| | |
|---|---|
| **LFP** | Lithium–iron phosphate |
| **Li-ion** | Lithium–ion |
| **LVRT** | Low-voltage ride through |
| **ML** | Machine learning |
| **MNRE** | Ministry of New and Renewable Energy |
| **MoP** | Ministry of Power |
| **MWh** | Megawatt hour |
| **NEP** | National Electricity Plan |
| **NETL** | National Energy Technology Laboratory |
| **NFCC** | National Fire Chiefs Council |
| **NIT** | National Institute of Technology |
| **NPTI** | National Power Training Institute |
| **NREL** | National Renewable Energy Laboratory |
| **NSAP** | National Skills Academy for Power |
| **NSDC** | National Skill Development Corporation |
| **NSQF** | National Skill Qualification Framework |
| **OEMs** | Original equipment manufacturers |
| **PCS** | Power conversion system |
| **PCU** | Power conditioning unit |
| **PIB** | Press Information Bureau |
| **PLI** | Production-linked Incentive |
| **PMKVY** | Pradhan Mantri Kaushal Vikas Yojana |
| **PSP** | Pumped storage project |
| **R&D** | Research and development |
| **RE** | Renewable energy |
| **RMI** | Rocky Mountain Institute |
| **RPO** | Renewable purchase obligations |
| **RTC** | Round-the-clock |
| **RTOs** | Registered training organization |
| **SAT** | Site acceptance test |
| **SCADA** | Supervisory Control and Data Acquisition |
| **SCGJ** | Skill Council for Green Jobs |
| **SECI** | Solar Energy Corporation of India |
| **SoC** | State of charge |
| **SoH** | State of health |
| **SLDC** | State Load Dispatch Centre |
| **TAFE** | Technical and further education |
| **TERI** | The Energy and Resources Institute |
| **UK** | United Kingdom |
| **UKBIC** | UK Battery Industrialization Centre |
| **UKRI** | UK Research and Innovation |
| **UNSW** | University of New South Wales |
| **US** | United States |
| **VET** | Vocational education and training |
| **VGF** | Viability gap funding |

# EXECUTIVE SUMMARY

India's power sector is undergoing a profound transformation driven by ambitious renewable energy (RE) targets, rising electricity demand, and long-term commitments to decarbonisation and energy security. As the share of variable renewable energy continues to increase, maintaining grid reliability, operational flexibility, and adequacy of supply has emerged as a critical challenge. In this context, battery energy storage systems (BESS) have become a cornerstone technology, enabling renewable integration, peak management, frequency regulation, and improved grid resilience.

While policy support, market mechanisms, and investment momentum for BESS have accelerated rapidly in India, the availability of a skilled and deployment-ready workforce has not kept pace with sectoral growth. This skill gap assessment, undertaken under the Indo–German development cooperation project ***Energy Storage for Renewable Energy Integration in India (StoREin)***, responds to this challenge by systematically analysing workforce readiness across the BESS value chain and identifying priority actions to build a future-ready skills ecosystem.

India's renewable energy capacity expansion—particularly in solar and wind—has intensified the need for flexible, fast-response storage solutions. BESS, with its modularity, rapid deployment, and suitability across transmission, distribution, and behind-the-meter applications, has emerged as a preferred technology for short- to medium-duration storage. National projections indicate a sharp increase in storage requirements by 2031–32, with BESS accounting for a substantial share of this capacity.

Despite strong policy momentum, including viability gap funding, energy storage obligations, and manufacturing incentives, the study finds that human capital development has lagged behind physical infrastructure deployment. Current training and education systems remain fragmented, uneven in quality, and insufficiently aligned with industry needs. This creates risks of project delays, safety incidents, increased costs, and underutilization of storage assets.

## Learning from Global Experience

International experience demonstrates that countries with advanced BESS markets have embedded workforce planning directly into energy transition and industrial strategies. Common features across leading markets include:

- Nationally aligned competency frameworks
- Strong industry–academia collaboration

### Global Best Practices Relevant for India

- Workforce planning linked to confirmed deployment pipelines
- Standardised but modular training pathways
- Safety and lifecycle management embedded across all skill levels
- Strong emphasis on experiential and field-based learning

- Mandatory safety and certification regimes
- Extensive hands-on training through learning factories and pilot facilities
- Continuous upskilling linked to technological evolution

These insights provide valuable reference points for India and highlight the need for context-specific solutions that reflect India's scale, institutional diversity, and regional variation.

## Evidence-based Assessment Approach

The skill gap assessment adopts a mixed-methods, stakeholder-driven methodology, combining desk research, curriculum and training programme reviews, labour market analysis, structured surveys, expert interviews, and focus group discussions. Stakeholders across utilities, manufacturers, EPC firms, financial institutions, training providers, academic institutions, and policymakers were engaged to ensure comprehensive representation across the BESS value chain.

This approach ensures that the findings are grounded in operational realities rather than theoretical skill requirements, strengthening their relevance for implementation.

## Employment Outlook and Growth Drivers

The analysis indicates a rapid and sustained expansion of employment in the battery energy storage sector through 2030, with job creation rising sharply across all scenarios. Growth is driven by accelerating clean energy deployment, rising electricity demand, and continued policy and investment support.

Based on three growth scenarios (pessimistic, base, and optimistic) for 2030 BESS demand and manufacturing capacity, projected capacity additions were converted into employment estimates. The estimates use industry benchmarks, expert-derived jobs-per-GWh multipliers, and job life-cycle assumptions, indicating overall job growth by 2030, with stronger growth expected under the base and optimistic scenarios. By 2030, overall employment is projected to grow across all scenarios—with even the pessimistic case showing modest gains, and the base and optimistic scenarios indicating strong expansion driven by clean energy deployment, domestic manufacturing incentives (such as PLI), and rising electricity demand. Installation and commissioning emerge as the largest contributors to total employment, reflecting the rapid deployment of BESS capacity by 2030. Operations and maintenance (O&M) also account for a significant share of jobs, providing sustained employment as the installed capacity grows, while manufacturing remains a smaller but growing contributor, supported by the expansion of domestic battery production and supply chains Indirect employment scales strongly alongside direct jobs, underscoring significant multiplier effects across supply chains, logistics, and local economies.

Outcomes remain sensitive to policy stability, investment flows, technology costs, and deployment pace, with a wide gap between pessimistic and optimistic scenarios. Overall, the findings point to a transformative, deployment- and services-led growth trajectory for India's battery energy storage sector, where employment growth is driven primarily by system integration, commissioning, and sustained operations. Realizing the

Employment demand is led by installation, commissioning, and indirect roles, closely reflecting high-demand technical profiles such as BMS, systems integration, and thermal management specialists. However, the wide range of scenarios highlights that accelerated policy support and investment will be critical to fully realise the sector's employment potential from 2027 onward.

sector's full job creation potential from 2027 onward will depend critically on continued policy support and accelerated investment.

## Skill Gaps Across the BESS Value Chain

The report provides a detailed mapping of existing and emerging skill gaps across BESS deployment, operation, and lifecycle management.

The assessment reveals that while basic electrical, mechanical, and engineering skills are available, specialised and application-oriented competencies remain critically undersupplied. Key gaps are observed in:

- System integration and commissioning
- Battery management systems (BMS) and energy management systems (EMS)
- Power electronics and grid-forming inverter technologies
- Digital monitoring, diagnostics, and predictive maintenance
- Safety, fire risk mitigation, and emergency response
- Standards compliance and regulatory interpretation
- End-of-life management, recycling, and circularity

These gaps are most pronounced at the technician and mid-level engineering tiers, which are essential for large-scale deployment, operation, and maintenance of BESS assets. The study also highlights cross-cutting deficiencies in practical exposure, standardisation of competencies, and familiarity with evolving safety and regulatory requirements.

Institutional constraints further compound these challenges. Many training institutions lack trained faculty, updated curricula, laboratory infrastructure, and industry linkage, limiting their ability to deliver field-ready skills.

## Workforce Demand and Institutional Readiness

The study examines workforce demand projections and the readiness of India's skilling ecosystem to respond to the rapidly expanding BESS market. Based on deployment trajectories, the demand for skilled personnel is expected to grow sharply over the next decade across utility-scale, distributed, and behind-the-meter applications.

The analysis identifies rising demand for:

- BESS technicians and electricians
- System integration and commissioning engineers
- Operations and maintenance professionals
- Safety and compliance specialists
- Project managers and planners with storage expertise

However, current training capacity and institutional preparedness remain inadequate to meet this scale and pace of demand. Without timely intervention, skill shortages risk becoming a binding constraint on BESS deployment, affecting timelines, quality, and safety outcomes.

Importantly, the report highlights that workforce needs will continue to evolve with advances in battery chemistries, digitalisation, grid operation paradigms, and business models. This underscores the need for adaptive, modular, and continuously updated skilling pathways.

# Translating Insights into Action: Recommendations and Roadmap

Chapter 8 presents a phased and actionable roadmap to address identified skill gaps and strengthen institutional capacity. The recommendations are structured across short-, medium-, and long-term horizons, emphasising coordination between government, industry, and training institutions.

Key priority actions include:

- Development of standardised, industry-aligned competency frameworks for BESS roles
- Integration of dedicated BESS modules into engineering, vocational, and technician curricula
- Expansion of hands-on training, simulations, and pilot-based learning
- Strengthening faculty capacity and training infrastructure
- Promotion of industry-led certification and apprenticeship models
- Embedding safety, standards, and digital skills across all levels of training

### Phased Action Framework for BESS Skill Development

- **Immediate (0–6 months):** awareness programmes, emergency training for DISCOMs, safety certifications, faculty upskilling, and updating outdated training materials
- **Short term (6–12 months):** standardized national BESS curricula, inclusive workforce development, hands-on vocational and engineering training, internships, and digital learning tools.
- **Medium term (12–18 months):** curriculum modernization, upgrade training infrastructure, degree programmes in energy storage, standardized competency frameworks, and stronger industry–academia collaboration.
- **Long term (18+ months):** Centres of Excellence, national talent pipelines, upgraded lab infrastructure, expanded testing facilities, and continuous curriculum updates.

In the medium to long term, the roadmap calls for the establishment of regional centres of excellence, structured industry–academia partnerships, and mechanisms for continuous upskilling to keep pace with technological change. To address workforce gaps, the study outlines phased workforce development strategies.

# Conclusion

This skill gap assessment demonstrates that human capital development is the critical missing link in India's otherwise strong BESS deployment ecosystem. While policy frameworks, market mechanisms, and investment flows are advancing rapidly, the lack of a skilled, deployment-ready workforce could undermine the pace, quality, and safety of energy storage expansion.

By aligning workforce development with technology pathways, deployment pipelines, and industry needs, India can ensure that BESS becomes a reliable enabler of its clean energy transition. The findings and recommendations of this report provide a structured, evidence-based foundation for building a resilient, scalable, and future-ready energy storage workforce, positioning India as a global leader in sustainable energy systems.

# 1.

# INTRODUCTION

## 1.1 Background

India's energy sector stands at the cusp of a transformative transition. The nation's commitment to achieving net-zero emissions by 2070 necessitates a fundamental shift in its electricity generation, transmission, and distribution systems. This transformation must prioritize high levels of renewable energy (RE) integration while maintaining grid stability, seasonal balancing, and resource adequacy.

India, as one of the rapidly expanding major economies, has a pivotal position in the global energy transition. Supported by sustained economic development, the country's energy demand is anticipated to expand at the highest rate among major economies. Consequently, India's share in global primary energy consumption is projected to nearly double by 2035 (PIB, 2025). To meet this increasing demand sustainably, the National Electricity Plan (Central Electricity Authority, 2023) projects that installed solar and wind capacity will exceed 480 gigawatt (GW) by 2031–32. However, large-scale renewable energy integration brings significant operational challenges, including variability in generation, transmission congestion, and the need to ensure uninterrupted power supply.

The intermittent nature of renewable energy sources continues to limit their ability to displace conventional power, and despite policy shifts emphasizing renewables, the electricity mix remains heavily reliant on fossil fuels. As of fiscal year 2025-26 (up to March 2026), coal accounted for approximately 67.7% of India's total electricity generation (PIB, 2026). Although new coal projects are being phased down, the intermittent nature of solar and wind energy underscores the urgent need for complementary energy storage technologies to ensure round-the-clock reliability and grid resilience.

In this context, energy storage systems (ESS) become critically important. They enable better management of renewable variability, improve grid stability, and help balance supply and demand in real time. The ESS also supports peak load management, reduces curtailment of renewable power, enhances the reliability of the distribution network, and facilitates the transition towards a more flexible and resilient power system. As India accelerates its RE expansion, energy storage will be central to ensuring that clean energy is not only generated but also delivered reliably and efficiently. Within the broader ESS landscape, battery energy storage systems (BESS) have gained particular importance due to their modularity, rapid response capability, and suitability for deployment across transmission, distribution, and behind-the-meter applications. The BESS is uniquely positioned to manage short- to medium-duration storage requirements critical for evening peak support, renewable energy firming, and curtailment mitigation.

To align renewable capacity expansion with stable and reliable grid operations, the Government of India has launched initiatives such as the round-the-clock (RTC) tenders and expanded viability gap funding (VGF) mechanisms to accelerate the deployment of grid-scale storage solutions alongside renewable generation. However, challenges remain in ensuring economic viability, regulatory coherence, and distributed deployment. Moreover, expansion of grid infrastructure must keep pace with renewable additions to avoid congestion and stranded assets.

## 1.2 Role of Energy Storage Systems in India's Energy Transition

The energy storage system plays a pivotal role in enabling India's shift towards a cleaner, more flexible, and more resilient power system. As renewable energy capacity expands rapidly, the ESS helps bridge the gap between intermittent generation and continuous demand by storing surplus electricity and delivering it when needed. This enhances grid stability, reduces dependence on fossil fuel-based peaking power, and supports the integration of high levels of variable renewable energy. Beyond grid balancing, ESS contributes to strengthening distribution networks, improving power quality, enabling electric mobility, and supporting emerging applications such as microgrids and rooftop solar. Collectively, these functions position energy storage as a cornerstone technology for achieving India's long-term energy security, decarbonization goals, and net-zero commitments.

As per the National Electricity Plan projections, the energy storage capacity of 16.13 GW/82.37 GWh with pumped storage projects (PSP)-based storage of 7.45 GW capacity and 47.65 gigawatt hour (GWh) storage and BESS-based storage of 8.68 GW/34.72 GWh is required by the year 2026–27. The storage capacity requirement increases to 73.93 GW (26.69 GW PSP and 47.24 GW BESS) with storage of 411.4 GWh (175.18 GWh from PSP and 236.22 GWh from BESS) by the year 2031–32 (CEA, 2023). Recognizing the strategic importance of storage, the Ministry of Power (MoP) approved an expanded VGF scheme in June 2025 to support the development of 30 GWh of grid-scale BESS, in addition to the 13.2 GWh already underway.

As of August 2026, BESS capacity of **9.41 GWh** is operational. (IESA, 2026)

The expansion of ESS is, therefore, not only a technical imperative but also a cornerstone for achieving India's long-term sustainability and energy security goals. Yet, realizing this vision hinges critically on the availability of a skilled, future-ready workforce capable of driving innovation, deployment, and lifecycle management of these technologies. However, the pace of ESS growth has outstripped the current availability of trained professionals, resulting in a widening skill gap across technical, managerial, and operational domains. Addressing this gap is essential to ensure that India's ESS ecosystem can scale sustainably and safely. This

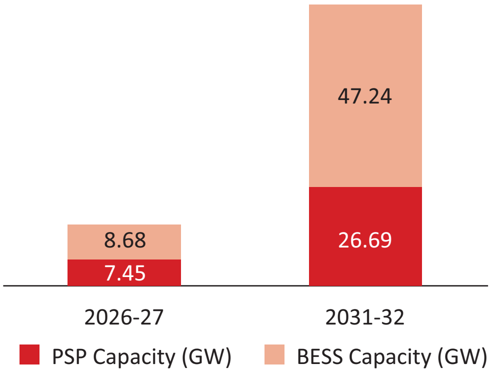

**FIGURE 1.1**: Projected energy storage capacity (GW)

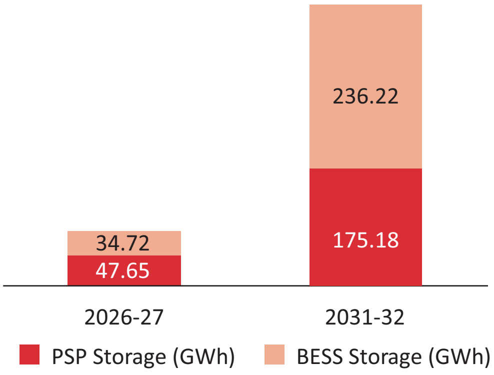

**FIGURE 1.2**: Projected energy storage requirement (GWh)

report examines the nature and extent of these emerging skill gaps and identifies the competencies, training needs, and capacity-building priorities required to strengthen India's ESS workforce.

## 1.3 StoREin Project: Scaling Up Energy Storage for Renewable Integration

Recognizing the critical role of energy storage in enabling transition towards a sustainable and secure energy future, the Indo–German development cooperation project **Energy Storage for Renewable Energy Integration in India (StoREin)** was launched under the International Climate Initiative (IKI) by Germany's Federal Ministry for the Environment, Climate Action, Nature Conservation and Nuclear Safety (BMUKN). The project is implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH in close cooperation with the Ministry of New and Renewable Energy (MNRE), Government of India, and is supported by a consortium of leading institutions, including Fraunhofer, Indian Institute of Technology (IIT) Bombay, The Energy and Resources Institute (TERI), and WRI India (GIZ, 2024). The Skill Council for Green Jobs (SCGJ) is engaged as a strategic partner, advancing green workforce development in India's energy storage sector.

The StoREin project is structured around five core output areas that collectively aim to accelerate the adoption of decentralized energy storage systems in India.

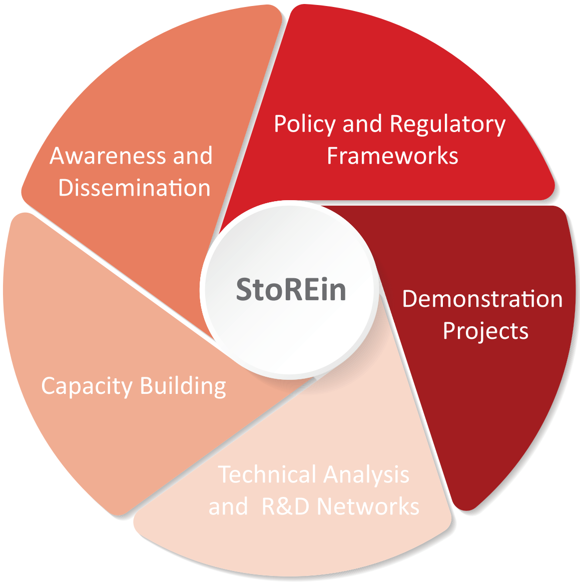

**FIGURE 1.3**: StoREin project: Output areas

### Output 1. Policy and Regulatory Frameworks

The project works to improve the enabling environment for decentralized energy storage by strengthening policy and regulatory conditions that support their integration into the power sector.

### Output 2. Demonstration Projects

Pilot installations provide practical evidence on technical performance, use cases, and viable business models, helping to de-risk future investments and guide large-scale deployment.

### Output 3. Technical Analysis and R&D Networks

Through targeted studies and the strengthening of R&D collaborations, the project enhances the Indian research community's comprehension of feasible decentralized energy storage applications.

### Output 4. Capacity Building

StoREin contributes to building human and institutional capacity in the planning, design, implementation, and operation of energy storage systems across key stakeholders.

### Output 5. Awareness and Dissemination

The project increases stakeholder awareness by systematically sharing insights, lessons learned, and findings, thereby supporting wider adoption and replication of decentralized storage solutions.

A critical component of Output 4 of the StoREin initiative is the skill gap assessment in the energy storage domain, which aims to evaluate workforce readiness and identify skill gaps that could hinder India's energy storage ambitions. Despite the rapid technological progress and rising demand, existing skilling and training programmes often lag behind industry needs—particularly in providing hands-on, field-ready expertise in areas such as system integration, operations, maintenance, and recycling.

## 1.4 Objectives of the Skill Gap Assessment

This skill gap assessment under the StoREin initiative is a crucial effort to ensure India's workforce development strategies are aligned with the rapidly evolving ESS ecosystem and the nation's ambitious clean energy transition goals. The study was designed around the following key objectives:

- **Identify jobs and demand**: To identify and quantify job roles and their demand in the current energy storage industry, and projected over the next 5 years.
- **Current skills mapping:** To assess existing skills and workforce capabilities across the BESS value chain.
- **Gap identification:** To identify current and emerging gaps in technical, operational, and managerial competencies.
- **Institutional readiness:** To evaluate the readiness of academic and training institutions to deliver energy storage-related education.
- **Actionable recommendations:** To formulate actionable recommendations for workforce and institutional capacity development.

## 1.5 Significance of the Study

As India scales up RE deployment and advances towards its net-zero vision, bridging the skills gap in the energy storage domain is both a strategic necessity and an opportunity. A skilled workforce will be the foundation for a resilient, low-carbon electricity system that not only meets national energy needs but also strengthens India's position as a global leader in clean technology innovation. By fostering collaboration between industry, academia, policymakers, and training institutions, the StoREin project's skill gap assessment paves the way to ensure that India's energy storage ecosystem can expand at the pace and scale required to meet national RE and grid modernization goals.

As the ESS technologies evolve and their applications diversify—from distribution-level storage to e-mobility and industrial systems—the demand for specialized technical, operational, and managerial competencies is growing rapidly. However, without a structured understanding of current workforce capabilities and future skill requirements, the sector risks facing deployment bottlenecks, safety lapses, higher project costs, and delays in achieving policy targets. The skill gap assessment helps address these challenges by identifying critical shortages in skills across the ESS value chain, from design and integration to operation, maintenance, and end-of-life management. Crucially, it highlights emerging competency needs driven by new technologies, evolving business models, and updated regulatory expectations.

In this report, the assessment of energy storage skills is framed mainly within the context of the BESS, given its growing relevance to India's energy transition. In essence, this study provides stakeholders with the actionable intelligence required to build a future-ready ESS workforce. This workforce will be capable of enabling India's vision of a reliable, resilient, and clean energy future.

# 2.
# APPROACH AND METHODOLOGY

## 2.1 Overview

This chapter outlines the systematic approach and methodological processes adopted to conduct a comprehensive skill gap assessment for the energy storage sector, with a specific focus on battery energy storage systems (BESS). The methodology adopted for the skill gap assessment under the StoREin project follows a mixed-methods approach, combining desk-based research, stakeholder consultations, and primary data collection through surveys, interviews, and focus group discussions. To address the proposed objectives, the study employed a structured set of methodological activities tailored to the energy storage sector, including the assessment of current and emerging job roles within the BESS segment through an extensive literature review, industry surveys, and expert consultations. Figure 2.1 presents the methodological framework that guided the skill gap assessment.

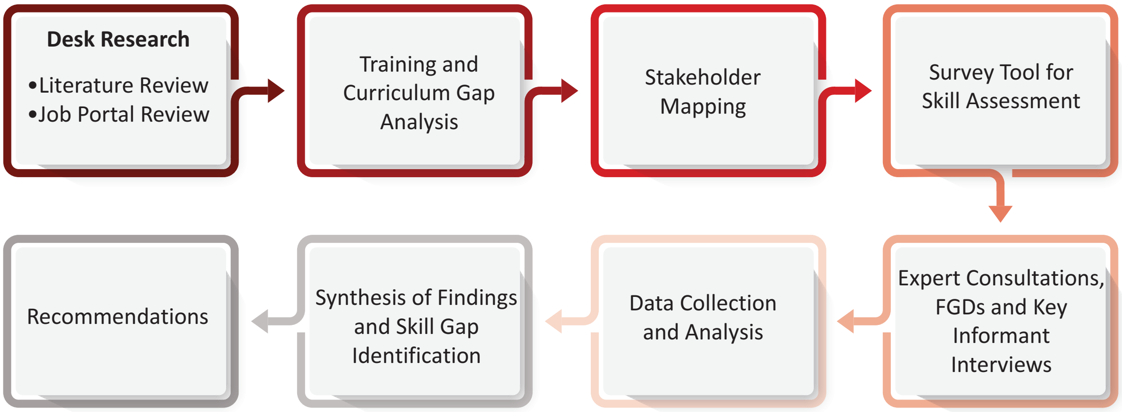

**FIGURE 2.1**: Methodology framework for BESS skill gap assessment

## 2.2 Desk Research

The study commenced with an extensive literature review to establish the analytical foundation for understanding the skill ecosystem and industry context of energy storage in India. This review covered national and international reports, policy documents, industry road maps, academic research, standards and guidelines, and publications from government agencies and sectoral bodies, enabling a comprehensive understanding of current technologies, workforce requirements, and emerging trends.

The desk research also included a systematic review of major job portals and employment platforms to analyze current labour market signals. This involved examining job postings, role descriptions, skill requirements, experience levels, and employer expectations for positions related to energy storage technologies. Insights from job portal analytics helped validate industry demand patterns, identify emerging job roles, and assess real-time trends in skills sought by employers.

This phase aimed to build a comprehensive understanding of the policy, institutional, and educational landscape shaping workforce development in the sector. The desk research was designed to:

- Map existing national and international studies on skill requirements within the sector.
- Identify global best practices in workforce development, particularly from countries with advanced energy storage markets.
- Analyze labour market trends through structured review of job portals to capture current and emerging job roles and skills demand.

## 2.3 BESS Training and Curriculum Gap Analysis

### 2.3.1 Analysis of BESS Training Programmes

To assess the state of BESS-related education and skilling in India, a detailed training programme analysis was undertaken through desk-based compilation and comparative assessment. The analysis focused on mapping existing courses and certifications related to energy storage offered by national and international institutions. The findings were structured into a comprehensive training matrix categorizing programmes by thematic area, duration, delivery mode, level of training, target audience, and other related areas.

The analysis revealed substantial variations across institutions in course content, duration, and levels of practical exposure. The findings underscored the need for:

- Standardized competency frameworks aligned with industry needs.
- Greater integration of hands-on training and experiential learning.
- Development of industry-led certification models to address emerging skill requirements in BESS technologies.

### 2.3.2 Curriculum Gap Assessment in BESS

The study employed a structured, five-stage process to review the academic coverage of BESS across Indian and international institutions and identify curriculum gaps.

**Institution selection and data collection**: Curricula, syllabi, and programme structures were gathered from IITs, NITs, state universities, private institutions, polytechnics, and select global universities. Information was compiled into a structured database.

**Identification of energy storage courses**: All collected syllabi were screened using keywords (battery, BESS, electrochemistry, grid integration, etc.) to extract relevant courses. Each course was examined for the breadth and depth of BESS content.

**Benchmark framework development**: A competency-based benchmark was created reflecting global trends, covering system modelling, battery management system (BMS), grid integration, hybrid systems, power electronics, techno-economics, standards, policy interfaces, simulation tools, and practical/lab components.

**Thematic mapping and gap analysis**: Courses were mapped against the benchmark to identify under-represented areas. Significant gaps emerged in advanced control, grid-forming inverters, AI-based diagnostics, digital twins, quasi-dynamic simulations, policy/regulatory coverage, and experiential learning.

**Categorization and synthesis**: Gaps were consolidated into 10 thematic areas and organized into a matrix showing current coverage and missing components. The synthesis highlighted the need for deeper technical content and stronger practical exposure, informing recommendations for a future-ready BESS curriculum.

The outcomes were synthesized to highlight curriculum improvement needs in both technical depth and practical exposure, forming the basis for recommendations towards a future-ready BESS curriculum.

## 2.4 Stakeholder Mapping

1. Distribution companies (DISCOMs) and utilities
2. Original equipment manufacturers (OEMs), project developers, and EPC firms
3. Commercial and industrial (C&I) consumers utilizing behind-the-meter storage
4. Financial institutions and banks financing BESS projects
5. Industrial training institutes (ITIs) and vocational training providers
6. Academic and research institutions working on energy storage education
7. Government agencies and policy bodies regulating and supporting skill development

Recognizing the multi-dimensional nature of the BESS ecosystem, a stakeholder mapping exercise was conducted to identify institutions, organizations, and market factors influencing or impacted by BESS skill development. Stakeholders were classified into seven broad groups.

The mapping exercise enabled the design of targeted survey questionnaires and interview protocols. It also helped identify potential institutional partners for validation and capacity-building. Together, these efforts ensured broad representation and inclusivity across the entire BESS value chain. The outcome was a comprehensive stakeholder database used for outreach and engagement throughout the study.

## 2.5 Survey Tool for Skill Gap Assessment

To complement the desk research, a series of structured survey questionnaires was designed and deployed to capture quantitative and qualitative data directly from the field. Six customized survey questionnaires were designed to suit the information needs of different stakeholder categories:

1. DISCOMs and utilities
2. OEMs and project developers
3. C&I sector and industries
4. Financial institutions and banks
5. ITIs and other training institutes
6. Academic and research organizations

Each questionnaire explored key dimensions critical to understanding the energy storage sector's evolving skill landscape, including:

- Workforce size, qualifications, and roles across the BESS value chain
- Existing and projected skill needs specific to BESS technologies

- Training programmes, certifications, and capacity-building initiatives currently adopted
- Barriers to recruitment, reskilling, and retention
- Anticipated technological and policy changes impacting skill demand

The surveys were disseminated online to a broad range of stakeholders representing six categories across India. Responses were collected over a defined period, allowing for a diverse and representative dataset that reflected operational and organizational variations within the sector.

## 2.6 Expert Consultations, FGDs, and Key Informant Interviews

In addition to quantitative data, qualitative insights were gathered through expert consultations and key informant interviews with representatives from industry, academia, government, and training organizations. These engagements aimed to:

- Capture experiential perspectives on workforce readiness and technological trends
- Validate early findings from desk research and surveys
- Understand institutional and regulatory challenges in scaling up BESS skill development

As part of the study, focus group discussions (FGDs)-cum-stakeholder workshops were organized to address challenges and identify improvements in BESS capacity development. These engagements were designed to facilitate peer learning, collective validation of emerging findings, and co-creation of actionable recommendations. The stakeholder interactions formed an essential component of the study to ensure validation, consensus-building, and ownership of proposed strategies. Three major consultation events were conducted:

1. **Roundtable discussion 1 – New Delhi (10 July 2025)**

Hosted by TERI at the India Energy Storage Week 2025, the workshop convened policymakers, industry representatives, and training institutions to gather feedback on preliminary findings and policy directions.

The discussion highlighted critical skill gaps in the BESS value chain, the need for updated curricula specifically for vocational and training institutes, hands-on training, better industry–academia alignment, and support from philanthropic/financial institutions.

2. **Roundtable discussion 2 – Lucknow, Uttar Pradesh (29 August 2025)**

Held at Integral University, this FGD focused on ITI faculty and technical training requirements, emphasizing gaps in instructor capabilities, curriculum delivery, and institutional readiness.

Key outcomes include recognition of the urgent need to integrate BESS modules into vocational curricula, develop specialized industry-collaborative courses, and strengthen lab infrastructure. Stakeholders committed to interdisciplinary research, pilot projects, and sustained industry-academia engagement for workforce innovation.

3. **Roundtable discussion 3 – Pune, Maharashtra (25 September 2025)**

Conducted at the IESA office, this session engaged the C&I and OEM sectors to discuss industry-aligned skilling pathways and workforce transition needs.

Roundtable discussion, New Delhi, 10 July 2025

Roundtable discussion, Lucknow, 29 August 2025

Roundtable discussion, Pune, 25 September 2025

**FIGURE 2.2**: Roundtable discussions on BESS capacity development

The FGD emphasized capacity development as the key to accelerate BESS deployment in India through a multi-pronged strategy of curriculum reform, hands-on training, standardization, and industry-academia collaboration. Encouraging domestic manufacturing, automation, and structured training will build a skilled workforce across the BESS value chain, enhancing India's global energy storage position.

These discussions were aimed to validate survey findings, prioritize skill development areas, and co-develop training strategies for various ecosystem segments. The deliberations focused on identifying skill development challenges and co-creating practical solutions to strengthen workforce capabilities across the energy storage sector. The qualitative data helped refine the skill gap framework and ensured that the assessment reflects ground-level realities.

## 2.7 Data Analysis and Validation

The data collected through surveys, expert consultations, and curriculum assessments was systematically analyzed using both qualitative and quantitative methods. Survey responses were coded and statistically examined to identify patterns in existing knowledge levels, skill proficiency, and training needs across different stakeholder groups. Qualitative insights from key informant interviews and expert consultations were thematically analyzed to capture sector-specific expectations, operational requirements, and emerging competency gaps in the BESS ecosystem.

Insights were reviewed with selected experts and training partners to confirm accuracy, resolve discrepancies, and align interpretations with current industry practices. This validation process strengthened the credibility of the results and ensured that the subsequent skill gap identification and training recommendations reflected real-world sectoral needs.

## 2.8 Synthesis of Findings and Identification of Skill Gaps

The insights from surveys, interviews, and curriculum reviews were consolidated to develop a comprehensive understanding of the existing capacity landscape for the BESS sector. This involved mapping current skills against the required competencies for various roles across design, installation, operation, maintenance, and safety functions. The comparison enabled clear identification of gaps in technical knowledge, operational capabilities, and cross-cutting skills such as safety compliance, quality assurance, and digital proficiency. The synthesis of findings provides the basis for targeted interventions to strengthen workforce readiness in the BESS domain.

Mapping of existing job roles across the BESS industry value chain was undertaken in alignment with the job roles identified through the skill gap analysis. The analysis also generated critical insights that informed the identification of priority actions. Accordingly, specific issues have been recommended in a phased manner, ranging from those requiring immediate attention to those forming part of a medium- to long-term strategic approach, which includes:

- Proposing customized training modules, curriculum enhancements, and capacity-building needs aligned with BESS technologies and industry standards.
- Recommending industry-aligned competencies for ITIs and other training institutions to integrate into their programmes.
- Suggesting short-, medium-, and long-term actions to upgrade training infrastructure, enhance faculty capability, expand practical exposure, and support continuous upskilling in line with technological advancements.

The methodological framework of the skill gap assessment reflects a comprehensive, iterative, and stakeholder-driven approach. Integrating desk-based evidence with field-level insights ensured that the study's findings are both evidence-based and practically useful for decision-making. This approach determines existing and emerging skill gaps across the BESS value chain and lays the groundwork for a future-ready, industry-aligned skilling ecosystem to support India's transition to sustainable and resilient energy systems.

## 2.9 Limitations of the study

While the study employs a comprehensive mixed-methods approach to assess skill gaps in the BESS sector, certain methodological limitations should be considered when interpreting the findings.

The availability and reliability of BESS-specific workforce data remain constrained due to the emerging and rapidly evolving nature of the sector. Comprehensive and disaggregated information on job roles, competency requirements, and workforce distribution is limited, necessitating reliance on secondary sources and stakeholder-reported inputs.

Stakeholder engagement across the BESS value chain also presents limitations. Despite efforts to ensure broad participation, input was more readily obtained from established organizations, technology providers, and institutional stakeholders. Smaller enterprises, early-stage project developers, and field-level technical personnel may be underrepresented, which could influence the breadth and depth of the identified skill gaps.

The fast-paced evolution of BESS technologies, including advances in battery chemistries, system integration, digital control systems, and safety protocols, poses additional challenges. Skill requirements in this sector are subject to rapid change, and the study's findings therefore represent a time-bound assessment rather than a comprehensive projection of future workforce needs. The assessment is aligned with the StoREin project's focus on strengthening battery energy storage deployment in the distribution sector. Accordingly, the survey tool focused on stakeholder groups directly involved in BESS planning, deployment, financing, operation, and skill development within the distribution ecosystem, including: DISCOMs and utilities; OEMs and project developers; C&I sector; financial institutions and banks; ITIs and other training providers; and academic and research organizations.

It should be noted that the job estimates presented do not include employment generated from upstream activities such as battery raw material mining and end-of-life battery recycling. Additionally, there is potential overlap between these estimates and job creation reported in other renewable energy sub-sectors (e.g., solar PV, wind, and hydropower).

The assessment of skills and capacities is largely perception-based, drawing on surveys, interviews, and expert consultations. Differences in respondents' interpretations of job roles, proficiency levels, and competency definitions may introduce subjectivity and limit consistency across responses. Constraints related to sample size and regional coverage may further affect the generalizability of the results. Variations in market maturity, regulatory frameworks, and levels of BESS deployment across regions may not be fully captured within the scope of the study. As the BESS ecosystem continues to evolve, these factors underscore the need for periodic updates to the assessment to reflect emerging technologies, changing market dynamics, and evolving skill requirements.

# 3.

# BESS LANDSCAPE IN INDIA

## 3.1 Overview

India is aggressively pursuing to achieve 500 gigawatt (GW) of electricity capacity from non-fossil fuel by 2030. By July 2025, India had surpassed the 50% milestone in non-fossil fuel power capacity, achieving 256 GW out of a total installed capacity of 501 GW, with solar and wind leading this growth (PIB, 2025).

However, the increasing share of renewable energy (RE) introduces challenges in grid stability and reliability due to its variability and intermittent nature. Energy storage has therefore become essential for the smooth integration of renewables into the grid.

Among the available storage options, while pumped storage projects (PSPs) and battery energy storage systems (BESS) both play key roles, BESS has an edge over PSP because of its high power density, modular design, faster deployment, and smaller land footprint.

### 3.1.1 Current Installed Capacity and Pipeline

According to the India Energy Storage Alliance (IESA), *India ESS Market Update – August 2026*, the BESS deployment landscape is provided in Table 3.1.

**TABLE 3.1**: BESS deployment landscape

| Project stage | Capacity (GWh) | Remarks |
|---|---|---|
| Operational | 9.41 GWh | Currently commissioned and in operation |
| Under construction | 52.6 GWh | ~ 2 GWh expected online by December 2026 |
| Awarded | 18.63 GWh | Construction initiation phase |
| Bid closed | 2.40 GWh | Awaiting final bidder selection |
| Bids open | 49.41 GWh | Developers preparing submissions |

The BESS projects of 80.7 GWh have been cleared for deployment and are at various stages; including operational, commissioning, and development and 51.81 GWh in the tendering pipeline.

### 3.1.2 Growth Outlook

Tender success rates have significantly improved over the years.

**76% cancellations (2018–23) → 10% in 2024 → 6% in 2025**

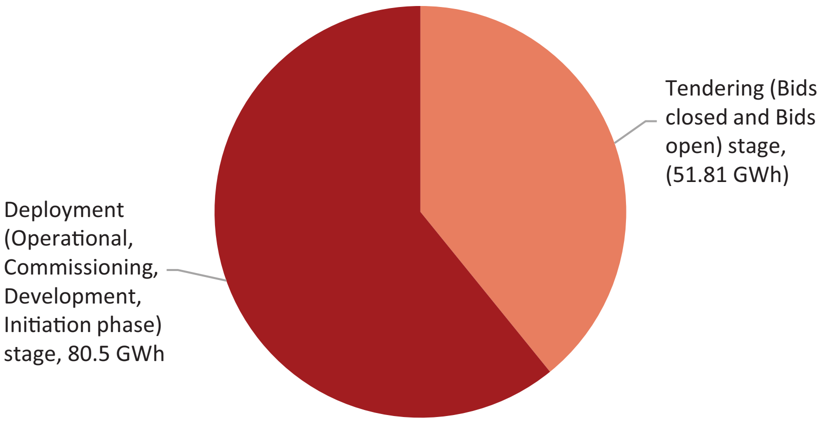

**FIGURE 3.1**: India BESS projects status (as of August 2026)

*Source:* India Energy Storage Alliance (IESA) – India ESS Market Update, August 2026

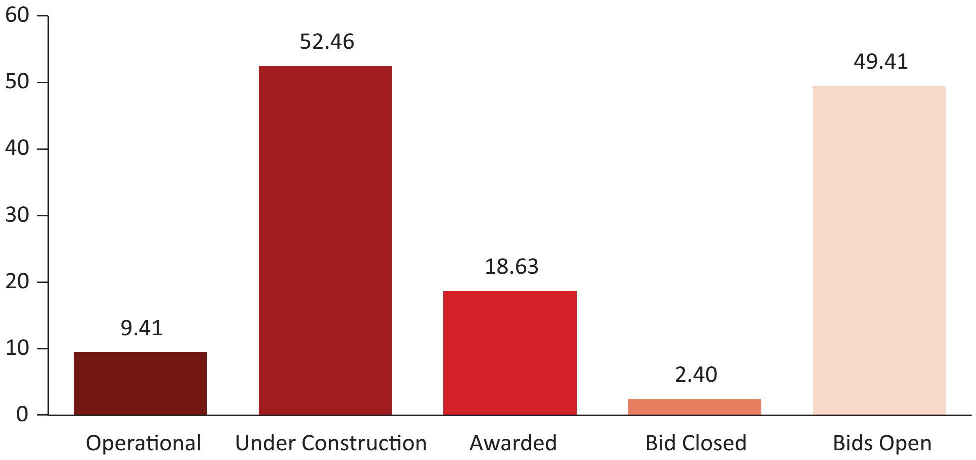

**FIGURE 3.2**: India BESS projects' cumulative status (as of August 2026)

*Source:* India Energy Storage Alliance (IESA) – India ESS Market Update, August 2026

This consistent progress and strong policy push suggest that India will surpass its interim National Electricity Plan (NEP 2023) target of 34.72 GWh of BESS by 2026–27.

With government initiatives such as viability gap funding (VGF), energy storage obligation (ESO), and the production-linked (PLI) scheme for advanced chemistry cell (ACC) batteries, coupled with declining battery prices and active participation from start-ups to large enterprises, India is well-positioned to reach its next milestone of 236.22 GWh of BESS capacity by 2031–32, potentially ahead of schedule.

**TABLE 3.2**: BESS capacity growth

| Year | Target (NEP 2023) | Actual/projected |
|---|---|---|
| 2025 | ~0.5 GWh | 0.76 GWh (operational) |
| 2026–27 | 34.72 GWh | On track |
| 2031–32 | 236.22 GWh | Likely to achieve early |

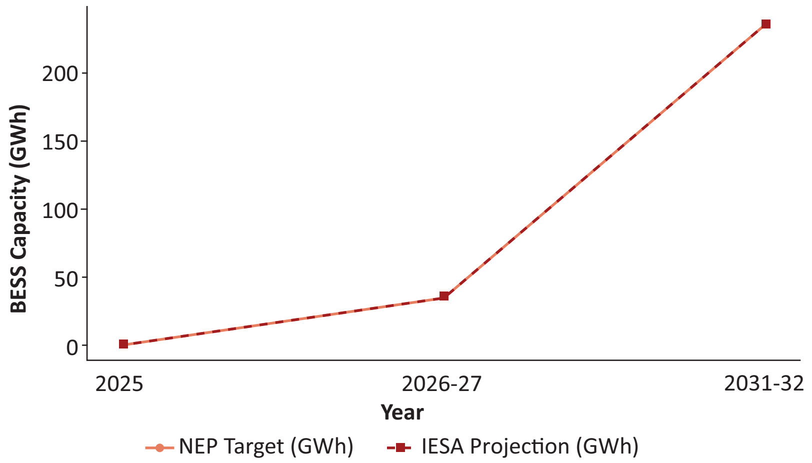

**FIGURE 3.3**: India BESS capacity growth pathways

*Source*: National Electricity Plan (2023), India Energy Storage Alliance (2025)

## 3.2 Key Technologies Enabling BESS Deployment

Battery energy storage systems are composed of multiple subsystems that work together to store, manage, and deliver energy efficiently and safely. The key enabling technologies that define the performance, reliability, and scalability of modern BESS installations in India have been discussed here.

### 3.2.1 Battery Technologies

#### *3.2.1.1 Lithium–ion batteries (Li-ion)*

Lithium–ion batteries dominate the global and Indian stationary storage markets owing to their high energy efficiency (90–95%), fast response, and modular scalability.

- **Lithium–iron phosphate (LFP):** The LFP batteries are the most widely adopted in India's utility-scale BESS projects. They offer excellent thermal stability, long lifecycle, high efficiency, and safety. The LFP technology is particularly suitable for India's climatic conditions and for applications requiring high reliability and minimal fire risk.

#### *3.2.1.2 Alternative and emerging technologies*

- **Flow batteries (e.g., vanadium redox, zinc–bromine):** Flow batteries store energy in liquid electrolytes and can deliver long-duration storage (6–10 hours) without significant capacity degradation. While commercial adoption in India is currently limited, pilot projects are underway through public–private collaborations.
- **Sodium–ion batteries:** Sodium–ion technology is emerging as a low-cost, resource-abundant alternative leveraging India's rich sodium reserves. These batteries promise comparable energy efficiency with reduced raw material dependency.
- **Zinc–ion batteries (ZIBs)**: ZIB systems have been attracting attention due to their high energy storage capacity, safety, and environmental friendliness. In addition, the natural abundance and low cost of zinc make ZIBs promising for large-scale and sustainable energy storage applications.

### 3.2.2 Power Conversion System/Inverters

The power conversion system (PCS) forms the interface between the battery (DC) and the electrical grid (AC). It enables bi-directional power flow (AC-DC), allowing the BESS to charge and discharge as per grid demand.

- **Grid-following mode (current source inverter)**: The conventional inverter configuration that synchronizes with the grid and injects or absorbs current as needed. This mode is widely used in current BESS installations for frequency and voltage support.
- **Grid-forming mode (voltage source inverter)**: It is a newer generation of PCS technology capable of independently establishing grid voltage and frequency. It supports black-start capability, provides synthetic inertia, and enhances grid resilience in regions with high renewable penetration or weak grid conditions.

### 3.2.3 Battery and Energy Management Systems

- **Battery management system:** Monitors cell parameters (voltage, current, temperature), prevents overcharge/discharge and ensures safe operation.
- **Energy management system:** Controls system-level operation, optimizes charge/discharge schedules, and interfaces with state load dispatch centres (SLDCs) for grid integration.

### 3.2.4 Thermal Management / HVAC

Temperature control is critical to the performance, safety, and longevity of battery systems, especially under India's high ambient temperature conditions.

- **Liquid cooling system:** Increasingly used in large utility-scale BESS installations for their precision temperature control, uniform heat dissipation, and higher energy efficiency.
- **Air cooling system:** Used in smaller or modular systems where cost and simplicity are prioritized, though less effective in extreme temperatures

### 3.2.5 SCADA, Safety, and Cybersecurity

- **SCADA (Supervisory Control and Data Acquisition) Systems:** These systems enable real-time monitoring, diagnostics, and remote control of BESS operations. The SCADA integrates data from BMS, PCS, sensors, and environmental systems, allowing predictive maintenance and grid coordination.
- **Safety system:** BESS installations are equipped with multi-layered safety mechanisms including fire detection, suppression systems (inert gas, aerosol, or water mist), and isolation barriers.
- **Cybersecurity**: With increased digitalization and grid interconnectivity, cybersecurity has become critical. Systems are designed to mitigate risks of unauthorized access, data breaches, or operational disruptions.

## 3.3 BESS Policy and Regulatory Landscape in India

India's journey towards large-scale deployment of BESS has been shaped through a sequence of policy, market, and regulatory interventions. Storage was classified as a grid asset in the Electricity (Amendment) Rules, 2022, and over the past decade, the Government of India has introduced multiple financial and manufacturing policies to support this. Currently, these initiatives are evolving into a full lifecycle framework covering deployment, integration, and recycling. What began as pilot tenders and technical guidelines has now grown into a structured national system: anchored by the National Framework for Energy Storage (2023), supported through central VGF and PLI–ACC manufacturing schemes, integrated into market mechanisms with the CERC ancillary service regulations, and guided by Battery Waste Management Rules, 2022 for end-of-life management. The timeline below shows how India has gradually aligned policy and market measures-from early pilots to MWh scale deployments.

### 2019

- NITI Aayog's National Mission for Transformative Mobility and Advanced Battery Manufacturing
- CEA & CERC regulations favouring inclusion of storage into grid.
- Regional policy initiatives on storage (Rajasthan and Tamil Nadu).

### 2020

- ACC battery manufacturing identified as one of the key sector for PLI .
- SECI mentioned deployment of storage in flexible RE projects.
- Maharashtra's and Telangana's policy with inclusion of storage.

### 2021

- The Ministry of Power issues amendments to the guidelines for tariff-based competitive bidding process for procurement of round-the-clock power (RE + Storage).
- RPF for implementation of PLI Scheme ACC battery manufacturing.
- Green Term Ahead Market (GTAM) to facilitate sale of RE power through exchanges.
- Notification on Production-linked Incentive (PLI) scheme, 'National Programme on Advanced Chemistry Cell (ACC) Battery Storage' by the Department of Heavy Industries.
- Order on waiver of inter-state transmission charges on transmission of the electricity generated from solar and wind sources of energy under Para 6.4(6) of the Tariff Policy, 2016 by Ministry of Power.

### 2022

- Clarification regarding usage of ESS in various applications across the entire value chain of power sector by the Ministry of Power.
- Guidelines for Procurement and Utilization of BESS for Generation, Transmission, and Distribution assets, including Ancillary Services.
- Draft National Electricity Plan (Generation-Volume 1).
- National Transmission System Plan by 2030.
- Scheme for flexibility in generation and scheduling of thermal/hydropower stations through bundling with RE and storage power by the Ministry of Power
- Order on renewable purchase obligation (RPO) and energy storage obligation (ESO) trajectory till 2029–30 by the Ministry of Power.
- Guidelines to promote development of pumped storage projects (PSP) by the Ministry of Power.
- Notification on Battery Waste Management Rules, 2022 by the Ministry of Environment, Forest and Climate Change, Ministry of New and Renewable Energy, Government of India

### 2023

- Scheme for VGF for development of BESS with a capacity of 4,000 MWh.
- PLI scheme to encourage investment in domestic manufacturing of cells for grid-scale applications.
- National Electricity Plan II (Transmission)
- The Ministry of Power issued national framework to promote ESS.
- Guidelines for tariff-based competitive bidding process for procurement of firm and dispatchable power from grid-connected RE power projects with energy storage systems, Government of India, Ministry of Power.

**2024**

- Operational guidelines for VGF scheme
- Operational guidelines for state component under VGF scheme
- Guidelines for tariff-based competitive bidding
- National Electricity Plan II (Transmission)
- Renewable energy resource adequacy planning to meet RPO by the states in India
- Andhra Pradesh Integrated Clean Energy Policy 2024, Rajasthan's Battery Storage Initiative

**2025**

- Advisory on Co-locating energy storage systems with solar power projects
- CEA drafts safety guidelines for BESS
- Expanded VGF scheme for 30 GWh of BESS
- Mandate for indigenous energy management software
- Waiver of inter-state transmission charges for energy storage systems

*Sources*: PIB, MNRE, MHI, and MoP (websites)

With the increasing traction in BESS and energy storage initiatives at the national level, states too have begun showing significant momentum in integrating storage solutions into their RE portfolios. However, it is critical that state-level policies and regulations keep pace with Central Government frameworks and transmission-level planning to ensure seamless integration, grid stability, and maximum utilization of storage assets. Several states have proactively included ESS in their RE policies, introduced incentives for storage deployment, and promoted hybrid renewable-plus storage projects. These measures not only complement national objectives but also provide a conducive environment for private investment, technology adoption, and reliable power supply at the state level.

**Uttar Pradesh**

» Emphasis on linking energy storage with rural agricultural loads and supporting rural grid stability

» Promotion of solar-powered microgrids integrated with storage systems, targeted at enhancing rural electrification and energy access

» Framework aimed at integrating DES in off-grid supply to agricultural pump sets under PM-KUSUM components

**Rajasthan**

» State policy promotes off-grid decentralized solar with mandatory or incentivized energy storage components

» Supportive net-metering regulations combined with DER-friendly open access rules encouraging residential and commercial rooftop solar with storage

» Development of rural solar micro-grids with integrated battery storage under state rural electrification programmes

**Gujarat**

» Advanced framework support rooftop solar-plus battery storage projects with proactive coordination between DISCOMs and regulators

» Implementation of state mandates for energy storage co-deployment with renewable projects to help grid balancing

» Incentive schemes available for behind-the-meter DES systems, promoting grid-interactive distributed resources

**Maharashtra**

» Mandated integration of 2-hour battery energy storage for new solar projects aimed at improving grid-stability

» DISCOM-led programmes incentivize energy storage for peak management and ancillary services

» Adoption of model regulations for DER grid interconnection, including energy storage systems for ancillary services provision

**Tamil Nadu**

» State mandates require all solar projects to include energy storage components to enable better grid integration and stability

» Financial incentive scheme encourages residential and commercial adoption of rooftop solar combined with battery storage

» Pilot projects underway exploring aggregation of DER including battery system for grid services

**Assam**

» Emerging state policies endorse decentralized RE systems integrated with energy storage to improve rural energy access

» Pilot solar micro-grid projects with battery storage underway, focusing on remote and unelectrified areas

» Focus on integrating storage in agricultural and community energy project under state rural electrification initiatives

### Andhra Pradesh

- Andhra Pradesh has opened its grid market to BESS enabling storage operators to provide frequency, voltage, and black start services.
- The framework establishes Distributed Energy Resources Aggregators, allowing independent entities to manage, dispatch, meter, and settle small-scale systems
- The framework enables AGC signals for the state load despatch centre to automatically adjust battery injection based on real-time demands.

### Telangana

- The policy allows utilities to procure Firm and Dispatchable (FDRE) or Round-The-Clock (RTC) RE solutions combined with BESS.
- The rules authorize commercial space optimization, enabling state-backed utilities to allocate designated spaces at substation grid-nodes under long-term contracts.
- The framework enables strict performance metrics, demanding baseline storage capacity deployments at critical substations.

### Bihar

- The policy intends to promote a diversified project folio spanning across regions and applications.
- Grid-connected RE projects that voluntarily include storage systems receive an extended 20-year transmission charge exemption
- Homeowners and businesses can set up grid-connected plants up to 1000 kWp within their premises.

### Odisha

- Odisha has opened its ancillary services market to BESS, enabling storage developers to generate additional revenue.
- BESS projects receive a 100% exemption on electricity duty for 15 years provided the energy is sourced from renewable energy projects within the state.
- The policy pushes for the development of new solar cities and dedicated industrial space to feature co-located BESS infrastructure.

# 4.

# INTERNATIONAL BEST PRACTICES IN BESS SKILLING

A comprehensive strategy that incorporates strong safety regulations, global cooperation, and focused training throughout the whole battery energy storage systems (BESS) value chain is emphasized by international best practices in BESS skilling. The following is a list of priorities in global best practices for BESS value chain skilling:

- **Creation of international certifications and standards:** Adopting international performance and safety standards is the key best practice that guarantees uniformity and quality throughout the sector.
- **Thorough value chain training:** The full BESS lifespan, from design and production to operation, maintenance, and recycling/end-of-life management, must be covered by skill development programmes.
- **Focused action plans for skill gap analysis:** To address workforce shortages, governments and industry stakeholders are required to carry out skill gap assessments and chart focused action plans to pinpoint specific needs of the BESS value chain.
- **Collaboration and knowledge exchange:** Knowledge sharing and policy developments depend on promoting collaboration through conferences and collaborations between industry executives, legislators, regulators, and researchers.
- **Integration of digital tools and AI:** Improvement in grid resilience and promotion of effective energy management in BESS applications and trainings should include next-generation digital tools, AI, and utility intelligence platforms.
- **Support from policy and regulations:** Clear and consistent policy and regulatory settings with long-term revenue visibility and predictability are required to boost investment in dedicated skilling infrastructure for BESS value chain.

This section will analyse the skilling initiatives and best practices followed in some countries where BESS adoption has been high.

## 4.1 United States

In 2024, the United States (US) added about 10.3 gigawatt (GW) of new utility-scale battery storage capacity (EIA, 2024), which is projected to increase to 450 gigawatt hour (GWh) by 2030 (ESS, 2025). In the US, workforce development for battery energy storage is explicitly connected to the national agenda for domestic battery manufacturing, supply-chain resilience, and clean energy transition goals. The US Department of Energy (DoE) and the US Department of Labor (DoL) jointly lead these efforts, with strong participation from national laboratories, industry consortia, trade unions, and community colleges.

### BESS Capacity-building Initiatives

These initiatives collectively reflect a workforce planning approach in which training and capacity-building interventions are aligned with the evolving skill and competency requirements associated with battery manufacturing, energy storage deployment, system operation, and lifecycle management.

a. **Battery Workforce Initiative (BWI):** The BWI is a US national initiative, launched in 2022, and led by the US Department of Energy to address the growing need for a high-skilled workforce in advanced battery manufacturing which is projected to expand nearly twenty-fold by 2030 (US Department of Energy, 2024). Implementation is supported by DoE's workforce offices and the national labs, e.g., National Energy Technology Laboratory (NETL), in collaboration with community colleges, industry employers, and labour organizations (NETL, *n.d.*).

The initial public funding announced for BWI was US $5 million to support up to five pilot training programmes in battery manufacturing and supply-chain workforce development, targeting energy and automotive communities (US Department of Energy, 2022). Further training financing is likely to occur via employers, colleges or state-level programmes.

BWI's core functions include rapidly developing high-quality training programmes, standardizing industry-aligned training models through expert collaboration, and establishing national apprenticeship guidelines to expand access to industry-recognized credentials.

BWI's focus areas span the entire battery supply chain, including mining, battery material processing, cell manufacturing, pack manufacturing, training materials for machine operators, technicians, and extending to end-of-life recycling (DoE, 2024).

Under the BWI, the US DoE and the US Department of Labor (DoL) have developed National Guideline Standards (NGSs), in 2024, for the battery machine operators that defines detailed skill requirements and competencies for workers in advanced battery manufacturing facilities. These standards provide nationally recognized training requirements that can be implemented across community colleges and training institutions (NETL, *n.d.*).

The Battery Workforce Initiative uses a 'blended training delivery model' combining in-person and virtual (hybrid) instruction, tailored to local training contexts:

- **Registered apprenticeships** under the National Guideline Standards (NGS) primarily involve in-person training at employer sites or community college laboratories, supported by classroom and theory modules delivered virtually or in blended formats.
- **Pilot training programmes**, funded under the initial US$5 million grant allocation, combine classroom instruction, hands-on equipment-based training, and online theoretical components.
- **Multi-stakeholder partnerships** between industry, community colleges, labour organizations and government agencies enable flexible, region-specific deployment models aligned with manufacturing demand and training capacity.

b. **Battery Workforce Challenge Program (BWCP):** The BWCP, funded by the US Department of Energy and managed by Argonne National Laboratory, addresses critical skill gaps in the battery and EV manufacturing ecosystem through a hands-on, industry-aligned skilling delivery model, structured around four core focus areas:

1) **Regional workforce training hubs**: Establishment of physical training centres equipped with manufacturing-grade battery systems to deliver experiential training for technicians and vocational workers.
2) **Collegiate engineering competition**: A multi-year programme where universities design, build, and test real EV battery packs, developing work-ready engineering and system-integration skills.
3) **Standardized curriculum and career pathways**: Development of nationally aligned curricula, credentials, and certifications linking schools, colleges, training centres, and employers.

4) **STEM outreach and talent pipeline development**: Early engagement at school level and community programmes, supported by digital learning platforms, to expand recruitment, diversity, and workforce inclusion.

Through BWCP, the programme seeks to address critical skill-gaps across the battery value chain by delivering training and education for the target group including high-school graduates, vocational and transitional workers, technicians, and engineers, thereby fostering a diverse talent pipeline for battery manufacturing, integration, testing, and maintenance.

c. **NYSERDA's Municipal Capacity-Building Framework** (sub-national-level regulatory training): NYSERDA provides a comprehensive suite of capacity-building tools to support safe and consistent deployment of BESS by local governments across New York State. The *Battery Energy Storage System Guidebook* offers a complete procedural and regulatory framework for BESS siting, permitting, inspection, and safety compliance, including model laws, model permits, and inspection checklists aligned with state building and fire codes. Complementing this, NYSERDA's dedicated webinar series delivers on-demand and expert-led training for municipal officials, code enforcement officers, and first responders on BESS technology fundamentals, permitting processes, and best practices for safety and community integration. Together, these resources strengthen municipal readiness and promote uniform regulatory standards for BESS development.

d. **'How-to' guide on operating and maintaining battery energy storage systems** by the National Renewable Energy Laboratory (NREL) and Rocky Mountain Institute (RMI). A comprehensive BESS 'how-to' guide has been developed by NREL and RMI and available on the RMI Energy Transition Institute which provides step-by-step guidance on planning, designing, implementing, and maintaining battery energy storage systems (NREL, *n.d.*).

**Key Lessons for India from the US**

- Workforce skilling must be linked to manufacturing and deployment plans.
  Example: The Battery Workforce Initiative (DOE + DOL) designed training standards only after mapping giga-factory hiring needs.
- National competency frameworks ensure consistency and portability of skills.
  Example: The registered apprenticeship for battery machine operators is recognized nationwide via the US Apprenticeship Office.
- Safety training must be embedded across all skill levels.
  Example: The NREL BESS Operations and Maintenance Guide (2024) is used for technicians, system designers, and grid operators.
- University–industry pipelines are necessary for next-generation battery talent.
  Example: The Battery Workforce Challenge Program requires student teams to design and test real battery packs under industry guidance.
- Hands-on training must take place in real equipment environments through regional hubs.
  Example: Argonne's Regional Workforce Training Hubs under the Battery Workforce Challenge Program use manufacturing-grade equipment for technician and operator training.

e. **Industry-oriented professional training courses** by private entities such as DNV, Tonex, the Bluenergy target mid-career energy professionals, emphasizing system planning, performance evaluation, risk assessment, and financial modelling.

## 4.2 United Kingdom

The UK government's BESS targets between 23 and 27 GW of battery storage capacity by 2030 to support its 'clean power by 2030' goal (UK Government Department of Energy Security and Net Zero, *n.d.*). The government's official UK Battery Strategy (2023) sets out a national framework to build domestic battery manufacturing, recycling, safety systems, and supply-chain capabilities, alongside investments exceeding £2 billion through 2030 to support R&D, pilot-scale manufacturing, and skills development. The UK is estimated to generate 100,000 full-time equivalent (FTE) jobs from battery manufacturing plants and the supply chain (UK Government Department for Business and Trade).

The UK has a dual-track workforce development approach which includes (i) advanced skills pipeline for battery manufacturing, systems engineering, and R&D through dedicated research institutions and Centres for Doctoral Training; and (ii) industry-facing vocational and professional training for BESS installation, safety compliance, electrical integration, and O&M delivered via trade bodies, national skills councils, and compliance agencies.

This reflects the UK's approach of aligning BESS capacity-building initiatives with workforce requirements across battery manufacturing, research and innovation, system integration, installation, operations and maintenance, and safety management.

The UK's storage workforce ecosystem is anchored by four major institutional pillars: (i) Faraday Institution (ii) UK Battery Industrialization Centre (UKBIC) (iii) EPSRC Centres for Doctoral Training (CDTs); (iv) National Skills Academy for Power (NSAP).

**a. University and Engineering Programmes**

- The Faraday Institution, established in 2017 under the UK Government's Faraday Battery Challenge, is the UK's national research institute for electrochemical energy storage. It is primarily funded through UK Research and Innovation (UKRI) with core public funding support from Innovate UK and the Department for Science, Innovation and Technology via the Industrial Strategy Challenge Fund; this is supplemented by industry co-funding of research programmes and doctoral studentships.

  Faraday's focus areas of training involve advanced battery science and engineering capacity building, including (The Faraday Institution, n.d.):

- Materials research
- Battery materials development and battery-pack design
- Degradation modelling
- Recycling and reuse
- Safety analysis
- Next-generation battery technologies (solid-state, sodium-ion, lithium-sulphur, etc.)

  Training is delivered through a structured, cohort-based doctoral programme embedded within university research groups across the UK. Training delivery model includes: in-person university research training, residential cohort schools and workshops, hands-on laboratory research, industry placements and secondments, professional skills training delivered via blended learning and seminars. The Faraday Institute provides structured skill development targeting PhD/EngD students, post-doctoral researchers, early-career academic scientists, industrial R&D researchers for tackling industrially relevant battery problems, combining high-level academic research with real-world application orientation.

Faraday Battery Challenge (under UKRI Challenge Fund) funded the establishment of National Battery Training and Skills Academy to develop a workforce to bridge the skills gap in lithium–ion battery research, development, and manufacturing (Newcastle University, n.d.). Training programmes are delivered by the Newcastle University in collaboration with New College Durham employing practice-oriented delivery model combining hands-on training on a scaled-down battery manufacturing line, classroom-based instruction, and use of immersive learning technologies, including digital simulations and virtual learning tools (e.g. safety training).

- **Centres for doctoral training (CDTs):** In the UK, doctoral training in energy storage and allied fields is often carried out via CDTs, funded by Engineering and Physical Sciences Research Council (EPSRC) under national doctoral training scheme. Each CDT receives multi-year public funding complemented by university co-funding and industry sponsorships for individual students or projects funded. Such CDTs deliver structured doctoral programme adopting a cohort-based model (typically '1 + 3': one taught/masters-equivalent year plus three years of PhD research) compared to the traditional 3-year individual-supervisor PhD (University of Sheffield, *n.d.*).

CDTs relevant to BESS provide multidisciplinary doctoral education with industrial links covering materials science, chemical and mechanical engineering, electrochemistry, system integration.

One concrete example of the EPSRC CDT for Doctoral Training in Energy Storage and its Applications is jointly hosted by the University of Southampton and University of Sheffield, which trains doctoral students in electrochemical storage (batteries, supercapacitors), mechanical storage, thermal storage, superconducting magnetic storage, and related system-integration aspects (University of Sheffield, *n.d.*).

### b. Hands-on manufacturing skilling

The UK Battery Industrialization Centre (UKBIC) was launched as the UK's national battery manufacturing scale-up and training facility to bridge the gap between lab-scale battery research and mass production. It serves as a 'learning factory' for organizations to develop blueprints for manufacturing processes and prototyping (UKBIC, *n.d.*). The UKBIC was funded mainly through UK Government investment via Innovate UK (UKRI), with regional contributions, alongside ongoing cost-recovery income from industrial users that pay to access the pilot manufacturing lines for testing and validation.

The UKBIC provides specialist skills development and training programmes to support the battery manufacturing workforce in the UK and internationally (UKBIC). Training is delivered primarily as short-course, hands-on, in-person instruction using industrial-scale equipment, with minimal online-only courses.

Courses of UKBIC's specialist training programmes include:

- Introduction to electrode processes
- Introduction to cell assembly
- Introduction to formation, ageing, and testing processes
- Substance awareness, clean and dry rooms in battery manufacturing
- Fundamentals of sustainable manufacturing processes
- UKBIC allows industry partners to place staff to undertake hands-on training alongside the Centre's expert instructors, in real-world battery production environments.

- UKBIC's flagship public-access course, 'Introduction to Battery Manufacturing', is a two-day course designed to deliver a foundational understanding of battery technologies and manufacturing processes, targeting manufacturing technicians, battery process engineers, SME technology developers, OEM engineering teams, and technical professionals transitioning from adjacent sectors such as automotive or electronics manufacturing. The course covers the full lifecycle of battery development and production, complemented by on-site experience of UKBIC's operational manufacturing lines at its Coventry facility.
- In addition, as a founding member of the Electrification Skills Network, UKBIC has delivered advanced training to battery developers from across Europe and the United States, contributing to international skills capacity building in the sector.
- UKBIC has also partnered with awarding body EAL to support the development of accredited vocational qualifications in battery manufacturing, strengthening progression pathways for technicians and production staff (EAL , 2025).

### c. Vocational and technician pathways

- **Battery Manufacturing Skills Pathway (B-MSP):** Launched in 2025 by the University College Birmingham and developed in direct collaboration with leading industry employers (employer-focused training solutions), this is the UK's first accredited vocational pathway combining hands-on skills development, and immersive digital technologies for preparing learners for advanced manufacturing roles in battery assembly, giga-factory operations and the wider electrification sector. It targets those starting their careers or employers seeking upskilling workforce solutions (University College Birmingham).
- **National Skills Academy for Power (NSAP):** The National Skills Academy for Power, was established with UK Government support and ongoing industry funding via employer membership contributions, sector levies, and apprenticeship funding streams. Its focus is workforce development across the power sector, increasingly aligned with low-carbon technologies, digital grids, and energy storage integration. The NSAP addresses the largest segment of the workforce pyramid such as installers, substation engineers, field-level technicians through knowledge of power systems power-sector pathway rather than through battery-only programmes with focus areas such as grid operation, maintenance, SCADA systems, systems integration, electrical installation.

### Birmingham Centre for Energy Storage (BCES), University of Birmingham—Interdisciplinary research, development, and innovation centre, going beyond Li-ion storage

The BCES convenes researchers across disciplines (materials science, chemical engineering, energy systems, thermal storage) and partners with international and national institutions and industry, placing emphasis on innovation, new storage technologies beyond Li-ion (thermal energy storage, liquid-air energy storage (LAES), phase-change and cryogenic storage), sustainability, grid integration, circularity—offering a different value proposition than purely manufacturing-scale training.

### d. Regulatory, Safety, and First-responder Training

Regulatory authorities and fire services conduct targeted training programmes to improve preparedness for lithium–ion battery incidents: Examples include (i) Health and safety executive (HSE) guidance and inspection training on health and safety responsibilities, BESS planning permission, environmental protection, and fire and rescue service (Health and Safety Executive), (ii) National Fire Chiefs Council (NFCC) imparts battery fire response training and operational doctrine. This institutional skilling ensures safety oversight capacity as large-scale BESS deployment accelerates.

**Key Lessons for India from the UK**

- Establish 'learning factories' to simulate full-scale industrial processes.

  Example: UK Battery Industrialisation Centre (UKBIC) enables hands-on training in pilot-scale manufacturing lines.
- Provide stacked progression pathways from vocational to advanced engineering.

  Example: National Battery Training Academy trains Level 2/3 technicians, while universities like Strathclyde train battery engineers.
- Align curriculum with national research programmes to prevent obsolescence.

  Example: The Faraday Institution transfers research outputs directly into curriculum and training modules.
- Offer modular specialist courses to enable rapid mid-career reskilling.

  Example: UKBIC's Electrode Manufacturing 'Deep Dive' upskills technicians in 3–5 day short programmes.
- Ensure industry co-designs and co-funds training pathways.

  Example: Battery manufacturers partner with the Birmingham Battery Manufacturing Skills Pathway (B-MSP) to refine training content.

## 4.3 Australia

The Australian Energy Market Operator (AEMO) has forecast that Australia will need 19 GW of energy storage capacity in the grid by 2030 (National Battery Strategy, *n.d.*). Australia's National Battery Strategy (NBS) was designed with the aim to strengthen Australia's position in the global battery supply chains and expand its manufacturing capabilities to align with the Future Made in Australia agenda. The $20.3 million Building Future Battery Capabilities measure underneath the NBS will build future battery industry skills and capabilities and strengthen national collaboration. The Battery Powered Pathways guide (2025) maps job opportunities in the battery value chain and estimates that a diversified battery industry in Australia could support 61,000 workers by 2030, with nearly 70% in vocational education and training (VET) roles (technicians, electricians, operators) and 30% in higher-skill / engineering roles (Powering Australia, 2025).

This workforce mapping has informed Australia's capacity-building initiatives, resulting in differentiated training pathways for vocational roles, engineering professionals, researchers, installers, and emergency response personnel across the battery value chain.

### a. Universities & Research Training

- **ARC Industrial Transformation Training Centre for Future Energy Storage Technologies (storEnergy)**: Advanced technical and scientific skills for the storage sector are anchored in ARC-funded industrial training centres, most prominently the ARC Industrial Transformation Training Centre for Future Energy Storage Technologies (storEnergy). Established in 2019, storEnergy is led by Deakin University with participation from multiple Australian universities and over 20 industry partners storEnergy's unique feature is its formal mandate to produce a skilled workforce alongside research outputs, institutionalizing skills creation inside national energy research funding. Training delivery targets predominantly physical and lab-based, embedding workforce development within PhD and post-doctoral research programmes. training focuses on:

  - Battery materials and electrochemistry
  - Device engineering and pack integration
  - Grid-connected storage systems and recycling
- **Deakin University's Battery Research and Innovation Hub (BatTRI-Hub 2.0)**: BatTRI-Hub 2.0 facility, complements **storEnergy**, is funded through university capital expenditure, ARC projects and industry partnerships. BatTRI-Hub operates as a 'teaching factory', providing:
  - Dry labs for electrode fabrication
  - Glove-box environments for cell assembly
  - Battery testing and diagnostics laboratories

This hub offers fully physical and hands-on training to engineering students, industry staff, for bridging a critical gap between university education and factory production environments, allowing trainees to build cell-to-pack manufacturing competencies.

- In parallel, postgraduate engineering programmes at UNSW, RMIT, and the University of Western Australia integrate battery storage modules into renewable and sustainable energy degrees. These are delivered via hybrid classroom and laboratory teaching, focusing on system modelling, grid integration, power electronics, and project design. Their graduates predominantly enter planning and engineering roles rather than manufacturing or technician positions.

### b. Vocational and installer training

Australia's BESS installer and technician workforce is developed through the nationally regulated vocational education and training (VET) system, delivered by accredited registered training organizations (RTOs) which can be both public and private. Technical and further education (TAFE) institutes operate as the publicly funded backbone of this RTO network, while specialist private RTOs complement delivery with agile, short-course programmes. Both TAFEs and private RTOs deliver the same nationally recognized qualifications, aligned with industry competency standards and embedded in regulatory and licensing frameworks, making participation in training mandatory for market entry rather than voluntary upskilling.

Technical and Further Education New South Wales (TAFE NSW), Australia's largest public vocational provider, plays a central role due to its state-wide campus network, dedicated electrical and renewable-energy labs, and workforce development mandate. It delivers micro-credentials such as:

- Energy storage systems (MHE20502C) focused on battery fundamentals and system applications (TAFE NSW, *n.d.*).
- Grid-connected Battery Storage Systems Designer–Installer Skill Set (UEESS00191-01) (TAFE NSW) , which is a nationally recognized core installer qualification. Certification under UEESS00191-01 is mapped directly to Solar Accreditation Australia (SAA) requirements. Only SAA-accredited electricians are legally permitted to design and install grid-connected battery systems. The nationally recognized UEESS00191-01 certification is also delivered by RTOs including Global Sustainable Energy Solutions (GSES), National Electrical and Communications Association (NECA), Project Management Vision (PMV), and Electrogroup, alongside TAFE**.**

The TAFE Centre of Excellence Clean Energy Batteries (TCE CEB), led by TAFE Queensland, established as a $20-million joint investment between the Australian and Queensland Governments, operates as a national coordination hub/networked Centre that collaborates with all TAFE campuses, universities, industry, and unions nationally to develop and deliver standardized battery training products (TAFE Queensland). It offers micro-credentials, skill-sets, and pathways for vocational cohorts (trade assistants, apprentices, licensed electricians) as well as applied research grants to develop innovative training content. The target learning group includes students seeking higher-level or degree-equivalent apprenticeship pathways; priority cohorts such as First Nations people, culturally and linguistically diverse people, and people with disability, to improve their participation and success in training.[1]

- Smaller vocational/private providers and RTOs offer short courses focused on battery installation and solar plus battery PV storage systems, enabling quicker upskilling for grid-tied or off-grid battery storage installation.

### c. Grants to organizations for employee upskilling

Recently (November 2025), Powering Australia Industry Growth Centre (PAIGC) launched the Battery Workforce Skills and Training Grants (BWST) programme, a A$ 1.6-million initiative running through to 2027, to provide training grants to organizations seeking to upskill their workforce and strengthen the skills pipeline for Australia's battery and BESS sector. The programme delivers funding across competitive rounds, with approved projects implemented through accredited training providers (TAFEs, RTOs, and universities), reinforcing PAIGC's role as a national skills-coordination and funding intermediary rather than a direct training provider (Powering Australia, 2025)**.**

### d. Fire safety and emergency response training

In 2025, Australasian Fire and Emergency Service Authorities Council (AFAC), developed strategy for fire safety at BESS (AFAC, 2025). Engineers Australia provides training on BESS fires (Engineers Australia, *n.d.*).

Key defining features of international BESS Capacity Building Initiatives:

- **Value-chain coverage:** Workforce planning spans R&D, manufacturing, installation, operations, recycling and emergency response.
- **Blended delivery models:** Universities and hubs offer fully physical lab training, while vocational institutions combine online theory with compulsory hands-on blocks.

**Key Lessons for India from Australia**

- Integrate skills development into national battery policy and research frameworks: For example, Australia embeds workforce creation directly into the National Battery Strategy and ARC-funded centres like storEnergy, ensuring skills evolve with technology and market needs.
- Build 'teaching factory' hubs for hands-on manufacturing and diagnostics training: For example, facilities such as Deakin's BatTRI-Hub provide real manufacturing environments ensuring factory-ready talent.
- Establish a unified national vocational system with mandatory certifications: For example, TAFE and accredited RTOs deliver standardized certifications, and only UEESS00191-01-certified electricians may design or install grid-connected BESS.
- Use networked centres of excellence to coordinate curriculum, industry partnerships, and inclusion pathways: TAFE Queensland's Clean Energy Batteries CoE links TAFEs, universities, industry, and unions to co-develop content, share infrastructure, and expand access.
- Mandate blended delivery with compulsory practical components. VET and university programmes require lab-based and site-based practical training regardless of online theory delivery.
- Treat safety, emergency response, and value-chain-wide competencies as core training pillars: AFAC's national BESS fire safety strategy and Engineers Australia's courses institutionalize safety alongside Battery Powered Pathways' value-chain role mapping.

- **Regulatory anchoring:** Certification is legally required for market participation, guaranteeing stable training demand.
- **Dedicated safety governance:** Battery fire risks are addressed through specialist institutions independent of technical installer pathways.

Together, these institutions form a coordinated national architecture for BESS skills development rather than a fragmented training marketplace.

## 4.4 Germany

By mid-2025, Germany had almost 22.1 GWh of installed battery storage capacity and nearly two million battery systems in operation, with strong growth in both home and large-scale storage (PV Magazine, 2025). Germany's battery workforce strategy spans university, professional and vocational levels, with strong emphasis on hands-on learning and industry co-design. Germany is using dual and practice-integrated Master's programmes to close the gap between high-end R&D and factory-ready skills, ensuring graduates are immediately productive in giga-factory environments. University degrees (doctoral, engineering) for R&D, innovation, advanced manufacturing. Germany treats circular economy skills and digital production monitoring as core competencies, not peripheral topics, aligning workforce capabilities with EU regulatory and sustainability mandates.

QuW-LIB is a flagship government-funded initiative (comprising consortium of public–private entities) to develop a national qualification framework for Li-ion battery roles, training 600–900 specialists per year from 2026. It has established national training centre at Fraunhofer ISIT in Itzehoe that combines a giga-factory-style 'learning street' with digitally enabled training (including VR/AR) across multiple levels of the German Qualifications Framework (DQR) (quw-lib, *n.d.*).

The QuW-LIB initiative explicitly links training provision with occupational profiles and competency requirements across battery manufacturing, quality assurance, system integration, safety, and recycling functions, ensuring that workforce development is aligned with the needs of Germany's rapidly expanding battery industry.

### a. University degrees—research, innovation, advanced manufacturing

- Helmholtz Institutes and Doctoral Training: Germany's advanced battery competence is anchored in the Helmholtz Association and its battery-focused institutes (listed below), which feed directly into university curricula and industrial innovation.
  - **Helmholtz Institute Ulm (HIU):** Focuses on next-generation battery concepts (beyond Li–ion, including solid-state, magnesium and sodium-ion) and fundamental electrochemistry (Helmholtz Institute Ulm, *n.d.*)
  - **Helmholtz Institute Münster:** specialises in electrolytes and interfaces (liquid, polymer, solid) for safer, higher-performance batteries, informing advanced modules at RWTH Aachen University and the University of Münster.
- **Advanced manufacturing degrees (engineering):** These programmes train the engineers and managers needed for giga-factories and complex BESS projects:
  - **RWTH Aachen, TU Munich, Universität Bayreuth, others**—offer M.Sc./M.Eng. programmes and advanced modules on:
    - Battery systems engineering and modelling
    - Ageing and lifetime prediction

  - Diagnostics and simulation (including digital twins/AI)
  - Production engineering, automation and robotics, example RWTH programmes.
- **SRH Berlin—M. Eng. Sustainable Battery Production Engineering (Dual)**: A practice-integrated master's that explicitly combines production engineering, automation, data analysis, quality assurance, specific modules on recycling, sustainable materials selection, end of life handling. SRH Berlin's M. Eng. Sustainable Battery Production Engineering, is a standout example under Germany's Dual Study Model**,** as it mandates continuous employment with an industrial partner alongside academic coursework.
- **Long-duration storage**: Germany is building specialized R&D skills beyond Li–ion through Fraunhofer-led doctoral training (ICT's SPACER/FlowCamp projects) and university–industry collaborations (HAW Hamburg/DECHEMA) focused on redox-flow battery materials, system durability, safety, for long-duration storage applications.

**b. Applied research and training hubs (Fraunhofer)**

Fraunhofer institutes run 'learning factories' that simulate giga-factory environments, pilot production lines, and modular industry courses. This approach trains workers (manufacturing, quality assurance practices, digital production methods) in controlled, high-fidelity simulated environments before they enter giga-factories, which reduces safety incidents, downtime and scrap rates.

- **Fraunhofer-FFB – Europäisches Lernlabor Batteriezelle (ELLB**) is Germany's national learning-factory platform which complements QuW-LIB by providing real giga-factory-grade, hands-on training inside clean and dry rooms, automated cell assembly, formation/ageing processes, and in-line quality control.
- **Fraunhofer-FFB – Training Metro** provides modular end-to-end skilling catalogue spanning cell development (materials and electrochemistry), battery cell manufacturing, digitalisation (data science and digital twins), and sustainability (recycling, battery passport, EU compliance).
- **Fraunhofer UMSICHT and partner institutes**: Practical workshop programmes using demonstrators (including flow batteries) to build early-stage technical skills and sector awareness among students and early-career professionals.

**c. Vocational training**

Germany's vocational battery skilling ecosystem directly underpins giga-factory scale-up by certifying installers, technicians.

- **RKW Sachsen:** Regional workforce training on battery fundamentals, energy management, and system integration tailored to SMEs and industrial users.
- **FGH e.V.:** Professional courses covering grid integration standards, testing protocols, fire safety, and commissioning (FAT/SAT) for storage installations.
- **QuW-LIB Campus (Itzehoe):** Vocational training on real learning production lines for cell assembly, quality testing, and safety procedures aligned with giga-factory operations.

**d. Professional seminars and short courses** target engineers, project developers and managers already in the workforce, focusing on short, high-impact, standardized training. A key example includes Fraunhofer 'business clubs' (e.g. European Battery Business Club – EBBC) that provide online modules on battery value chains, data, manufacturing, and dismantling and recycling, aimed at bridging R&D and business practice.

**e. Safety, fire protection, risks:** TÜV Rheinland's storage courses embed compliance with German and international safety standards, including correct installation, testing and operational protocols.

**Key Lessons for India from Germany**

- Align curricula with real giga-factory hiring pipelines (e.g., QuW-LIB linked to Northvolt's giga-factory pipeline), not generic skill lists.
- Establish regional battery learning factories where technicians and engineers would be trained to operate under real giga-factory constraints before entering actual plants, significantly lowering industrial scale-up risks.
- Create a national, modular qualification framework for BESS roles to ensure skill portability across states and employers.
- Treat circular economy skills and digitalization/AI (for manufacturing) as core competencies, not an add-on.
- Treat digitalization as a core production skill, not an add-on for Industry 4.0.
- Institutionalize industry embedding even at master's level, ensuring graduates enter giga-factories with experience and real production systems.

## 4.5 Global Insights on BESS Workforce Development and Skilling

### Summary of Key Lessons for India

- **Link training to hiring pipelines:** Workforce programmes must be anchored to confirmed giga-factory and BESS project demand (e.g., USA's BWI, Germany's QuW-LIB with Northvolt, UK's employer-designed B-MSP).
- **Create learning-factory hubs:** Hands-on training on manufacturing-grade equipment is essential before deployment (e.g., UKBIC, Germany's Fraunhofer-ELLB, USA's Argonne hubs, Australia's BatTRI-Hub).
- **Adopt national portable qualifications:** Modular certifications enable skill mobility across regions and employers (e.g., USA's NGS apprenticeships, Germany's DQR framework, Australia's VET installer licences, UK's accredited B-MSP pathways).
- **Mandate blended delivery models:** Scale online theory but require compulsory lab and site training (e.g., hybrid BWI programmes, UKBIC immersive courses, Fraunhofer Training Metro, Australian university–TAFE models).
- **Build dual pipelines—vocational + engineering:** Balance technician training with advanced R&D and systems engineering pipelines (e.g., UK Faraday CDTs + B-MSP; Germany's Helmholtz institutes + dual-study masters).
- **Institutionalize safety and regulatory training:** Prepare inspectors, municipalities, and first responders alongside installers (e.g., NYSERDA, HSE/NFCC UK, AFAC Australia, TÜV Germany).
- **Use public–private training consortia:** Public funds de-risk infrastructure while OEMs co-design curricula and placements (e.g., QuW-LIB Germany, UKBIC & Faraday UK, BWI USA, TAFE CoE Australia).
- **Embed digitalization and circular economy skills:** Manufacturing data systems and recycling/EoL management must be core competencies, not electives (e.g., Fraunhofer Training Metro, Faraday recycling modules, storEnergy Australia, BWI life-cycle scope).

# 5.

# EXISTING CAPACITY BUILDING AND TRAINING ECOSYSTEM IN INDIA

## 5.1 Overview

The battery energy storage system (BESS) sector in India is rapidly evolving, driven by the country's transition towards renewable energy (RE) integration, electric mobility, and grid modernization. To support this transition, a robust capacity-building and training ecosystem is essential for developing the necessary technical skills, operational expertise, and institutional capabilities across the entire value chain.

National and institutional programmes such as National Mission on Transformative Mobility and Battery Storage (NMTMBS) promotes domestic battery manufacturing and associated skill development. The Ministry of New and Renewable Energy (MNRE)-supported Energy Storage Demonstration Projects, Central Institute of Road Transport (CIRT) Training modules on battery systems, EV integration, and transport-linked energy storage applications, IITs and leading engineering institutions (e.g., IIT Madras, IIT Bombay, IIT Delhi, IIT Roorkee) research-led training, executive education, and certification programmes on advanced battery technologies, BMS, and storage applications contribute to strengthening human resource capacity in the BESS domain. Various government bodies such as the Ministry of Power (MoP), Ministry of New and Renewable Energy (MNRE), Bureau of Energy Efficiency (BEE), and National Skill Development Corporation (NSDC) have launched training and skilling programmes aligned with India's clean energy mission. In addition, institutions such as the National Power Training Institute (NPTI), Central Institute of Road Transport (CIRT), and Skill Council For Green Jobs (SCGJ), as well as leading engineering institutes, are actively engaged in designing and conducting specialized modules on battery technologies, energy storage management, and safety protocols.

However, the existing ecosystem remains fragmented, with limited coordination between stakeholders from academia, industry, and government. Training programmes are often technology-specific and concentrated in urban or industrial clusters, leaving significant skill gaps in rural areas and among small and medium enterprises. There is also a pressing need to update training curricula to match emerging technologies such as advanced chemistries (e.g., solid-state, sodium-ion), system integration, and recycling of batteries.

A well-structured and collaborative training ecosystem for BESS should therefore focus on:

- Developing standardized and accredited training modules across different levels (technician, engineer, manager).
- Enhancing industry–academia partnerships for practical, hands-on exposure.
- Leveraging digital platforms and virtual labs for broader accessibility.
- Creating a national database of trained professionals and certified institutions.

Strengthening the existing capacity-building ecosystem will ensure that India develops a skilled workforce capable of supporting large-scale BESS deployment, thereby contributing to grid stability, energy security, and the country's net-zero ambitions.

## 5.2 National-level Initiatives and Policy Anchors

- **MNRE (energy storage/ESS skill development activities)**

MNRE has organized workshops and is coordinating skill development pilots under ESS-related programmes (including India-UK ASPIRE activities). These are the government's central reference points for ESS capacity building (MNRE).[1]

- **National Skill Development Corporation (NSDC)/Pradhan Mantri Kaushal Vikas Yojana (PMKVY)**

National skilling delivery platform, PMKVY and NSDC, manage training centres and funding routes that can incorporate battery/BESS job roles and short courses (NSDC, PMKVY).

- **Skill Council for Green Jobs (SCGJ)**

Industry-led council specifically for green sectors; working to define job roles, curricula and large upskilling programmes under guidance from MNRE (e.g., Surya Ghar Muft Bijli and other electrification/renewables upskilling programmes).

## 5.3 Online Certifications of BESS

The rapid deployment of renewable energy and the growing need for grid stability have positioned **BESS** as a cornerstone of India's clean energy transition. As the demand for skilled professionals in energy storage continues to rise, several institutions—both national and international—have begun offering **specialized certification courses** to bridge the knowledge and skill gap in the sector.

These online certification programmes are designed for **engineers, technicians, project managers, policy professionals, and energy sector stakeholders**, covering the entire value chain of BESS—ranging from **system design, installation, and commissioning to operations, safety, and lifecycle management**.

BESS certification courses in India are primarily delivered in flexible online formats, accommodating both working professionals and full-time students. They integrate theoretical learning with practical, project-based assignments to enhance technical competence and industry readiness.

### 5.3.1 Leading BESS Certification Providers

Several providers offer online BESS certification courses in India, catering to engineers, technicians, project managers, and other energy professionals. These certifications cover topics from installation and commissioning to design and grid integration.

***Tonex-certified BESS Specialist (USA-based)***[2]

- Focuses on BESS installation, commissioning, operations, and maintenance
- 4-day online programme, total of 16 hours (4 hours per day)
- Covers safety, design, grid integration, troubleshooting, and lifecycle management
- Suitable for engineers, project managers, installers, O&M technicians, and compliance officers.

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[1] https://mnre.gov.in/

[2] https://www.tonex.com/training-courses/certified-bess-installation-commissioning-and-operations-maintenance-specialist/

**TABLE 5.1**: Glimpse of secondary data collected about online certifications in BESS

| S. No | Name of training | Institute | Target audience | Qualification | Duration of training | Mode of training |
|---|---|---|---|---|---|---|
| 1 | **Online BESS training** | Advance Electrical Design and Engineering Institute (AEDEI) | Students/ working professionals | Bachelor's degree, diploma and degree in electrical, electronics, mechanical, and instrumentation<br>For entrepreneurship, no education is required with no age limit<br>Candidates preparing for GATE/IES/government jobs; should have 1 years min. Experience of bachelor degree qualification experience (BDQE) | 2 months | Online |
| 2 | **Battery energy storage and micro-grids in India** | Indian Institute of Solar Energy | Working professionals, industries | Civil engineer, electrical engineer and mechanical engineers; electrical and general contractors, solar design engineer, electrical designers, solar companies and solar industry professionals. | 4 hours/ per day (flexible timing as required) | Online |
| 3 | **Battery energy storage and micro-Grids in India** | National Power Training Institute | DISCOMs, engineers | Officers of the power sector organizations, GENCOs, DISCOMs, regulatory commissions, TRANSCOs and all power sector stakeholders | 2 days | Offline |
| 4 | **Advanced energy storage technology, applications training and certification programme** | IESA and GERMI | Students/ working professionals | Students, IESA members, PSU/Government officials | 2 days | Offline |

- Completion requires a 60-question certification exam.
- Internationally recognised, accessible to Indian candidates online.

**AEDEI (Advanced Electrical Design and Engineering Institute) (India-based)[3]**

- Offers online BESS design training with modules on system analysis, battery sizing, PCU (power conditioning unit)/inverter selection, cable design, earthing, protection schemes, HVAC, and engineering layouts.
- Flexible batches on weekdays and weekends.
- Registration via website, phone, WhatsApp, or Skype, with hands-on assignments and real-world scenarios.

**Dr Gopal Energy Foundation (DGEF) (India-based)[4]**

- Runs online certificate courses in energy laws, renewable energy, and BESS-related policy aspects accessible to Indian professionals.
- 3-month courses with live sessions, industry-relevant content, and certification awarded by DGEF.
- Registration via website and WhatsApp; well-suited for legal, regulatory, and compliance aspects of energy storage

### 5.3.2 Flexible online schedules (weekdays/weekends)

India's clean energy transition is rapidly advancing, increasing the need for skilled professionals who can support reliable and efficient renewable integration. BESS play a crucial role in enhancing grid stability and enabling electric mobility, yet a significant skill gap persists in their design, installation, and maintenance. The flexible online training on BESS addresses this need by offering structured, practical learning through self-paced modules, live sessions, and real-world assignments—making it accessible for working professionals, students, and organizations across the country.

The primary objectives of the training are to build technical and operational understanding of BESS, equip participants with the skills required for system design, integration, commissioning, and O&M, familiarize learners with international and Indian standards, policies, and safety practices related to BESS, offer flexibility in learning modes—self-paced, live interactive, and blended learning—to accommodate diverse learner profiles, support India's energy transition by developing a skilled workforce capable of supporting grid modernization and renewable integration.

### 5.3.3 ITI and Vocational Programmes in BESS in India

Programmes aligned with NSQF Levels 4 to 6 are available in India, although their availability varies across sectors and institutions. Input eligibility for both certificate and diploma are aligned at NSQF level 4 and after completion one year certificate is aligned at level 4.5 and two-year diploma is aligned at level 5. These programmes are particularly suitable for technical roles related to installation and operations and maintenance (O&M). In addition, three-year diploma engineering programmes offered after completion of Class 10 (10+3) are widely available through Polytechnics and are aligned with NSQF Level 4.5. Undergraduate diploma and higher-level skill programmes aligned to NSQF Level 6 are also offered by select institutions, primarily catering to supervisory, system integration, and advanced technical roles.

A significant portion of the future workforce for energy storage will come from ITIs, Polytechnics, and vocational programmes; however, these institutions still primarily focus on traditional trades rather than battery and storage technologies. With increasing industry and policy emphasis, several organizations have begun offering short-term specialized courses in energy storage—such as GSES India's 3-month online BESS

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[3] https://www.advanceelectricaldesign.com/

[4] https://www.dgef.in/

programme, IESD's 60-day certification on battery and storage technologies, and NPTI's two-day course on BESS and microgrids. MNRE's Human Resource Development scheme also supports short-term training in renewable energy, creating scope to integrate dedicated BESS skilling into vocational frameworks.

A credible one- or two-year ITI programme after 10th is aligned at NSQF level 3.5 or 4 and one- or two-year vocational programme is aligned at level 4.5 or 5. The course must cover battery technology, BMS, inverter/PCS, DC/AC systems, safety, system design, and O&M. It should include extensive hands-on training through battery test rigs, BMS kits, inverter demos, and fault-simulation labs. Modules on safety standards, lithium–ion hazards, e-waste handling, and fire prevention are essential. The programme should offer industry internships, NCVET/NSDC certification, and placement support, with linkages to renewable energy, EVs, and microgrids. Its modular structure should allow both students and working professionals to skill, reskill, and upskill flexibly.

### 5.3.4 Secondary Research on Existing Battery Energy Storage Systems Engineering Syllabus

Secondary research on engineering curricula across leading Indian institutions, including IITs, NITs, state technical universities, and select private universities, indicates that education on BESS is gradually gaining prominence, primarily within electrical engineering, power systems, renewable energy, and electric mobility programmes. However, this integration remains fragmented and largely introductory in nature, revealing substantial gaps when assessed against rapidly evolving industry requirements.

**Coverage of core and foundational topics:** Most existing syllabi provide a reasonable foundation in electrochemical energy storage and associated power electronics. Commonly covered areas include:

- Battery chemistry (Li–ion variants, lead–acid, emerging chemistry)
- Cell characteristics, degradation mechanisms, and thermal behaviour
- Power electronic converters and inverters for energy storage integration
- Battery Management Systems (BMS) fundamentals
- State of Charge (SoC) and State of Health (SoH) estimation algorithms
- Basic grid interconnection principles

However, advanced system-level competencies essential for modern BESS deployment—such as utility-scale system modelling, grid-forming and grid-following controls, dynamic grid support services, hybrid storage configurations, and co-optimization of multiple grid services—are largely absent or addressed only conceptually. Furthermore, emerging digital dimensions including AI/ML-based diagnostics, predictive maintenance, digital twins, cybersecurity of BMS and grid-connected storage, and data-driven optimization receive minimal attention. The techno-economic, regulatory, and sustainability aspects of BESS—covering project financial modelling, lifecycle assessment, recycling, Indian grid codes, market mechanisms, and revenue stacking—are also weakly integrated into engineering education. Practical learning opportunities remain limited, with most hands-on exposure confined to cell-level testing or simplified simulations rather than real-world, grid-connected systems, hardware-in-the-loop platforms, or industry-grade digital simulation tools. Consequently, current BESS curricula lack the multidisciplinary depth, systems perspective, and experiential learning needed to equip graduates with industry-relevant skills in advanced control, analytics, optimisation, safety, and regulatory compliance.

### 5.3.5 Secondary Research on Current BESS Training Curriculum Landscape

Secondary research indicates that BESS training is still an emerging domain globally, with curricula varying widely across institutions, industry providers, and vocational training ecosystems. Most existing programmes focus on foundational electrochemistry, system architecture, and safety protocols. At the same time, advanced modules on grid integration, battery analytics, and lifecycle management are less common and often offered by industry-led or short-term certification programmes (IEA).

Internationally, universities and technical institutions offer BESS-related content as part of broader renewable energy or electrical engineering programmes. These typically emphasize battery chemistry, power conversion systems, and control strategies. Some specialized training providers deliver intensive short courses designed for engineers and technicians, covering installation, commissioning, operations, and maintenance. However, hands-on modules and real-world simulation exercises vary by provider, indicating a lack of standardization (IRENA).

In India, formal BESS curricula are limited but growing, with a few IITs, industry associations, and private skill providers offering training aligned to current market needs.

This matrix presents a comparative analysis of BESS training curricula across eight global regions—Germany, Denmark, India, the Netherlands, Sweden, the United Kingdom, and the United States. The objective is to assess the availability of essential ESS modules and identify common gaps that constrain workforce readiness for emerging energy storage markets.

Germany and Denmark lean heavily towards theoretical or introductory material, with limited offerings in safety, risk mitigation, and market-aligned training. India offers the ESS training programmes, yet displays inconsistency in module depth, with several advanced topics, such as demand-side management (DSM), inverter sizing, and certification processes, missing across providers. The Netherlands and Sweden demonstrate relatively mature training ecosystems, offering strong technical and industry-linked modules, although they still lack policy, case study, and applied project components. UK provides a curriculum with ESS-specific training, while the USA shows strength in safety and system design, yet misses modules related to market readiness, recycling, and demand-side management.

In India, BESS training are mostly unstructured and evolving with sectoral demand. Among the popular training courses, many BESS modules are not covered or partially covered, resulting in incomplete learning for trainees. A review of Indian existing BESS training courses revealed that topics related to basics of ESS, risk analysis and mitigation and system design and sizing are covered either fully or partially in all training courses. However, many important areas pertinent to BESS learning need more attention which include fire safety, energy storage project guidelines, project development, policy issues, peak load management and DSM, PCU and inverter sizing, operation and maintenance issues, alternate technologies, reuse and recycling, safety, standards, FAT (factory acceptance test (FAT), site acceptance test (SAT), etc. which are not covered in many Indian BESS training courses.

Across all regions, assessment-driven learning—through quizzes, case studies, and hands-on project discussions—is rarely included, highlighting a global need for enhanced experiential learning. Policy and market context, especially global and Indian ESS policy frameworks, remains largely absent in most countries. Modules addressing circular economic principles, such as ESS reuse and recycling, are also minimal despite growing global focus on sustainability and responsible battery lifecycle management.

**TABLE 5.2**: Heatmap of battery energy storage training modules by country

| BESS Training Module | Germany | Denmark | India | Netherlands | Sweden | UK | USA |
|---|---|---|---|---|---|---|---|
| **Fire safety** | ▧ | ▧ | ▧ | ▨ | ▧ | ◌ | ▨ |
| **ESS risk analysis and mitigation** | ▧ | ◌ | ◌ | ▧ | ▨ | ▧ | ▨ |
| **Energy storage project guidelines** | ▧ | ▧ | ▧ | ▧ | ▨ | ▨ | ◌ |
| **Project development** | ▧ | ▧ | ▧ | ▧ | ▧ | ▧ | ▧ |
| **ESS status and policy** | ◌ | ▧ | ▧ | ▧ | ▧ | ▧ | ▧ |
| **Peak load Management and DSM** | ◌ | ◌ | ▧ | ▧ | ◌ | ◌ | ▧ |
| **PCU and inverter and sizing** | ◌ | ◌ | ▧ | ▧ | ▨ | ▧ | ▨ |
| **Operation and maintenance (O&M)** | ◌ | ◌ | ▧ | ▨ | ◌ | ◌ | ▨ |
| **Alternate ESS technologies** | ◌ | ▧ | ▧ | ▨ | ▨ | ◌ | ◌ |
| **Case studies and discussions** | ▧ | ◌ | ▧ | ▧ | ▧ | ▧ | ▧ |
| **Quiz: energy storage** | ▧ | ▧ | ▧ | ▧ | ▧ | ▧ | ▧ |
| **ESS reuse and recycling** | ▧ | ▧ | ▧ | ▨ | ▨ | ◌ | ▧ |
| **Introduction to ESS** | ◌ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ |
| **System design and sizing** | ◌ | ◌ | ◌ | ▨ | ▨ | ◌ | ▨ |
| **Safety/standards / FAT-SAT** | ◌ | ◌ | ▧ | ▨ | ▧ | ◌ | ▨ |

▨ Fully covered ◌ Partially covered/limited ▧ Missing

Overall, the analysis indicates that except Germany (which provides near comprehensive BESS training modules), no country currently delivers a fully comprehensive ESS curriculum aligned with the needs of rapidly expanding clean energy markets. In India, training modules don't cover BESS manufacturing and testing components. There is a clear opportunity to develop a unified, industry-driven global training model that integrates regulatory, technical, manufacturing, testing, certification, and practical competencies across the Battery Energy Storage System (BESS) value chain. In addition to installation, operation, and maintenance, future curricula should include dedicated modules on battery manufacturing processes, quality assurance, testing and validation protocols, performance evaluation, compliance with national and international standards, and product certification requirements. Strengthening these modules will be essential for preparing a skilled workforce capable of supporting the complete BESS ecosystem—from manufacturing and quality control to deployment and lifecycle management—in line with global climate and energy transition goals.

# 6.

# CATALYSING EMPLOYMENT THROUGH BATTERY ENERGY STORAGE SYSTEMS IN INDIA

## 6.1 Overview

On November 11, 2025, the Adani Group announced its ambitious entry into the BESS sector with a groundbreaking 1,126 MW/3,530 MWh project at the Khavda renewable energy park in Gujarat. It is the largest BESS installation in India and one of the world's most significant. This development not only underscores the accelerating pace of BESS adoption but also highlights a transformative shift in India's energy landscape. As the nation races towards its 500 GW non-fossil fuel capacity target by 2030, BESS emerges as an indispensable bridge, smoothing the intermittency of solar and wind power to ensure reliable grid stability. Between 2018 and December 2025, India auctioned approximately 60.73 GWh of BESS capacity for both hybrid and standalone applications. However, only about 760 MWh of BESS capacity is reported to be operational, leaving a large pipeline of projects under construction.[5] A modest but foundational figure compared to the projected 41 GW (208 GWh) required by 2030 to underpin renewable growth.[6]

This surge not only enhances energy security but also catalyses job creation across the BESS value chain—from R&D & manufacturing to installation & commissioning, operations, and associated services. Projections suggest BESS could generate millions of jobs by 2030, with skilled roles in high demand amid gigafactory expansions and policy incentives like the production-linked incentive (PLI) scheme. Drawing on updated market analyses, job estimations, and scenario modelling, this chapter delves deeper into the evolving landscape of BESS employment. Real-world examples from 2025 listings are taken, skill imperatives highlighted, and job estimates refined to reflect mid-2025 realities, projecting ~124K to ~162K cumulative jobs by 2030 under varying adoption trajectories.

The chapter proceeds to detail key job roles, along with current vacancies; explores trends and qualifications through secondary research; followed by job estimation scenarios.

## 6.2 Key Job Roles in the BESS Value Chain

India's BESS ecosystem spans design innovation, high-volume production, and field deployment, creating roles that blend engineering prowess with a focus on sustainability. Based on analyses from various job portals, over 300 specialized BESS positions were active in 2025, emphasizing integration with renewables and grid stability. Below is a breakdown of key roles involved in the design, R&D, production, quality assurance, and support functions of battery storage manufacturing for renewable energy systems and electric vehicles.

Figure 6.1 illustrates the end-to-end value chain for BESS as it is taking shape in India, structured as a flow across the battery value chain, organized into three main categories:

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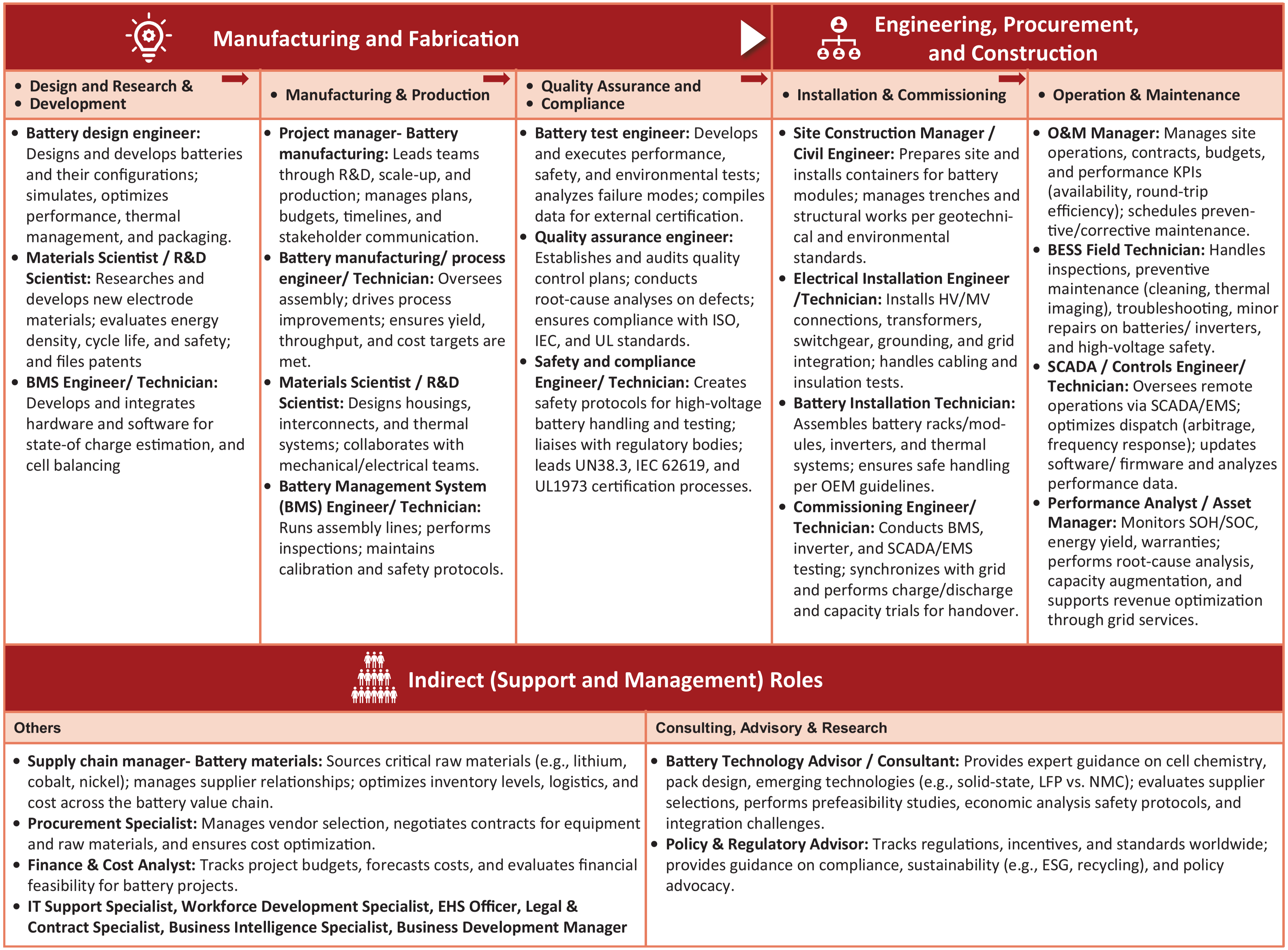
[5] IEEFA, last accessed on 14 Nov 2025

[6] CEA, Report on optimal generation mix 2030 version 2.0, last accessed on 14 Nov 2025



| Manufacturing and Fabrication | | | Engineering, Procurement, and Construction | |
|---|---|---|---|---|
| • Design and Research & Development | • Manufacturing & Production | • Quality Assurance and Compliance | • Installation & Commissioning | • Operation & Maintenance |
| • **Battery design engineer:** Designs and develops batteries and their configurations; simulates, optimizes performance, thermal management, and packaging.<br>• **Materials Scientist / R&D Scientist:** Researches and develops new electrode materials; evaluates energy density, cycle life, and safety; and files patents<br>• **BMS Engineer/ Technician:** Develops and integrates hardware and software for state-of charge estimation, and cell balancing | • **Project manager- Battery manufacturing:** Leads teams through R&D, scale-up, and production; manages plans, budgets, timelines, and stakeholder communication.<br>• **Battery manufacturing/ process engineer/ Technician:** Oversees assembly; drives process improvements; ensures yield, throughput, and cost targets are met.<br>• **Materials Scientist / R&D Scientist:** Designs housings, interconnects, and thermal systems; collaborates with mechanical/electrical teams.<br>• **Battery Management System (BMS) Engineer/ Technician:** Runs assembly lines; performs inspections; maintains calibration and safety protocols. | • **Battery test engineer:** Develops and executes performance, safety, and environmental tests; analyzes failure modes; compiles data for external certification.<br>• **Quality assurance engineer:** Establishes and audits quality control plans; conducts root-cause analyses on defects; ensures compliance with ISO, IEC, and UL standards.<br>• **Safety and compliance Engineer/ Technician:** Creates safety protocols for high-voltage battery handling and testing; liaises with regulatory bodies; leads UN38.3, IEC 62619, and UL1973 certification processes. | • **Site Construction Manager / Civil Engineer:** Prepares site and installs containers for battery modules; manages trenches and structural works per geotechnical and environmental standards.<br>• **Electrical Installation Engineer /Technician:** Installs HV/MV connections, transformers, switchgear, grounding, and grid integration; handles cabling and insulation tests.<br>• **Battery Installation Technician:** Assembles battery racks/modules, inverters, and thermal systems; ensures safe handling per OEM guidelines.<br>• **Commissioning Engineer/ Technician:** Conducts BMS, inverter, and SCADA/EMS testing; synchronizes with grid and performs charge/discharge and capacity trials for handover. | • **O&M Manager:** Manages site operations, contracts, budgets, and performance KPIs (availability, round-trip efficiency); schedules preventive/corrective maintenance.<br>• **BESS Field Technician:** Handles inspections, preventive maintenance (cleaning, thermal imaging), troubleshooting, minor repairs on batteries/ inverters, and high-voltage safety.<br>• **SCADA / Controls Engineer/ Technician:** Oversees remote operations via SCADA/EMS; optimizes dispatch (arbitrage, frequency response); updates software/ firmware and analyzes performance data.<br>• **Performance Analyst / Asset Manager:** Monitors SOH/SOC, energy yield, warranties; performs root-cause analysis, capacity augmentation, and supports revenue optimization through grid services. |

| Indirect (Support and Management) Roles | |
|---|---|
| Others | Consulting, Advisory & Research |
| • **Supply chain manager- Battery materials:** Sources critical raw materials (e.g., lithium, cobalt, nickel); manages supplier relationships; optimizes inventory levels, logistics, and cost across the battery value chain.<br>• **Procurement Specialist:** Manages vendor selection, negotiates contracts for equipment and raw materials, and ensures cost optimization.<br>• **Finance & Cost Analyst:** Tracks project budgets, forecasts costs, and evaluates financial feasibility for battery projects.<br>• **IT Support Specialist, Workforce Development Specialist, EHS Officer, Legal & Contract Specialist, Business Intelligence Specialist, Business Development Manager** | • **Battery Technology Advisor / Consultant:** Provides expert guidance on cell chemistry, pack design, emerging technologies (e.g., solid-state, LFP vs. NMC); evaluates supplier selections, performs prefeasibility studies, economic analysis safety protocols, and integration challenges.<br>• **Policy & Regulatory Advisor:** Tracks regulations, incentives, and standards worldwide; provides guidance on compliance, sustainability (e.g., ESG, recycling), and policy advocacy. |

**FIGURE 6.1**: Key job roles in the BESS value chain

1. **Manufacturing and fabrication** – Covers roles involved in battery design, research, production, and quality assurance. This includes activities like R&D, assembly, and compliance with standards.
2. **Engineering, procurement, and construction** – Focuses on roles responsible for installation, commissioning, and ongoing operation and maintenance of battery systems, ensuring performance and reliability.
3. **Support and management roles** – Encompasses indirect and strategic functions such as supply chain management, consulting, advisory, and research. These roles handle material sourcing, regulatory compliance, and technological guidance.

The figure visually maps the entire lifecycle of battery projects, from design and manufacturing to deployment and long-term support, highlighting both technical and managerial responsibilities.

## 6.3 Evolving Competencies: Skills, Trends and Pathways in the BESS Workforce

Most of the roles listed above require degrees in electrical, chemical, or materials engineering, along with on-ground experience in energy storage systems. Table 6.1 summarizes high-demand BESS-related job roles identified from five major online portals—Indeed, LinkedIn, Naukri, Jooble, and Monster.

**TABLE 6.1**: High-demand BESS-related job roles across major portals

| Category | Job Role | Typical Employers |
|---|---|---|
| Design and R&D | Battery Design Engineer/ Technician | EV OEMs, Energy Storage Startups |
| | Materials Scientist (Battery Chemistry) | Cell Manufacturers, RCD Labs |
| | BMS (Battery Management System) Engineer/ Technician | Automotive Tier-1s, ESS Integrators |
| Production and Manufacturing | Process/Manufacturing Engineer – Battery | Gigafactories, Cell Assembly Plants |
| | Battery Pack Assembly Technician | Contract Manufacturers, OEMs |
| | Mechanical Design Engineer – Battery Packs | EV OEMs, ESS Integrators |
| Testing and Quality | Battery Test Engineer | Certification Labs, OEM QA Teams |
| | Quality Assurance Engineer – Battery | Cell C Pack Manufacturers |
| Utilization and Integration | Energy Storage Systems Engineer/ Technician | Renewable EPCs, Grid Operators |
| | Application Engineer – Battery Systems | Simulation Software Firms, OEMs |
| | Field Service Engineer/ Technician – ESS/EV Batteries | Service Providers,OEM Aftersales |
| Commercial and Supply Chain | Supply Chain Manager – Battery Materials | Mining to Manufacturing Firms |
| | Procurement Specialist – Battery Components | OEMs, EPCs |

**Note**: Roles serve RE, EV and BESS sector (many candidates are cross-deployable)

These consistent demand patterns observed across job portals provide a robust foundation for quantifying the overall employment potential in India's battery energy storage sector. By aligning the most sought-after technical and cross-functional skills with the ongoing expansion of gigafactories, R&D centres, and emerging areas, qualitative market signals can be translated into structured workforce projections.

Building on these skill trends, job creation potential are estimated under different growth scenarios as follows.

## 6.4 Estimated Job Creation in India's BESS Sector by 2030

To arrive at these projections, a conservative yet comprehensive estimation methodology was developed, drawing directly from the insights highlighted earlier—particularly the balanced demand across the value chain and the rapid growth in manufacturing and second-life segments.

The estimation applies a top-down, scenario-based approach using linear extrapolation. It is intentionally simplified to ensure clarity and ease of communication for stakeholders. The methodology accounts for jobs across all stages—manufacturing, installation and commissioning, operation and maintenance, as well as indirect roles such as research and development, consulting and assessment, and policy and regulatory functions.

### Approach Adopted for Job Estimation by 2030

Three growth scenarios were defined (Pessimistic, Base, Optimistic) with different 2030 targets for BESS installed capacity (demand side) and BESS manufacturing capacity (supply side). The projections for BESS deployment and domestic manufacturing capacity was converted into employment estimates using fixed jobs-per-GWh multipliers informed by expert opinion and targeted consultations with key BESS manufacturers in India.[7] This linear extrapolation method used capacity forecasts, job multipliers, and job life-cycle durations to estimate employment in India's battery energy storage sector.

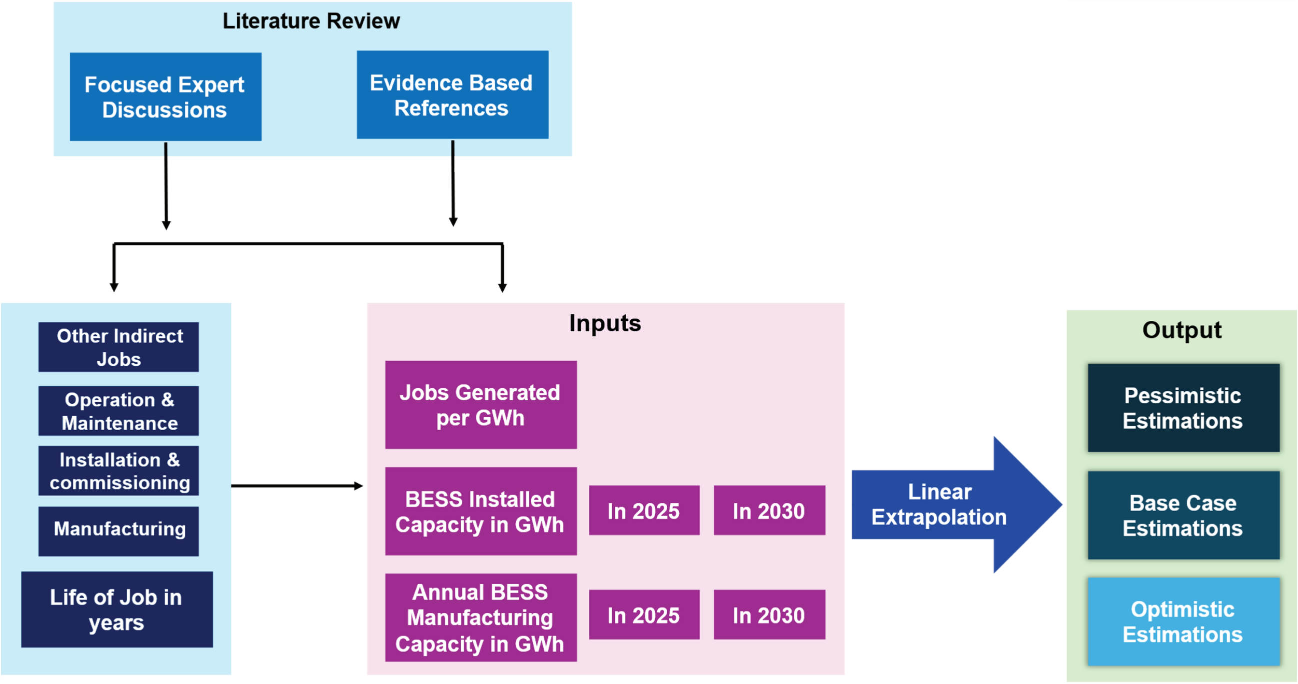


**FIGURE 6.2**: Illustrative overview of approach and methodology used for job estimation

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[7] Jobs-per-GWh" means the average number of jobs (direct and indirect) created for every gigawatt-hour of battery energy storage capacity that is manufactured, installed, and operated

The high-level steps in the approach (Figure 6.2) are mentioned below:[8]

1. **Literature review–** Reviewed key reports, including CEA Report on *Optimal Generation Capacity Mix 2030 (Version 2.0)*, scientific and technical research, website of developers etc. It was followed by a focus group discussion with industry experts to validate assumptions including target capacities and job multipliers.
2. **Set target capacities**– Set clear targets for 2030 in two key areas:

- Total BESS capacity installed in the country
- Total domestic battery manufacturing capacity built in India

3. **Scenario creation**– Created three scenarios (Pessimistic, Base, and Optimistic) based on published government reports, policy targets, and market studies.
4. **Linear extrapolation**– Calculated linear annual growth rates needed between 2025 and 2030 to reach each scenario's 2030 targets.
5. **Accounting job multipliers**– Standard job-creation multipliers (jobs per GWh), as identified by experts, were applied to annual capacity additions across each stage of supply chain, i.e., manufacturing, installation & commissioning, and operation & maintenance. These multipliers were used in conjunction with the expected job life cycle for each job category. Annual capacity additions were multiplied by the relevant job multipliers for each year and scenario. For example, jobs associated with installation and commissioning are typically required for only about two years. After this period, the same personnel can be redeployed to subsequent installation and commissioning projects. Therefore, the effective job life cycle per GWh for installation and commissioning is approximately two years.

   In contrast, manufacturing-related roles are tied to the operational lifespan of the manufacturing facility, which generally exceeds 20 years. As a result, the per GWh job life cycle for manufacturing roles is assumed to be around 20 years.

   Therefore, jobs created in the installation and commissioning phase (based on installation & commissioning capacity and the corresponding jobs per GWh) persist for only about two years, whereas jobs generated in manufacturing typically last for more than 20 years

6. **Estimations**– Summed the active jobs each year (considering only those still within their life cycle) from 2025 to 2030 to arrive at the total cumulative job creation reported for the period. Jobs are counted in the year the capacity is added and remain active only for their respective life-cycle duration.

Figure 6.3 presents the estimated jobs in each scenario.

Overall, the findings indicate a deployment- and services-led employment trajectory for the battery energy storage sector by 2030. Job creation is dominated by Installation & Commissioning (~41%) and O&M (~39%), while Manufacturing remains a smaller but growing share (~9%). Indirect employment (~10%) scales in step with direct jobs, highlighting meaningful multiplier effects. However, some of the estimated jobs, particularly those associated with installation, commissioning, and O&M, may overlap with employment generated by renewable energy technologies, especially where battery energy storage systems are deployed as part of integrated renewable energy projects.

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[8] The assumptions are in Annexure-1

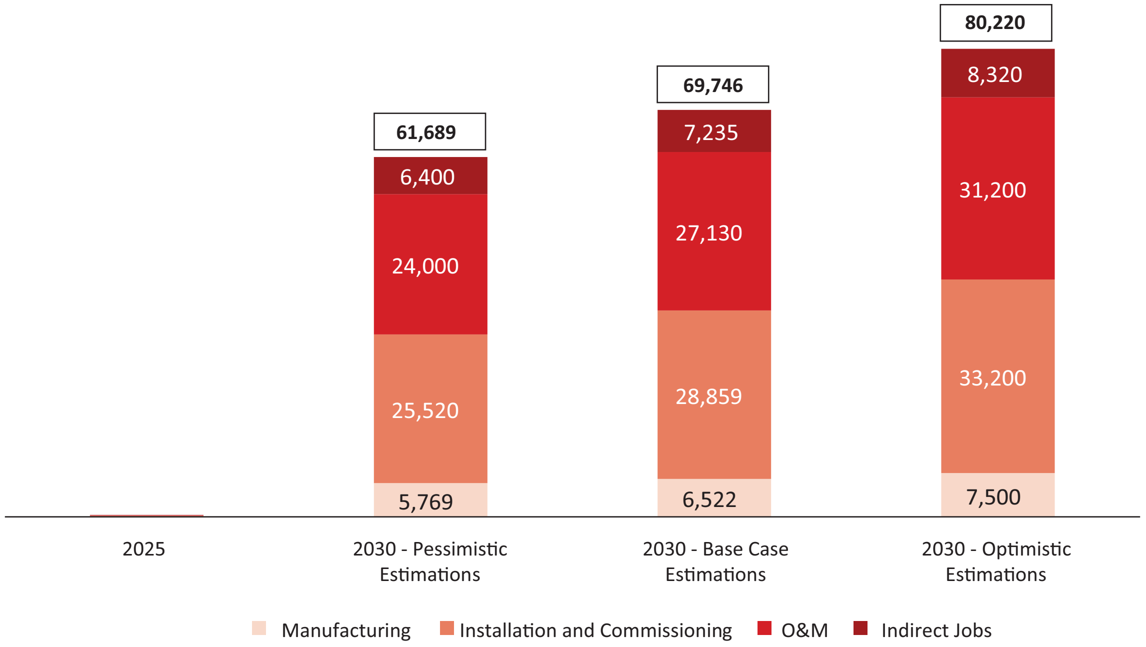


**FIGURE 6.3**: Estimated jobs by 2030 in each scenario

**Note**: The Indirect Jobs category reflects cross-cutting ecosystem roles that support both manufacturing and deployment but cannot be attributed to any single stage of the supply chain. These include regulatory and compliance functions, financing and risk assessment, modelling and system studies, certification and testing services, power-electronics-related services, as well as consulting and policy advisory roles. Manufacturing jobs, by contrast, represent the approximate manpower required to operate a BESS gigafactory.

This pattern strongly suggests that the sector's workforce demand will concentrate on systems integration, commissioning, field engineering, diagnostics, safety, controls, and sustained operations, aligning closely with high-demand technical profiles such as BMS/controls engineers, system integration engineers, electrical commissioning specialists, and thermal/safety-focused roles. Finally, the ~30% gap between pessimistic and optimistic outcomes underscores the importance of policy stability, project pipeline certainty, and investment velocity to unlock the upper end of job creation.

# 7.

# BESS SECTOR SKILLS GAPS ANALYSIS: JOB ROLE REQUIREMENTS AND SKILLING PRIORITIES

## 7.1 Overview

India reached a significant milestone in June, 2025 by deriving 50% of its cumulative installed electricity capacity from non-fossil fuel sources, five years ahead of the 2030 target outlined in its Nationally Determined Contributions (NDCs) under the Paris Agreement (PIB, 2025). A massive commitment to renewable energy and the increasing need for storage give India a positive BESS outlook. The country remains on track to have 500 GW of installed electricity capacity from non-fossil fuel sources by the end of the decade. However, having adequate power storage is equally important. The Indian BESS market added 341 MWh of new capacity last year and has a 2047 target of 1,840 GWh. India boasts a promising BESS outlook with the market expected to surpass $30 billion by 2030. Although the market is projected to experience significant growth between now and 2032, it remains constrained by insufficient technology, resources, capabilities, and expertise to meet its established objectives. Major projects have come online in recent years, while more are in the pipeline. High costs, uncertainty over revenue mechanisms and market participation in the short term are the major obstacles.

Supply chain development and building local BESS manufacturing capabilities are priorities for the country. The BESS value chain in India is rapidly developing, driven by the nation's renewable energy goals and an increasing need for grid stability. The chain includes raw material sourcing, battery manufacturing, BESS integration and assembly, and project development and operation. Key areas of focus for the value chain include developing local manufacturing capabilities and diversifying the monetization of BESS services beyond simple energy shifting.

To achieve the target of 47 GW of BESS capacity by 2032, a dedicated skilled workforce trained through structured curriculum-based approach is required. This section discusses in detail the job estimates, job roles across the key sections of the BESS value chain and the necessary skilling requirement. Figure 7.1 highlights the key activities across the BESS value chain.

| **Raw material sourcing** | **Battery manufacturing** | **BESS integration and assembly** | **Project development & operation** |
|---|---|---|---|
| This is a critical stage, and India is working to build a robust supply chain for battery-grade materials. | India is prioritizing the development of local manufacturing capabilities for batteries to reduce reliance on imports and build domestic expertise. | This involves assembling the battery packs with other components like inverters, power conversion systems, and control software. | This phase includes designing, building, and operating large-scale and distributed BESS projects for utilities, industries, and DISCOMs (distribution companies). |

**FIGURE 7.1**: Key activities across the BESS value chain

This chapter highlights in detail the following key areas:

- Skill gaps identified across key stakeholder categories
- BESS job roles in demand and key skill requirements

## 7.2 Skill Gaps Identified through Desk Research and Training/ Academic Ecosystem

### 7.2.1 Skill gaps identified through desk research

Being a fast-developing sector, BESS studies are of importance to evaluate possibilities of renewable energy integration, increased viability of renewables in storage, new technology adoption, grid stability and reliability, cost savings for consumers, environmental and social impacts and many more. During the skill gap analysis, a significant number of studies and reports were assessed to identify possible reference of skill gaps to show that BESS adoption is critical for modern storage ecosystem development, particularly in integrating renewable energy by storing excess power and releasing it during peak demand, which helps stabilize the grid, reduce fossil fuel dependence, and lower costs. These studies highlight some skill gaps in different thematic areas including BESS & ACC manufacturing, emerging storage technologies and new market, skills for hydrogen-based storage, testing, certification & safety competencies, institutional research capabilities, operations and maintenance (O&M) technical skills and digital skills in the storage. The analysis of these gaps is listed in Table 7.1 which emphasizes positive BESS outlook in terms of the economic benefits of energy arbitrage, enhanced grid reliability through frequency and voltage control, along with significant cost savings for consumers.

### 7.2.2 Skill gaps identified in training/academic ecosystem

The rapid deployment of renewable energy and the growing need for grid stability have positioned BESS as a cornerstone of India's clean energy transition. At the national and institutional levels, initiatives such as the National Energy Storage Mission, Skill India Mission, and capacity-building programmes led by IPPAI, NPTI, NSDC, CEA, SECI and IESA are contributing to the development of a skilled workforce for BESS across planning, deployment, operation, and maintenance functions. BESS adoption in industries requires a robust capacity-building and training ecosystem to develop necessary technical skills, operational expertise, and institutional capabilities across the entire value chain.

As the demand for skilled professionals in energy storage continues to rise, several institutions, both national and international, have begun offering specialized certification courses to bridge the knowledge and skill gap in the sector. In India, BESS skilling is offered by different training institutes and academic bodies using offline, virtual and hybrid mode. A thorough analysis of the existing trainings reveals that the online certification programmes are designed for power sector engineers, technicians, project managers, O&M ranging from system design, installation, and commissioning to operations, safety, and lifecycle management.

BESS certification courses in India are primarily delivered in flexible online formats, accommodating both working professionals and full-time students. BESS training offered by existing courses provides theoretical learning with technical assignments, which are limited to enhance technical competence and industry readiness. There remains a significant skill gap in the design, installation, commissioning, and maintenance of BESS at the industry level. Engineers and technicians require both foundational knowledge and practical experience with the operational aspects of BESS to meet industry demand.

**TABLE 7.1**: Skill gaps identified through literature review

| Thematic Area | Identified Gaps |
|---|---|
| BESS and ACC manufacturing workforce capacity | » Significant shortage of skilled manpower for BESS and Advanced Chemistry Cell (ACC) manufacturing, especially for advanced/emerging battery chemistries.<br>» Limited technical know-how and insufficient collaboration with global technology leaders restrict the development of operational expertise. (CES, IESA, 2023; CEEW, n.d.) |
| Skills for emerging storage technologies and new market segments | » Growing sectors such as solar module manufacturing, cell manufacturing, hybrid RE storage systems, and recycling require advanced analytical, business, and technical capabilities.<br>» New competencies needed include solid-state battery skills, equipment engineering, robotics, and automation. (CEEW, NRDC India & SCGJ, 2023) |
| Specialized skills for hydrogen-based storage (cross-sectoral) | » Need for skilled and semi-skilled workforce for manufacturing hydrogen storage canisters, Type III tanks, and personnel for large-scale production/ testing of storage systems across short, medium, and long-term R&D phases. (SCGJ, 2024) |
| Research, development and institutional skill gaps | » Shortage of skilled R&D professionals and limited institutional research capabilities. Insufficient academia–industry partnerships constrain innovation, technology development, and specialized skill creation in the energy storage domain. (Siemens Energy India, n.d.)<br>» Limited advanced skills constrain R&D and market competitiveness. (IISD, 2024) |
| Testing, certification and safety competencies | » India lacks adequate battery testing and evaluation centres—particularly for stress conditions such as high temperature/humidity. This indicates deficits in skilled personnel for testing, certification, and safety engineering roles. (Ray Chowdhury, 2025)<br>» Skill shortages adversely impact safety as insufficiently trained workers increase accident and hazard likelihood. (IISD, 2024) |
| O&M technical skills | » Limited availability of technicians and engineers trained in BESS performance monitoring, troubleshooting, and safe plant operations. Companies face difficulties in hiring skilled labour for O&M roles. (NITI Aayog, RMI, and RMI India, 2022) |
| Digital and data-driven skillsets | » There is a rising demand for digital skills in the storage and renewables sector: data science, SCADA systems, predictive maintenance, real-time monitoring, and analytics are essential because they enable safe, efficient, and reliable operation of storage assets.<br>» This gap affects operations, as success of modern BESS plants rely on data on various parameters regarding performance. Though India has large IT professionals, lack of data inhibits development of skills to enhance performance, extend battery life, and reduce downtime thereby reducing the economic efficiency of projects. (A Joshi, 2025) |

During the study, BESS training topics coverage was mapped as indicated in earlier chapters. Training content analysis in India identified that BESS training contents are mostly unstructured with many important components partially covered or missing in India's existing training courses. In Figure 7.2, modules coverage in existing BESS trainings in India are mapped. The data presented percentage availability of various course modules in existing BESS training courses.

Figure 7.2 highlights that important topics such as project development and guidelines, risk management, O&M issues, peak load management, BESS policies, recycling, safety issues are not covered in many of the BESS training courses in India. Absence of such modules has made many of the existing training courses below par and not attractive for BESS industry value chain. A need is therefore felt to develop standard BESS training courses for stakeholders incorporating important topics in the training curricula.

During skill gap analysis, BESS teaching course syllabus in engineering institutes was also studied. Engineering education in BESS sector primarily refers to topics on fundamentals and architecture, battery chemistry and selection, system sizing and design, grid integration and applications, safety and standards, project management and economics, and operations and maintenance. These programmes are designed to equip engineers with the knowledge and practical skills required to design, implement, and manage BESS for modern power systems and renewable energy integration. In India, BESS teaching courses for engineering students cover topics like BESS design, grid integration, installation, maintenance, and financial analysis. This skill gap analysis noted the following gaps in the engineering teaching syllabus.

## 7.3 Skill Gaps Identified through Stakeholder Consultations and Surveys

Developing skills for an ESS ecosystem in India requires a balanced approach that leverages both existing technical talent and creates new avenues for employment in the emerging storage sector. India already has strong capabilities in areas such as electrical engineering, power systems, battery manufacturing, inverter

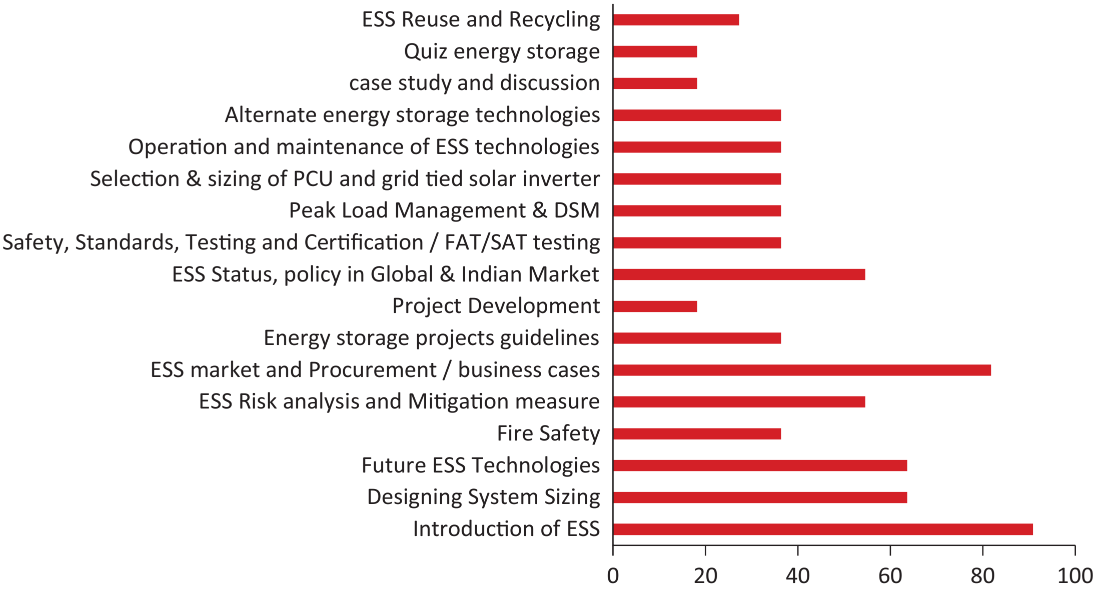


**FIGURE 7.2**: Module coverage in existing BESS trainings in India

**TABLE 7.2**: Skill gaps identified in the existing BESS syllabus for engineering students

| S. No. | Thematic Area | Current Academic Coverage | Identified Gaps |
|---|---|---|---|
| 1 | System-level modelling and control | Basic coverage of battery characteristics, converter interface, and control loops | » Absence of integrated BESS–converter–grid modelling under dynamic scenarios.<br>» Limited exposure to dq-frame control, droop, VSM, grid-forming and grid-following strategies.<br>» No focus on low and high-voltage ride-through (LVRT/HVRT), black-start capability, or synchronization algorithms. |
| 2 | Battery management systems (BMS) and diagnostics | SoC/SoH algorithms, cell balancing, and hardware architecture commonly discussed | » Lack of AI/ML-based diagnostics for SoH prediction and fault prognosis.<br>» Cyber-secure and adaptive BMS architectures under fluctuating grid voltage/frequency not addressed.<br>» No exposure to real-time estimation or predictive maintenance frameworks. |
| 3 | Grid integration and ancillary services | BESS integration with renewable and microgrid systems covered conceptually | » Limited understanding of BESS-based grid services such as frequency regulation, inertia emulation, voltage support, and ramping.<br>» Lack of discussion on ancillary services (frequency and voltage support, congestion management, black-start support). |
| 4 | Hybrid and distributed configurations | Hybrid architectures (battery-supercapacitor/ fuel-cell) and control logic briefly introduced | » Energy management and control co-ordination among hybrid components not demonstrated.<br>» No focus on distribution-connected and behind-the-meter (BTM) BESS configurations.<br>» Aggregated and Virtual Power Plant (VPP) operation concepts not included. |
| 5 | Power electronics and converter interface | Converter and inverter fundamentals covered under general power electronics courses | » Missing converter-level dynamic control, fault ride-through, and protection co-ordination aspects.<br>» No real-time control strategies for grid-supportive operation (droop/VSM/V2G).<br>» Synchronization and islanding detection mechanisms absent. |
| 6 | Techno-economic and lifecycle modelling | Sustainability, safety, and recycling protocols discussed at high level | » No modelling of lifecycle cost, degradation-linked dispatch, or warranty-based operation strategies.<br>» Economic optimization and value-stacking frameworks absent.<br>» Lack of exposure to circular-economy-oriented reuse and recycling pathways (second life BESS). |

| S. No. | Thematic Area | Current Academic Coverage | Identified Gaps |
|---|---|---|---|
| 7 | Standards, regulations, and compliance | General introduction to ESS and safety standards (IEC/ANSI) | » Grid-tied BESS compliance (CEA 2019, IEEE 2800/1547) not incorporated.<br>» No emphasis on interconnection testing, certification, and inter-operability with national/state grid codes.<br>» Limited linkage with Indian regulatory frameworks for storage participation. |
| 8 | Market and policy interfaces | Energy storage policy and market discussions rarely integrated | » Limited exposure to ancillary service markets, frequency reserve mechanisms, and capacity markets.<br>» No modelling of BESS participation in day-ahead or real-time markets.<br>» Insufficient coverage of regulatory mechanisms governing storage procurement and remuneration. |
| 9 | Simulation tools and digital twins | Component-level simulations performed | » Lack of system-level simulation using advanced software tools.<br>» No quasi-dynamic or optimization-linked case studies under realistic grid events.<br>» Absence of digital-twin frameworks for predictive operation and analytics. |
| 10 | Laboratory, field-based and experiential learning | Cell-level laboratory exercises available in select programmes | » Lack of grid-connected BESS demonstration or pilot-scale experiments<br>» No exposure to real-time control validation, SCADA integration, or dispatch operation.<br>» Absence of field visits or collaborative projects with utilities and testbeds. |

design, electronics, mechatronics, and renewable energy operations and maintenance. With focused upskilling, these existing skill pools can be effectively channelled into ESS applications. As the sector grows, several professional roles—such as battery technicians, BMS engineers, EMS programmers, safety officers, recycling engineers, and grid-integration specialists—are rapidly emerging and can be developed upon the current expertise already present in the workforce. At the same time, new job opportunities are expected to expand across the ESS value chain, covering cell manufacturing, module and pack assembly, testing, transport logistics, installation and commissioning, predictive maintenance, and end-of-life management.

Stakeholder survey was conducted to understand BESS implementation among various categories of stakeholders including ITI, academic institutions, DISCOMs, C&I, financial institutions and OEM sectors. Following stakeholder survey and subsequent consultations provide us primary inputs for analysis to understand existing gaps among different stakeholders across BESS value chain. The survey pointed out that across the value chain, majority of employees in BESS segment are engaged in OEM, followed by DISCOMs, academics and ITIs. Significantly low responses received from C&I and financial sectors where only a few employees are engaged. Across all stakeholder categories, women engagement in BESS sector jobs remains insignificant. Low awareness of BESS-related career opportunities, especially among women, limits their participation across the energy storage value chain. However, majority of the stakeholders expressed positive desire to send women employees engaged in related sectors for upskilling, if standard industry-oriented training courses are available.

In this section, consolidated responses of types of stakeholders in the BESS sector have been analysed. While consolidated responses across different stakeholder categories on BESS awareness, technology and policy knowledge are presented here, their preferred skill requirement are mentioned under the Stakeholder-wise response analysis in Annexure 2.

The study on awareness of BESS among different stakeholders was found to be mixed—it was found considerably high among OEMs, DISCOMs and academic sector, however, awareness was significantly low among financial institutions. C&I and ITI segments have shown moderate awareness level (Figure 7.3). Therefore, BESS awareness programmes are recommended among FIs, C&I and ITIs/polytechnic level.

The stakeholder's study has found that the awareness on battery technology used in BESS implementation (Figure 7.4) was quite high among the DISCOMs, however, it was found to be low among C&I sector and financial institutions. This indicates that appropriate trainings are necessary among these stakeholders.

Similarly, the stakeholder study revealed that awareness on BESS policies, regulations and guidelines remain moderate among DISCOMs and financial institutions (Figure 7.5) but were found to be low among C&I sector and training courses should address this issue.

A detailed analysis showed that the barriers to BESS adoption are diverse and vary significantly across stakeholder groups (Table 7.3). DISCOMs were concerned about technical knowledge on system sizing & optimization, battery charging & discharging cycles, issues during grid integration, grid frequency & voltage impact on BESS, power electronics & control systems and safety protocols to be followed for BESS implementation. DISCOMs were also found to be facing project implementation challenges, O&M planning issues, performance guarantees, and reliability risks during the BESS implementation processes. C&I sector, financial institutions and OEMs had felt limited institutional support, lack of high-quality training programmes, cost of trainings, time constraint and availability of trained manpower were major bottlenecks towards BESS

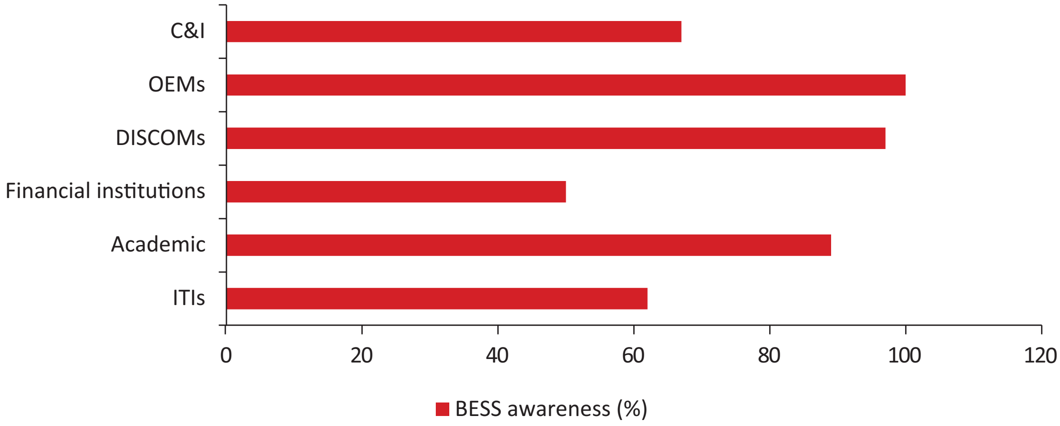


**FIGURE 7.3**: BESS awareness in % across stakeholder types

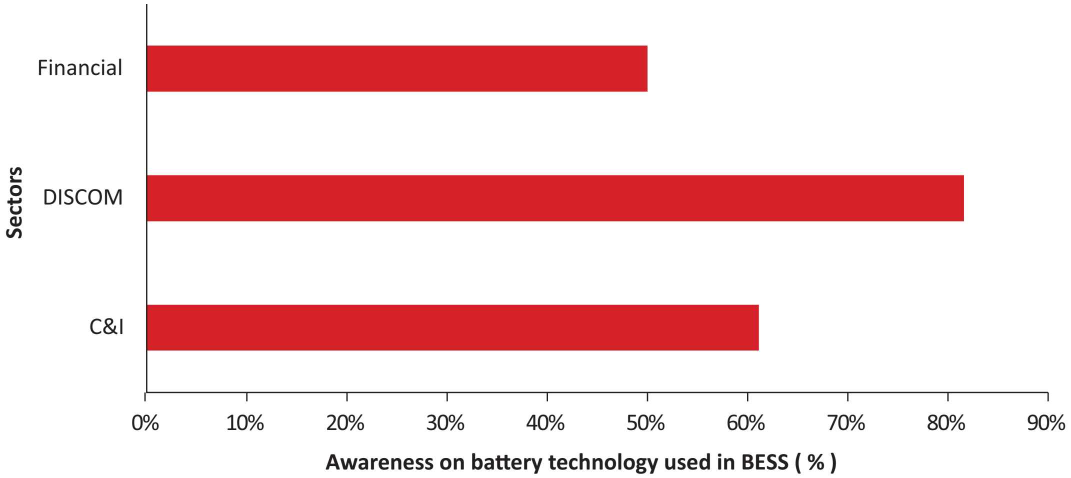


**FIGURE 7.4**: Awareness (%) on battery technology used in BESS

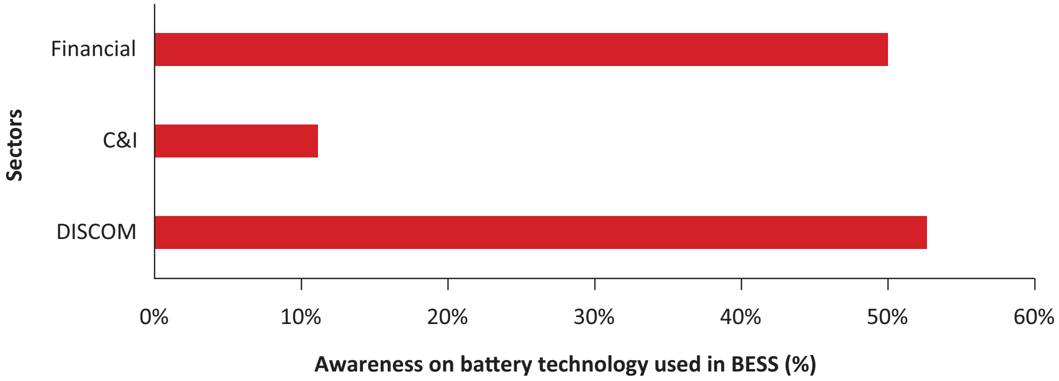


**FIGURE 7.5**: Awareness (%) on BESS policy and guidelines

implementation. Additionally, OEMs also felt complexity in BESS battery pack assembly process, battery degradation monitoring and component replacement costs also contributed negatively towards BESS implementation.

Stakeholders from the academic and ITI sectors identified high costs, financial constraints, and inadequate infrastructure and facilities as key barriers to BESS implementation. Additionally, for other stakeholder categories, limited awareness and gaps in practical learning and skills, technological limitations, insufficient R&D outcomes, operational and maintenance challenges, awareness and understanding of policy & regulatory guidelines, and market uncertainties further constrain the effective deployment and scaling of BESS solutions. The survey identified major training challenges among different stakeholder categories (Table 7.4). It was noted that across all stakeholder categories, similar concerns were prevalent which include lack of funding, lack of infrastructure and institutional support, unavailability of courses in the sector, high cost of training, time constraints, and certification & career opportunities. Lack of awareness in BESS certification, clarity in future career opportunities and unavailability in practical hands-on learning during training are major challenges faced in BESS sector.

**TABLE 7.3**: Barriers to BESS adoption among different stakeholders

| DISCOMs | C&I | Academic | Financial | OEM | ITI |
|---|---|---|---|---|---|
| System sizing and optimization | Lack of available training programmes | High cost and financial constraints | Lack of available training programmes | Lack of trained personnel | Lack of available training courses and programmes |
| Charging and discharging cycles | Limited institutional support | Lack of infrastructure and facilities | Time constraints | BESS battery pack assembly process | Lack of infrastructure and facilities |
| Grid integration | High cost of training | Lack of awareness and skill development | Limited institutional support | Battery degradation monitoring | Lack of awareness and skill development |
| Grid frequency and voltage impact | Time constraints | Technological limitations and lack of R&D | | Component replacement costs | Lack of funding |
| Power electronics and control systems | | Policy and regulatory barriers | | | Need for refresher courses for ITI teaching faculty |
| Safety protocols | | Environmental and sustainability concerns | | | |
| Project implementation and O&M planning | | Operational and maintenance challenges | | | |
| Performance guarantees and reliability | | Educational and practical learning gaps | | | |
| | | Market and deployment uncertainty | | | |
| | | Indigenous/ commercial manufacturing challenges | | | |

**TABLE 7.4**: Training challenges among different stakeholders

| ITI | DISCOMs | C&I | Academic | Financial | OEM |
|---|---|---|---|---|---|
| Lack of funding and student awareness | Lack of available training programmes | Lack of available training programmes | Cost of the training | Lack of available training programmes | Lack of available training programmes |
| Lack of infrastructure and relevant equipment/ materials | High costs of training | High cost of training | Certification and career opportunities | Time constraints | High cost of training |
| Unavailability of courses in the sector | Time constraints | Time constraints | Practical hands-on learning | Limited institutional support | Time constraints |
| No advanced training options or supporting organizations | Limited institutional support | Limited institutional support | Expert faculty | | Limited institutional support |
| Need for refresher courses for teaching faculty | | | Industry collaboration | | |

Across stakeholder categories, a dire need of skill development was felt, however, the purpose of such trainings varies significantly. ITIs require technical and financial knowledge on BESS to meet industry demand of technical assistants/ technicians, electrical fabrication, repair, battery repair and renewal, EVs, operation, and maintenance roles. Academic stakeholders feel that training on BESS implementation is necessary for career advancement, undertaking research, starting entrepreneurship/start-ups, meeting industry compliance. For operation and maintenance, DISCOMs feel that technical expertise of BESS implementation is a necessity. C&I sector feels technical expertise is necessary for BESS implementation, and financial support is required for training the staff. OEM sector needs trainings on technical expertise in system sizing & design, power electronics & control systems, grid integration, performance optimization, safety & fire protection, BESS qualification and test requirement, etc., for large scale production.

Across stakeholder categories, DISCOMs preferred offline trainings over online/hybrid mode. OEMs are ready for either offline or online modes of training. On the other hand, C&I, academic and financial institutions preferred hybrid training mode. Across stakeholder categories, respondents were open to both non-residential and residential trainings. Furthermore, respondents from ITIs felt long-term residential trainings are necessary to understand BESS technologies.

Different stakeholders are looking for skilling on BESS sector for different purposes, stakeholders have identified some important training topics (Table 7.5) to be part of BESS training courses including BESS sizing and design, feasibility assessment, financial modelling, technological aspects, safety, grid integration & energy management, maintenance & recycling of batteries, O&M best practices, investment opportunities, risk assessment and mitigation strategies, end-of-life disposal, regulatory compliance, etc.

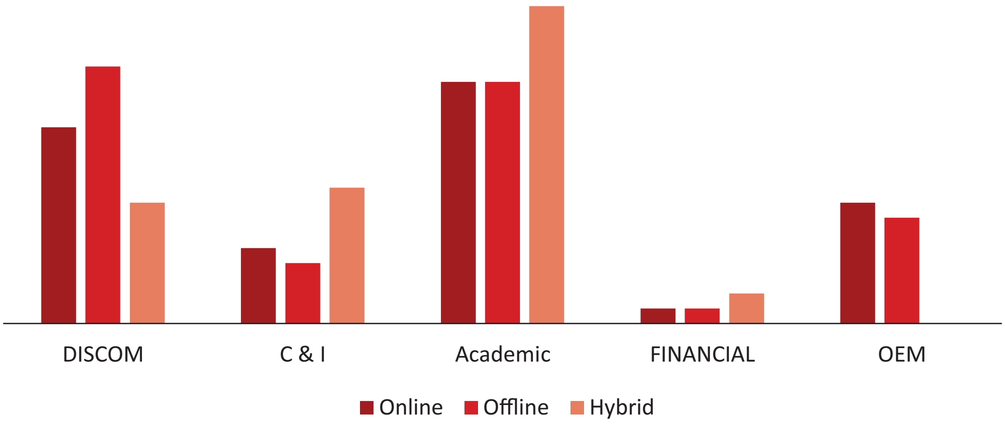


**FIGURE 7.6**: Stakeholders' preference for BESS training type

**TABLE 7.5**: Training topics to be covered for different stakeholders

| DISCOMs | C&I | Academic | Financial | OEM |
|---|---|---|---|---|
| BESS sizing and design | BESS sizing and design | Basics of energy storage technologies | Technical aspects of BESS | BESS sizing and design |
| Feasibility assessment | Feasibility assessment | Design and manufacturing of BESS | Financial modelling for BESS projects | Feasibility assessment |
| Procurement and contract management | Procurement and contract management | Grid integration and energy management | Risk assessment and mitigation strategies | Procurement and contract management |
| Financial modelling | Financial modelling | Safety, maintenance and recycling of batteries | Policy and regulatory framework | Financial modelling |
| O&M best practices | O&M best practices | Policies and regulations in BESS | Case studies of successful BESS financing | O&M best practices |
| End-of-life disposal | End-of-life disposal | Business and investment opportunities in BESS | | End-of-life disposal |
| Regulatory compliance | Regulatory compliance | Energy conservation | | Regulatory compliance |
| | | | | Safety and fire protection |

## 7.4 Consolidated Skill Gaps Identified in the Assessment

The rapid deployment of ESS in India is driving growing demand for skilled professionals across multiple sectors. As manufacturing, infrastructure planning, and grid modernization accelerate, every stage of the ESS value chain now requires specialized expertise.

In the manufacturing sector—including cells, modules, power conversion systems (PCS), BMS, and EMS—there is a growing need for process engineers, quality controllers, and safety supervisors, as well as chemical technicians. Additionally, as BMS and EMS architectures become more complex, the demand is increasing for specialists in system design and firmware development, as well as technicians skilled in pack assembly, thermal management, materials science, and reliability testing.

Within the power sector, including DISCOMs and transmission utilities, there is a growing demand for engineers proficient in battery sizing, system integration, and evaluating grid impacts. Technicians for substation installation, commissioning, and O&M are also vital, while professionals with expertise in energy market operations, demand response mechanisms, and ancillary services are increasingly sought after. This is consistent with the broader trend in India's green-transition workforce—employers are actively recruiting for storage operators alongside traditional roles in solar and wind. For commercial and industrial (C&I) consumers, ESS adoption is creating entirely new roles. Facility managers now must be trained in ESS operations and safety. Energy auditors are needed to design BTM systems, while engineers are being sought to manage load shifting, backup power and integrated solar and storage configurations. OEMs and system integrators are also broadening their talent base by hiring software engineers for firmware development, field technicians for deployment and servicing, and specialists in reliability, safety, and lifecycle management to ensure strong performance throughout a storage system's life. At the same time, the recycling, repair, and second-life segment is gaining momentum. This emerging area requires battery-dismantling experts, engineers proficient in materials recovery and recycling-plant operations, and technicians responsible for second-life testing and battery repurposing.

Such insights were derived from the skill gap analysis and are summarized in Table 7.6 under stakeholder-wise skill gaps. Existing areas of expertise were also identified across stakeholder categories that can be leveraged to bridge BESS-related skill gaps. This section highlights the overall skill gaps identified through the assessment, drawing on findings from desk research, primary surveys, and stakeholder consultations.

**TABLE 7.6**: Stakeholder-wise skill gaps and existing expertise that can be leveraged for ESS adoption

| S. No. | Sector | Existing Expertise/Capability | Existing Skill Gaps | Expertise to be Leveraged |
|---|---|---|---|---|
| 1 | **Academic Sector**<br>(IITs, NITs, Universities) | » Academic institutions have a strong theoretical foundation in electrochemistry and battery materials, supported by extensive R&D on advanced chemistries.<br>» They conduct high-quality power systems modelling and grid integration studies that support renewable and BESS research.<br>» Also possess well-equipped laboratories with battery cyclers, thermal chambers, and other testing facilities. | » Most engineering students receive limited hands-on exposure to real-world BESS commissioning, integration, and safety procedures.<br>» BESS is generally not taught as a standalone subject in engineering curricula, resulting in conceptual gaps.<br>» Academic programmes offer inadequate training related to DC systems, battery balancing, and the design of cell-pack architectures.<br>» Many engineers lack practical understanding of series/parallel configurations, battery hierarchy (cell–pack–rack), and real charge–discharge behaviour.<br>» There is a major industry–academia disconnect. Academic learning does not align with real-world BESS applications and lacks systems-thinking exposure.<br>» Students receive minimal exposure to multidisciplinary fields like power electronics, digital systems, cybersecurity, and automation required in modern BESS.<br>» Testing, certification, and battery safety protocols are not covered adequately in curriculum, creating a foundational skills gap.<br>» Lack of exposure to international standards (UL 9540A, NFPA 855).<br>» Limited understanding of battery lifecycle, recycling, and second-life use.<br>» Faculty capacity limitations and outdated curricula. | » Research laboratories within academic institutions can be upgraded to act as regional BESS testbeds for hands-on training.<br>» Academia can introduce practical, BESS-focused modules covering cell-to-pack hierarchy, balancing techniques, and DC-side safety procedures.<br>» Jointly designed certification programmes between academia and industry can enhance employability and bridge the skills gap. |

| S. No. | Sector | Existing Expertise/Capability | Existing Skill Gaps | Expertise to be Leveraged |
|---|---|---|---|---|
| | | | » A large share of respondents (over 60%) reported that students lack practical exposure to ESS and primarily study theoretical content.<br>» Training demand is highest for hands-on laboratory work, safety practices, and system-level understanding, indicating major practical skill gaps.<br>» Students have limited familiarity with advanced BESS technologies such as flow batteries, sodium-ion systems, and hybrid energy storage systems.<br>»<br>» Academic respondents indicate insufficient knowledge of industry applications such as grid services, EV charging integration, and renewable hybridization.<br>» Limited awareness about testing, certification, and national/international safety codes was repeatedly highlighted by faculty participants.<br>» Syllabus lacks LVRT/HVRT, black-start capability, synchronization algorithms.<br>» No AI/ML-based BMS diagnostics, predictive maintenance, or cyber-secure BMS architecture.<br>» Limited coverage of ancillary services—frequency regulation, inertia emulation, voltage support, congestion management.<br>» Energy management in hybrid systems and BTM/VPP configurations not addressed.<br>» Missing converter-level dynamic control, protection coordination, droop/VSM/V2G strategies, synchronization and islanding detection.<br>» No lifecycle cost modelling, degradation-linked dispatch, value stacking, or circular-economy reuse frameworks. | |

| S. No. | Sector | Existing Expertise/Capability | Existing Skill Gaps | Expertise to be Leveraged |
|---|---|---|---|---|
| | | | » Lack of alignment with Indian regulatory frameworks, CEA 2019 compliance, IEEE 2800/1547, and inter-operability testing.<br>» No structured exposure to ancillary service markets, reserve markets, or BESS participation in day-ahead/real-time markets.<br>» Lack of system-level simulation, optimization-linked case studies, and digital twin frameworks.<br>» No grid-connected BESS demonstration labs, SCADA integration exercises, real-time control validation, field visits, or utility testbed collaborations.<br>» Lack of common curriculum across academic institutes.<br>» Need of national level curricula development through multi-stakeholder collaborations. | |
| 2 | **Financial Sector** (Banks, NBFCs, DFIs) | » Financial institutions have experience financing solar, wind, and hybrid RE projects.<br>» They also possess strong capabilities in due diligence, credit risk assessment, and structuring financial products such as green bonds. | » Many financial organizations have limited understanding of BESS-specific business models, resulting in hesitation to finance storage projects.<br>» BESS projects are often seen as financially risky because of unclear revenue streams and uncertain cashflows.<br>» There is no standardized approach for valuing ESS assets, making evaluation difficult.<br>» Lack of awareness of state-level storage policies, regulatory frameworks, and multi-service revenue models leads to inconsistent financial assessments.<br>» Limited technical understanding of BESS warranties, degradation, and safety standards needed for due diligence.<br>» Few tools exist for modelling multi-service revenue stacking. | » RE financing frameworks can be adapted to finance the storage sector.<br>» Financial institutions can develop assets such as ESS leasing, RESCO/OPEX financing, and standardized ESS risk assessment tools. |

| S. No. | Sector | Existing Expertise/Capability | Existing Skill Gaps | Expertise to be Leveraged |
|---|---|---|---|---|
| 3 | **OEM Sector** (Battery, PCS, Inverters, Integrators) | » OEMs possess strong capabilities in integrating BMS, PCS, and EMS.<br>» Many companies have in-house EMS/control system development capabilities.<br>» They have deployed C&I, residential, and utility-scale systems across India. | » More than 90% of high-quality battery packs/modules are imported.<br>» Domestic BMS units often fail due to low design maturity.<br>» Many small manufacturers lack quality control and standardized SOPs.<br>» OEMs report shortages of skilled manpower for integration, commissioning, and system design, including insufficient workforce for high-voltage and multi-voltage BESS applications.<br>» Technicians lack training in battery safety systems, monitoring, and control integration—key for system reliability.<br>» There is inadequate expertise in cybersecurity for BESS communication and monitoring networks.<br>» Limited expertise in fire safety design and thermal runaway mitigation.<br>» Shortage of professionals skilled in simulations, techno-commercial optimization, and PPA interpretation.<br>» Limited capacity to design climate-specific systems for hot/cold regions. | » OEMs can help develop national standards for testing, safety, and inter-operability.<br>» Domestic manufacturing can scale with improved QA and adoption of global practices. |
| 4 | **DISCOM Sector** (Distribution Companies) | » DISCOMs have strong capacity in operations and maintenance, protection, etc.<br>» Experience in RE procurement through SECI | » Only one-third of surveyed DISCOM staff have BESS exposure.<br>» DISCOMs face uncertainty about regulations, ownership, and BESS operational roles.<br>» Limited expertise in PPA interpretation, regulatory compliance, and techno-commercial aspects of BESS projects and application in BESS operations. | » DISCOMs can use AMI/SCADA data for BESS siting.<br>» They can host substation pilots to demonstrate peak shaving and reliability improvement.<br>» Standardized procurement models like BOOT/BOO can improve uniformity and transparency. |

| S. No. | Sector | Existing Expertise/Capability | Existing Skill Gaps | Expertise to be Leveraged |
|---|---|---|---|---|
| | | | » There is a shortage of structured operator training on ESS safety, EMS operations, and grid integration.<br>» Lack of trained personnel for multi-voltage BESS operations, including low, medium, and high-voltage integration requirements.<br>» Limited technical understanding of BESS system design, cable routing, grounding, and interconnection requirements.<br>» DISCOMs lack awareness of battery degradation patterns, safety protocols, and emergency response procedures for ESS.<br>» Minimal exposure to use-cases like peak shaving, congestion mitigation, frequency response.<br>» Control room teams lack training in SOC/SOH interpretation and cycling patterns.<br>» Difficulty interpreting technical testing reports and hazard assessments. | |
| 5 | **C&I Consumers Sector** (Industry, Data Centres, Campuses) | » Industries operate rooftop solar, DG sets, and microgrids for reliability.<br>» They routinely monitor energy use, demand charges, and load curves.<br>» Many have engineering teams for infrastructure management. | » 40–50% of C&I consumers are unaware of BESS applications beyond backup.<br>» High capital cost remains the main adoption barrier.<br>» Engineers often fail to detect issues such as reversed polarity or loose terminals due to limited practical training.<br>» C&I engineers lack training in safety systems, battery monitoring, and DC-side fault identification—critical for large industrial sites.<br>» There is insufficient understanding of BESS cybersecurity risks and digital tools used for predictive analytics. | » C&I users can adopt behind-the-meter BESS for peak shaving, reliability, and arbitrage.<br>» They can demonstrate business models for industrial storage. Industries can participate in hands-on OJT programmes for safety, wiring diagnostics, and fault detection. |

| S. No. | Sector | Existing Expertise/Capability | Existing Skill Gaps | Expertise to be Leveraged |
|---|---|---|---|---|
| | | | » Technicians lack exposure to high-voltage BESS operations and hybrid system integration.<br>» Limited understanding of integrating BESS in commercial contracts/PPAs.<br>» Low awareness of fire protection and thermal runaway risk in industrial settings.<br>» Limited use of digital diagnostics and predictive analytics. | |
| 6 | **Industrial Training Institutes** (ITIs & Polytechnics) | » ITIs have strong orientation and practical exposure in electrical wiring, motor systems, and equipment maintenance.<br>» Several ITIs offer basic modules on renewable energy, electrical safety, and power systems. | » Curriculum does not include BESS, DC safety, cell–pack configuration, or EMS/BMS basics.<br>» Instructors lack exposure to modern storage technologies and high-voltage battery systems.<br>» Limited access to real batteries, PCS, EMS, or diagnostic equipment for hands-on training.<br>» No standard training modules for BESS component, installation, O&M, battery safety, thermal events, fire suppression, battery lifecycle, second-life use, and recycling.<br>» Students lack cross-disciplinary exposure in power electronics, sensors, digital tools, cybersecurity.<br>» Limited BESS-focused content in ITIs. Most engineering and vocational training curricula (ITI/diploma/graduate programmes) still treat energy storage as an add-on topic under electrical engineering or renewable energy.<br>» Most ITI/diploma graduates are trained in general electrical wiring, electronics repair, or motor winding, but lack battery-specific skills. | » ITIs can serve as national skilling hubs for technicians in installation, O&M, wiring, safety, and commissioning.<br>» They can host hands-on training using OEM-supplied equipment. Modular short-term courses can quickly build BESS-ready workforce. |

| S. No. | Sector | Existing Expertise/Capability | Existing Skill Gaps | Expertise to be Leveraged |
|---|---|---|---|---|
| | | | » ITIs lack BESS-specific laboratory infrastructure such as battery cyclers, thermal chambers, or diagnostic tools needed for modern battery training.<br>» Curriculum does not include cell testing, thermal behaviour analysis, venting systems, or charge–discharge profiling.<br>» Faculty require extensive upskilling, as most come from traditional electrical backgrounds with limited exposure to battery storage technologies.<br>» Strong need for industry-institute collaboration/linkages for internship, on-the-job training (OJT), field/plant visit and summer camp.<br>» Limited capability to teach battery safety, emergency response, and DC-side protection.<br>» Lack of availability of digital tools (e.g., simulators and animated learning modules), to support real-time modelling, diagnosis and experiential learning. | |
| 7 | **Safety Certification and Testing Labs** (CPRI, NABL Labs, UL Affiliates) | » CPRI and select NABL-accredited labs have expertise in electrical testing, power electronics validation, and battery safety evaluation.<br>» Some labs follow international standards such as IEC 62619, IEC 62109, and UL protocols. | » Insufficient number of accredited labs for large-format BESS testing.<br>» High cost of PCS/BMS testing makes certification unaffordable for smaller manufacturers.<br>» Limited capacity for advanced tests—fire propagation, thermal runaway, shock/vibration, and abuse tests.<br>» Lack of harmonized national standards for commissioning, safety, and EMS/BMS testing.<br>» Testing of second-life batteries and recycling processes almost non-existent. | » Labs can develop national BESS safety and performance certification systems.<br>» Can partner with OEMs and academia to build advanced test facilities including UL-9540A fire testing.<br>» Can support workforce development by offering training in testing protocols, safety norms, and certification methods. |

# 7.5 Stakeholder-wise Job Roles, Skill Gap Analysis and Priority Areas

## 7.5.1 Methodology

The comprehensive analysis in the section above used a structured, multi-step synthesis of the survey reports, combining quantitative patterns and qualitative insights across respondent categories.

- **Data extraction and structuring**

Key data points were first extracted from each survey document—respondent segments (academic, financial, OEMs, DISCOMs, C&I), job roles mentioned, experience levels, stated demand (current and future), identified gaps, and narrative comments on challenges and priorities. These were then organized into common fields in a comparative matrix so that like-for-like items (e.g., BESS engineer roles, grid integration functions, financial analysts) could be aligned across sectors.

- **Cross-sector consolidation**

Once structured, job roles from all five segments were clustered into functional families (systems/engineering, grid/distribution, finance/commercial, safety/compliance, operations/O&M, R&D/strategy). Demand indications in each document (e.g., "urgent", "currently missing", "needed in 3–5 years") were mapped to short, medium and long-term horizons for each role family. Similar or overlapping titles were merged under a common role name to avoid duplication and to create a consolidated role list for the BESS ecosystem.

- **Skill gap and challenge analysis**

Skill gaps were coded by type (technical BESS knowledge, grid integration, power electronics, safety, financial modelling, hands-on/practical skills) and then ranked by severity using frequency of mention, explicit 'critical/high' flags in the surveys, and the seniority bands most affected (e.g., junior vs senior staff). Challenges and priorities (e.g., lack of trained staff, absence of standard procedures, low awareness, limited training access) were synthesized thematically and then tagged back to the affected sectors and role families to show where systemic issues were most acute.

- **Prioritization logic**

Finally, roles, skill gaps, and challenges were given 'critical/high/medium' labels based on three converging criteria: (1) how many sectors depend on that role or skill; (2) whether it is a precondition for safe and reliable BESS deployment (e.g., safety, grid integration); and (3) the time horizon in which respondents indicated the need will materialize. This prioritization step produced the short, medium, and long-term planning view and allowed the analysis to highlight immediate pipeline needs (e.g., systems and grid engineers, safety roles) versus strategic, longer-horizon roles (e.g., EoL, R&D, strategy).

## 7.5.2 Comprehensive analysis of BESS sector workforce requirements (Job roles)

Based on the skill gaps identified and analysis of survey documents covering academic institutions, financial organizations, OEMs, DISCOMs, and C&I consumers, this consolidated analysis presents critical workforce insights for strategic planning in the BESS sector.

### *7.5.2.1 Job role landscape*

The BESS sector requires 29 distinct job roles across five key categories, with significant variation in requirements and readiness levels. The most urgent roles center on technical implementation and safety.

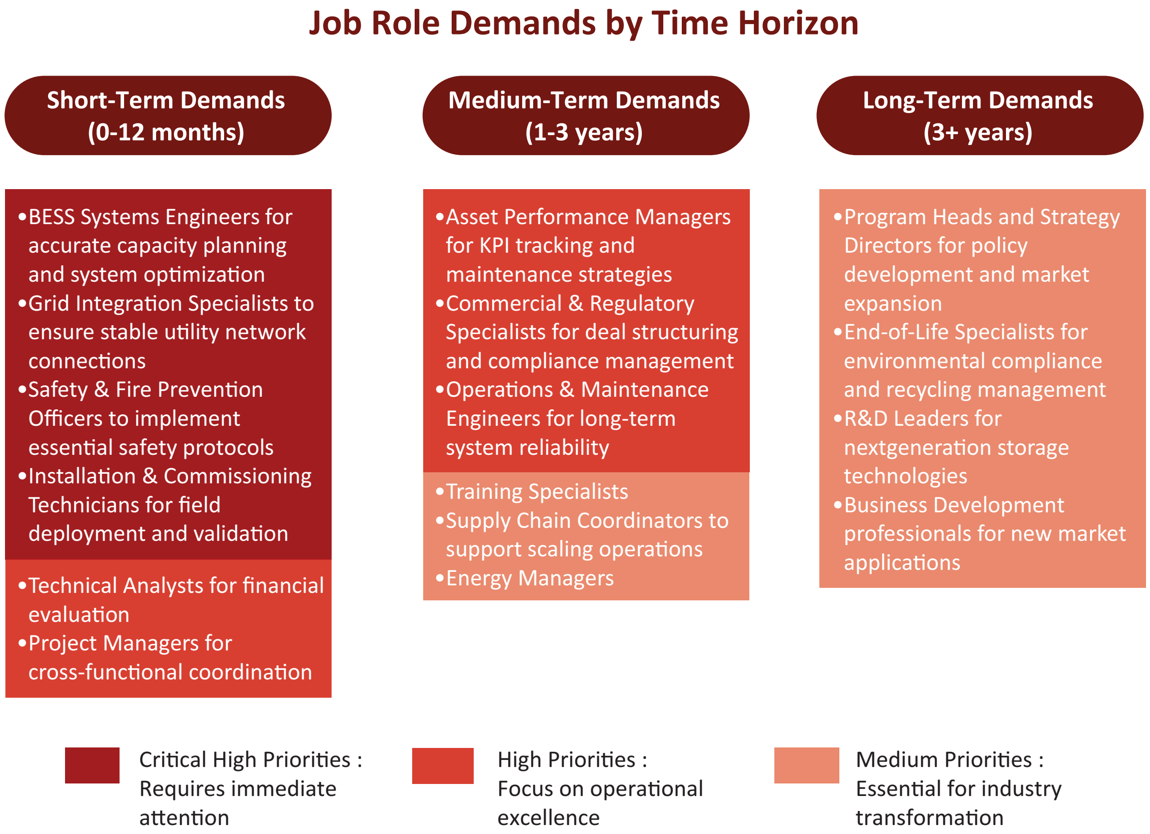
- BESS Systems Engineers (Critical priority) - Responsible for system sizing, optimization, and feasibility assessment
- Grid Integration Engineers (Critical priority) - Ensuring stable interconnection with utility networks and compliance with grid codes
- Power Electronics Engineers (Critical priority) - Managing inverters, converters, and energy management systems
- Safety & Compliance Officers (Critical priority) - Developing protocols and safeguards for high-energy installations

As per the skill gap analysis, 29 identified job roles of the BESS sector are distributed as follows:

- Academic, financial, and C&I consumer stakeholders each identify 5 essential roles
- OEM sector leads with 7 specialized roles focused on design and manufacturing
- DISCOMs sector requires 7 roles emphasizing grid integration and asset management

### *7.5.2.2 Distribution of BESS job role demands*

BESS sector job demands are categorized based on existing skills and expertise, market maturity level and industry demand. The job roles are distributed among different timelines—short-term spanning a period of 0–12 months (where job roles are critical to sectoral growth); medium-term with a period of 1–3 years (where job roles focus on operational excellence for sector's functioning and integration with market demand); and long-term spanning a period of over 3 years (where strategic leadership roles become essential for industry transformation).



**Job Role Demands by Time Horizon**

**Short-Term Demands (0-12 months)**

- BESS Systems Engineers for accurate capacity planning and system optimization
- Grid Integration Specialists to ensure stable utility network connections
- Safety & Fire Prevention Officers to implement essential safety protocols
- Installation & Commissioning Technicians for field deployment and validation

- Technical Analysts for financial evaluation
- Project Managers for cross-functional coordination

**Medium-Term Demands (1-3 years)**

- Asset Performance Managers for KPI tracking and maintenance strategies
- Commercial & Regulatory Specialists for deal structuring and compliance management
- Operations & Maintenance Engineers for long-term system reliability

- Training Specialists
- Supply Chain Coordinators to support scaling operations
- Energy Managers

**Long-Term Demands (3+ years)**

- Program Heads and Strategy Directors for policy development and market expansion
- End-of-Life Specialists for environmental compliance and recycling management
- R&D Leaders for nextgeneration storage technologies
- Business Development professionals for new market applications

Critical High Priorities : Requires immediate attention

High Priorities : Focus on operational excellence

Medium Priorities : Essential for industry transformation

**FIGURE 7.7**: BESS job role demand by time horizon

Further to this, high-priority short-term needs include Technical Analysts for financial evaluation and Project Managers for cross-functional coordination. Medium-priority roles include Training Specialists and Supply Chain Coordinators to support scaling operations. Long-term roles are necessary for policy development, market expansion and taking care of technology obsolescence.

#### *7.5.2.3 BESS job demand by time horizon*

The job demand has been distributed into short, medium and long-term requirement with specific demand level where 'critical' demand indicates immediate requirements. The 29 identified BESS sector job roles have been distributed under 15 categories namely technical engineering, safety & compliance, financial analysis, installation & commissioning, technical BESS, project management, asset management, commercial & regulatory, research & development, training & development, supply chain, strategic leadership, sustainability & ESG, advanced technologies and market development. Further, the skill gap study also identified key requirements for successful integration of these job roles in the BESS sector.

#### *7.5.2.4 Distribution of job roles in BESS sector*

This section will analyse stakeholder-wise distribution of job roles in the BESS sector. In this case, we have mapped the required job roles in the sector adapted from occupational standard defined by the National Skill Qualification Framework (NSQF) and UGC. Each job role has been categorized as per different qualification and experience levels listed under NSQF on a scale of 1 to 8, where 8 is the most qualified with rich experience (Figure 7.9).

In the following section, 29 identified job roles in the BESS sector spread across 5 stakeholders categories have been analysed and mapped (Figure 7.10). Stakeholder-wise data were mapped with (a) job demand (critical, high, medium); (b) with 5 time-horizons (long, long-medium, medium, short-medium and short-term); (c) job roles and experience requirement aligned with NSQF levels; and (d) specific job roles (29) for overall workforce requirement in the BESS sector.

### 7.5.3 BESS skill gaps analysis

In this section, data generated based on desk research and stakeholder surveys have been analysed to understand skill gaps in the BESS sector. Figure 7.11 analyses stakeholder-wise skill gaps mapped with severity level and affected job roles.

#### *7.5.3.1 Key skill gaps identified*

In the previous section, skill gaps were identified across different stakeholder categories. While many of these gaps need immediate attention and corrective actions, following are the significant skill gaps identified across all categories drawn from 29 job roles (mentioned in the job role landscape) required in BESS sector with 5 of these skill gaps identified as most critical and 5 skill gaps identified as high-priority skill gaps.

### 7.5.4 Sector-specific priorities and challenges

Based on identified skill gaps, this section (Figure 7.13) highlights stakeholder specific priorities, major challenges and readiness levels.

In the academic sphere related to BESS sector, enhanced practical training and industry collaboration were identified as priorities. However, the existing skill sets of faculty members, and the available facilities were found to significantly limit hands-on learning opportunities. Building technical competency in BESS for junior staff was identified as top priority in financial institutions, which is getting hindered due to limited BESS expertise

## Job Role Demands by Time Horizon

**Short Term**

**Technical Engineering**
- BESS Systems Engineers
- Grid Integration Engineers
- Power Electronics Engineers

Key requirements:
- System sizing
- Grid codes
- Safety protocols

**Technical BESS**
- Instructor
- Master Trainer

Key requirements:
- Faculty upskilling
- Enhanced training knowledge

**Project Management**
- Project Managers
- Coordinators

Key requirements:
- Timeline management
- Cross-functional coordination

**Safety & Compliance**
- Safety Officers
- Compliance Leads

Key requirements:
- Fire prevention
- Standards implementation

**Installation & Commissioning**
- Master Trainer
- Commissioning Engineers

Key requirements:
- Hands-on deployment validation

**Financial Analysis**
- Technical Analysts
- Financial Modelers

Key requirements:
- BESS project evaluation risk assessment

**Medium Term**

**Asset Management**
- Performance Managers
- O&M Engineers

Key requirements:
- KPI tracking
- Maintenance strategies

**Research & Development**
- Research Scientists
- Technology Specialists

Key requirements:
- Advanced technologies innovation

**Supply Chain**
- Procurement Specialists
- Logistics Coordinators

Key requirements:
- Component sourcing vendor management

**Commercial & Regulatory**
- Contract Specialists
- Regulatory Affairs

Key requirements:
- Deal structuring
- Compliance management

**Training & Development**
- Training Specialists
- Curriculum Developers

Key requirements:
- Program design
- Knowledge transfer

**Long Term**

**Strategic Leadership**
- Program Heads
- Strategy Directors

Key requirements:
- Industry transformation policy development

**Sustainability & ESG**
- End-of-Life Specialists
- ESG Managers

Key requirements:
- Recycling environmental compliance

**Market Development**
- Business Development
- Market Analysts

Key requirements:
- New applications market expansion

**Advanced Technologies**
- R&D Leaders
- Innovation Managers

Key requirements:
- Next-gen storage emerging technologies

● Critical ● High ● Medium ▭ Key Requirements

**FIGURE 7.8**: BESS job demand and key requirements by time horizon

**Job level aligns with the Occupational standard defined by National Skills Qualification Framework (NSQF)**

| NSQF Level | Skills/role complexity |
|---|---|
| Level 2 | Entry-level or helper jobs — routine tasks undesupervision, basic skills. |
| Level 3 | Junior technician / operator level — broader routine tasks, some independence, limited supervision. |
| Level 4 | Skilled technician / operative / Mid-level roles — can work independently, handle well-defined jobs, possibly some supervision or small-scale responsibility. |
| Level 5 | Supervisor / Executive level — greater responsibility, some decision-making, potentially supervising others. |
| Level 6 | Higher supervisory / junior managerial / specialist role — advanced skills and knowledge, responsibility for quality, possibly managing teams or projects. |
| Level 7 | Senior/managerial level - complex tasks, high responsibility, decision-making, oversight of operations/projects. |
| Level 8 | Superior-level professional with high-level skills, qualifications, and advanced academic credentials |

**FIGURE 7.9**: Merged NSQF and UGC levels for BESS job roles

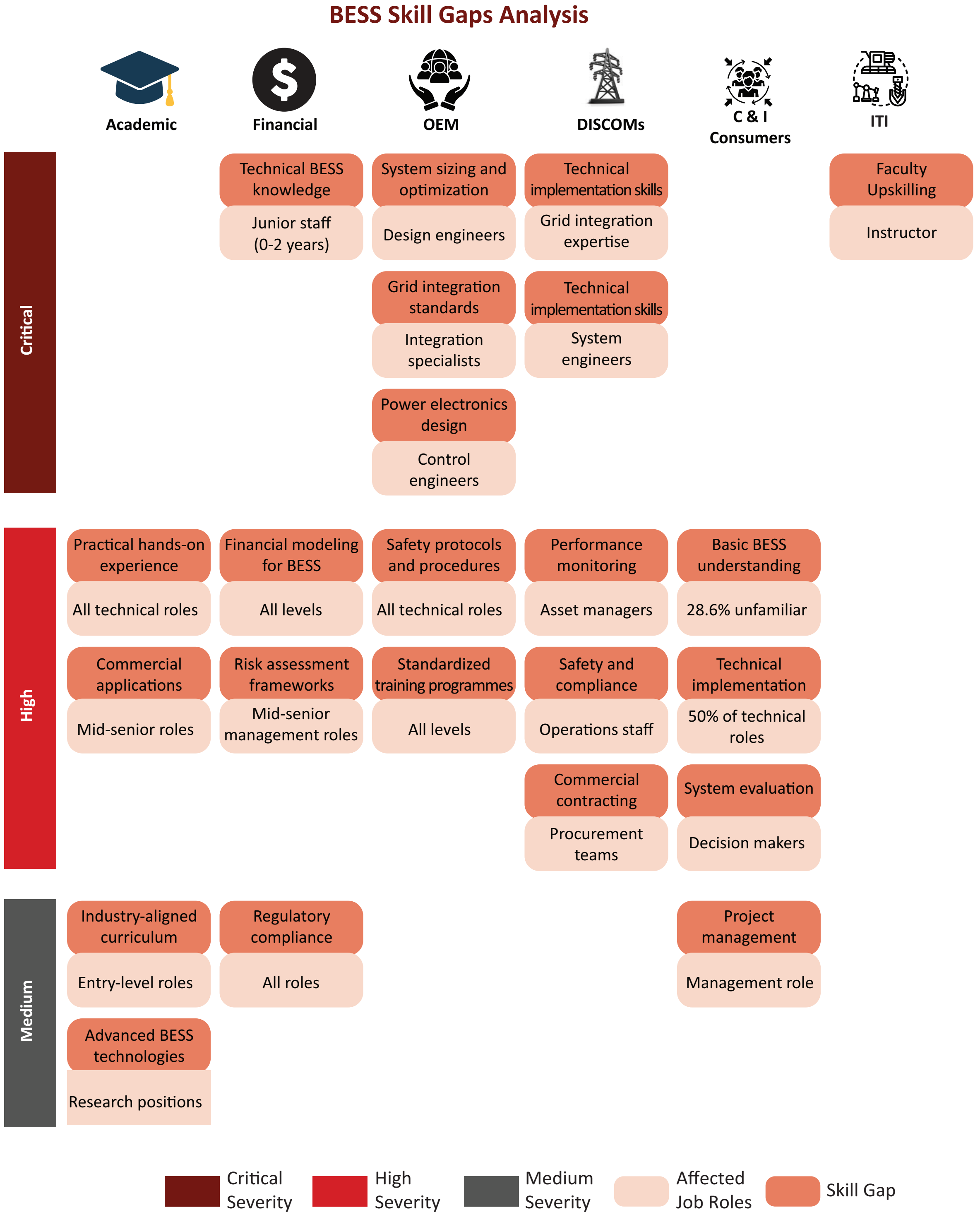
among relationship managers and junior staff. BESS system design expertise and safety standardization were found to be priorities among OEMs, while shortage of trained personnel and lack of standardized procedures put in place were major challenges faced by these stakeholders. DISCOMs priority is to build technical capability and grid integration expertise to adopt BESS technology, however lack of trained BESS

## Stakeholder-wise BESS Job Roles Identified across Time Horizon

| | Academic | Financial | OEM | DISCOMs | C & I Consumers | ITI |
|---|---|---|---|---|---|---|
| Short Term | | Assistant General Manager L7+Exp<br>Financial Modeling Specialist L7+Exp | System Sizing & Design Engineer L6+Exp<br>Grid Integration Specialist L6+Exp<br>Power Electronics Engineer L6+Exp<br>Installation & Commissioning Technician L4 | BESS Systems Engineer L6+Exp<br>Grid Integration Engineer L6+Exp | Executive Level L5+Exp | Instructor L6+Exp |
| Short-Medium Term | Principal Consultant L8+Exp | Manager L5+Exp | Safety & Fire Prevention Officer L4 | Safety & Compliance Lead L6+Exp<br>Commercial/ Contracts Specialist L5+Exp | Management Level L6+Exp<br>Senior Technical Level L5+Exp<br>Project Management Level L4 | Master Trainer L7 |
| Medium Term | | Relationship Manager L6+Exp | BMS Developer L5+Exp<br>O&M Personnel L4 | Regulatory Affairs Manager L7+Exp<br>Asset Performance Manager L6+Exp | Technical Level L4 | |
| Medium-Long Term | Assistant Professor L7+Exp | | | O&M Engineers L6<br>O&M Managers L7 | | |
| Long Term | Professor L8+Exp<br>Associate Professor L7+Exp<br>Research Scientist L7+Exp | | | Energy Managers L7+Exp | End-of-Life Specialist L5+Exp | |

Exp: Experience ● Critical ● High ● Medium L : NSQF Level

**FIGURE 7.10**: Stakeholder-wise BESS job roles by time horizon



BESS Skill Gaps Analysis

| | Academic | Financial | OEM | DISCOMs | C & I Consumers | ITI |
|---|---|---|---|---|---|---|
| Critical | | Technical BESS knowledge<br>Junior staff (0-2 years) | System sizing and optimization<br>Design engineers | Technical implementation skills<br>Grid integration expertise | | Faculty Upskilling<br>Instructor |
| | | | Grid integration standards<br>Integration specialists | Technical implementation skills<br>System engineers | | |
| | | | Power electronics design<br>Control engineers | | | |
| High | Practical hands-on experience<br>All technical roles | Financial modeling for BESS<br>All levels | Safety protocols and procedures<br>All technical roles | Performance monitoring<br>Asset managers | Basic BESS understanding<br>28.6% unfamiliar | |
| | Commercial applications<br>Mid-senior roles | Risk assessment frameworks<br>Mid-senior management roles | Standardized training programmes<br>All levels | Safety and compliance<br>Operations staff | Technical implementation<br>50% of technical roles | |
| | | | | Commercial contracting<br>Procurement teams | System evaluation<br>Decision makers | |
| Medium | Industry-aligned curriculum<br>Entry-level roles | Regulatory compliance<br>All roles | | | Project management<br>Management role | |
| | Advanced BESS technologies<br>Research positions | | | | | |

Critical Severity High Severity Medium Severity Affected Job Roles Skill Gap

**FIGURE 7.11**: Stakeholder-wise BESS skill gap analysis

staffs remains a critical challenge. Basic awareness building and access to high quality training programmes in BESS were major priority areas among C&I consumers and the availability of training programmes remain serious challenge.

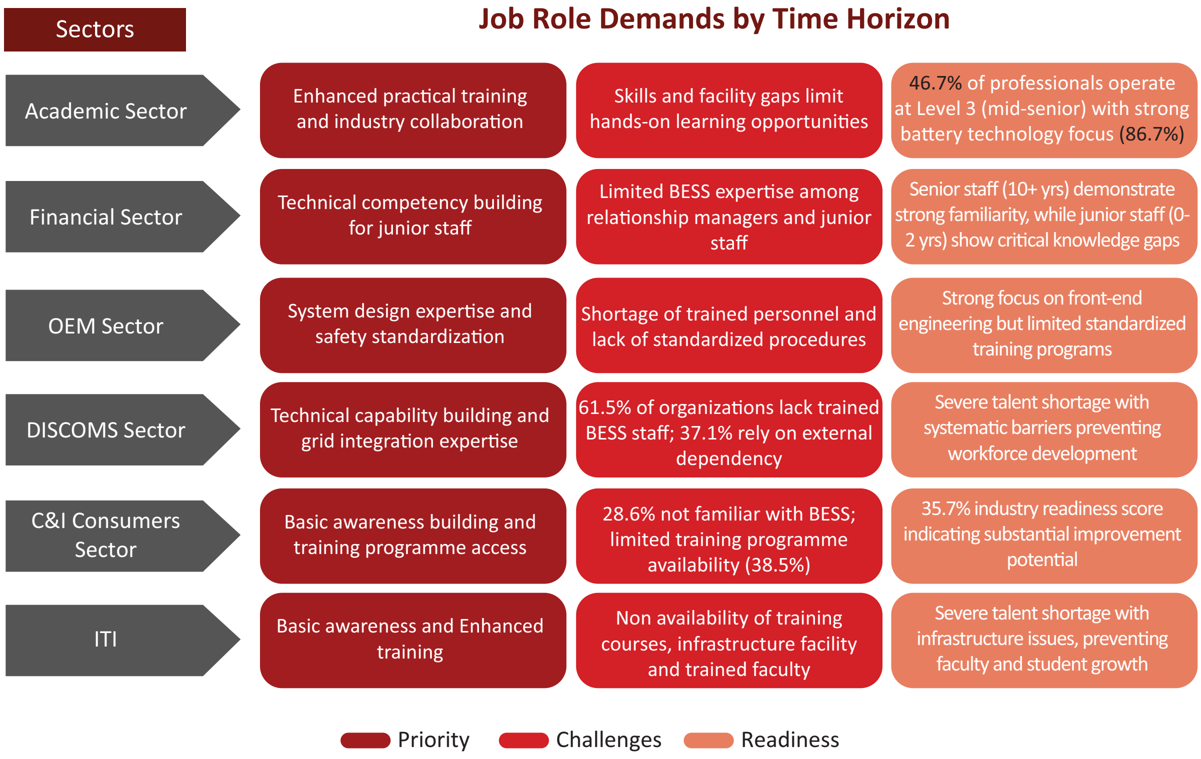
**Most Severe Gaps**

- Technical BESS knowledge among High-Priority Gaps junior financial staff **(0-2 years experience)**
- System sizing and optimization capabilities across OEM organizations
- Grid integration expertise within DISCOMS **(68.8% of senior-level positions affected)**
- Power electronics design competencies for control engineers
- Technical implementation skills across DISCOMS operations

**High-Priority Gaps**

- Basic BESS understanding: **28.6%** of C&I consumers unfamiliar with technology
- Practical hands-on experience in academic institutions
- Financial modeling for BESS projects across all financial roles
- Safety protocols and procedures for all technical positions
- Performance monitoring capabilities in asset management

**FIGURE 7.12**: Critical skill gaps in BESS sector across value chain



**Job Role Demands by Time Horizon**

| Sectors | | | |
|---|---|---|---|
| Academic Sector | Enhanced practical training and industry collaboration | Skills and facility gaps limit hands-on learning opportunities | 46.7% of professionals operate at Level 3 (mid-senior) with strong battery technology focus (86.7%) |
| Financial Sector | Technical competency building for junior staff | Limited BESS expertise among relationship managers and junior staff | Senior staff (10+ yrs) demonstrate strong familiarity, while junior staff (0-2 yrs) show critical knowledge gaps |
| OEM Sector | System design expertise and safety standardization | Shortage of trained personnel and lack of standardized procedures | Strong focus on front-end engineering but limited standardized training programs |
| DISCOMS Sector | Technical capability building and grid integration expertise | 61.5% of organizations lack trained BESS staff; 37.1% rely on external dependency | Severe talent shortage with systematic barriers preventing workforce development |
| C&I Consumers Sector | Basic awareness building and training programme access | 28.6% not familiar with BESS; limited training programme availability (38.5%) | 35.7% industry readiness score indicating substantial improvement potential |
| ITI | Basic awareness and Enhanced training | Non availability of training courses, infrastructure facility and trained faculty | Severe talent shortage with infrastructure issues, preventing faculty and student growth |

Priority Challenges Readiness

**FIGURE 7.13**: Specific priorities and challenges in the BESS sector across value chain

Priorities and challenges differ in BESS sector across the value chain. In the following section, based on desk research and stakeholder surveys, BESS priorities and challenges of stakeholders distributed across different time horizon were analysed.

The skill gap analysis reveals a critical inflection point in BESS workforce development, with urgent technical skill gaps requiring immediate intervention, while building foundations for sustainable long-term growth across all sector categories. Training and skilling initiatives should focus on these priority job roles to begin with.

**Stakeholder-wise BESS Job Roles Identified across Time Horizon**

| | Academic | Financial | OEM | DISCOMs | C & I Consumers | ITI |
|---|---|---|---|---|---|---|
| Short Term | Enhanced practical training | Technical competency building | System design expertise<br>Grid integration capabilities | Technical capability building<br>Grid integration expertise | Technical capability building<br>Training programme access | Faculty upskilling<br>Enhanced practical training |
| | Skills and facility gaps | Limited BESS expertise | Shortage of trained personnel<br>Complex technical requirements | 61.5% lack trained staff<br>Complex interconnection | 28.6% not familiar with BESS<br>Limited availability (38.5%) | Skills and facility gaps |
| Short-Medium Term | | Risk assessment frameworks | Safety standardization | | Technical implementation | |
| | | Uncertain business models | Lack of standardized procedures | | External dependency (38.5%) | |
| Medium Term | Industry-academia collaboration | Institutional capacity<br>Regulatory alignment | Manufacturing scaling | Performance management<br>Regulatory compliance | Cost management | |
| | Limited industry partnerships | High training costs<br>Policy uncertainty | Supply chain constraints | Inconsistent monitoring systems<br>Evolving standards | High training costs (15.4%) | |
| Medium-Long Term | Advanced research infrastructure | | | | | |
| | Infrastructure constraints | | | | | |
| Long Term | Career pathway development | | | | | |
| | Unclear progression | | | | | |

● Priority ● Challenges

**FIGURE 7.14**: Specific priorities and challenges in the BESS sector by time horizon

# 8.

# CONCLUSION, RECOMMENDATIONS AND WAY FORWARD

## 8.1 Conclusion

In the BESS skill gap study, literature across the countries where BESS adoption is high, training courses and engineering institutes, syllabi were reviewed and stakeholders' survey across the value chain (Academic, Manufacturing/OEM, C&I, ITI, etc.) were conducted through questionnaire, FGDs and interviews. The overall process has resulted in the identification of skill gaps in the sector across the value chain.

**Academic sector:** BESS is generally not taught as a standalone subject in engineering curricula, resulting in conceptual gaps among engineers. Academic programmes offer inadequate training related to DC systems, battery balancing, and the design of cell-pack architectures, etc., resulting in major industry–academia disconnect.

A review of BESS training courses, syllabus and stakeholders survey revealed that many BESS training courses in India do not cover important topics such as project development and guidelines, risk management, O&M issues, peak load management, BESS policies, recycling, safety issues, system-level simulation, optimization-linked case studies, and digital twin frameworks and compliance with global standards like UL and NFPA.

Training demand is highest for hands-on laboratory work, cost modelling, safety practices, and system-level understanding, indicating major practical skill gaps. Students receive minimal exposure to multidisciplinary fields like real-world BESS commissioning, integration, and safety procedures, power electronics, digital systems, cybersecurity, and automation required in modern BESS. Testing, certification, and battery safety protocols, AI/ML-based BMS diagnostics, predictive maintenance, or cyber-secure BMS architecture are not covered adequately in curriculum, creating a foundational skill gap.

Absence of such modules has made many of the existing training courses below par and unattractive for BESS industry value chain. A need is therefore felt to develop and standardize BESS training curricula for stakeholders incorporating important topics along with integrated learnings based on project-based assignments to enhance trainees' industry readiness level (IRL).

In addition, the development of a robust domestic BESS ecosystem will require focused capacity building in battery manufacturing, prototyping, testing, and certification functions. The availability of pilot-scale manufacturing facilities, prototyping centres, and testing laboratories can support hands-on learning, technology validation, product development, and quality assurance while reducing the gap between academic research and industrial deployment. Strengthening these enabling infrastructures will be important for supporting domestic manufacturing ambitions, technology localization, and the development of a globally competitive battery ecosystem in India.

**DISCOMs:** Only one-third of surveyed DISCOM staff have BESS exposure. DISCOM professionals have limited expertise in PPA interpretation, regulatory compliance, techno-commercial aspects of BESS projects including system design, cable routing, grounding, and interconnection requirements and application in multi-voltage BESS operations. DISCOMs lack awareness of battery degradation patterns, safety protocols, and emergency response procedures for ESS. DISCOMs require structured operator training on ESS safety, EMS operations, grid integration and control room operations like SOC/SOH interpretation and cycling patterns.

**OEMs/C&I consumers:** The study noted that about 40–50% of C&I consumers are unaware of BESS applications beyond backup. High capital cost remains the main adoption barrier. C&I engineers lack trainings and expertise to be used for large industrial sites, which include safety systems, battery monitoring, and DC-side fault identification, BESS cybersecurity risks and digital tools used for predictive analytics.

The study also identified that more than 90% of high-quality battery packs/modules are imported, as domestic BMS units often fail due to low design maturity. Many small manufacturers lack quality control and standardized SOPs. OEMs report shortages of skilled manpower for battery safety systems, monitoring and control integration; commissioning and system design; including insufficient workforce for high-voltage and multi-voltage BESS applications. Also, inadequate expertise was noted in cybersecurity for BESS communication and monitoring networks, simulations, techno-commercial optimization, PPA interpretation and designing of climate-specific systems.

**Financial institutions:** Majority of the financial organizations have limited understanding of BESS-specific business models, standardized approach for valuing ESS assets such as warranties, degradation, and safety standards needed for due diligence, resulting in hesitation to finance storage projects. Further to this, because of unclear revenue streams and uncertain cashflows, financing of BESS projects is largely viewed as risky.

**ITIs/polytechnics:** Many ITIs and polytechnics offer basic modules on renewable energy, electrical safety, and power systems. Basic curriculum does not include BESS, DC safety, cell-pack configuration, testing, safety, battery-specific skills or EMS/BMS basics. Also, ITIs and polytechnics lack BESS-specific laboratory infrastructure such as battery cyclers, thermal chambers, and availability of digital tools (e.g., simulators and animated learning modules) to support real-time modelling, diagnosis and experiential learning. Moreover, the ITI and polytechnic instructors lack exposure to modern storage technologies and high-voltage battery systems. Faculty require extensive upskilling, as most come from traditional electrical backgrounds with limited exposure to battery storage technologies. Also, strong need was felt for extensive upskilling of ITI faculty and industry-institute collaboration, linkages for internship, on-the-job training (OJT), etc., to align the curriculum with technicians.

Based on the skill gap analysis, 29 BESS sector job roles were identified and distributed under 15 categories aligning with the job demand noted in the job assessment chapter. Below are some recommendations pertaining to these job roles:

a. Prioritize job roles for which trainings need to be carried out

b. Recommendations & time-bound steps for BESS sector development

c. Policy perspective for BESS training

## 8.2 Key Priority Job Roles in the BESS Sector

This section focuses on identification of priority job roles derived from the comprehensive skill gap and demand analysis conducted across the value chain (stakeholders). The objective is to guide and prioritize key job roles necessary for growth of BESS sector from the perspective of skilling requirements.

### 8.2.1 Methodology

In the previous section, critical skill gaps across the BESS value chain were identified. The desk study as well as stakeholders have identified demands for specific job roles in the sector. Through this skill gap analysis, requirement of 29 job roles in BESS sector was noticed. These job roles have been categorized into critical, high, and medium level based on the extent of skilling required.

As first step, mapping of existing job roles across the BESS industry value chain was carried out with the required job roles identified in the skill gap analysis. The merged and industry aligned sectors are design and R&D, manufacturing & production, quality assurance & compliance, installation & commissioning, operations & maintenance and cross-cutting sectors.

The deployment of BESS generates a diverse and sustained employment ecosystem that spans across the entire supply chain while consistently drawing upon similar skill profiles across key stakeholder groups—academic, financial, OEMs, DISCOMs, C&I consumers, and ITI institutions.

- In the initial design and R&D phase, roles such as material scientists, researchers, system sizing & design engineers, and power electronics engineers (typically requiring L7+ to L10+ experience) mirror the R&D-focused academic and OEM profiles while also engaging highly experienced financial modelling specialists for techno-economic analysis in specific cases.
- As the value chain progresses to manufacturing & production, process engineers, process managers, and power electronics engineers remain critical, aligning closely with OEM technical teams and ITI-trained technicians moving into medium-senior roles.
- Quality assurance and compliance stages heavily rely on safety & compliance officers job role that directly correspond to the safety, regulatory, and grid-integration expertise originally developed within DISCOMs/ independent consultants and regulatory-focused academic research groups.
- During installation and commissioning, project managers, procurement specialists, system sizing & design engineers and BESS engineers (L5+ to L7+ experience) take the centre-stage, reflecting project execution capabilities built within C&I consumers, DISCOMs, and OEM/EPC field teams.
- In the longest-lasting O&M phase, grid integration specialists, grid integration engineers, executive/ technician-level O&M personnel, and management-level oversight roles ensure system longevity and performance, predominantly filled by experienced professionals originally categorized under DISCOMs, C&I consumers, and ITI-trained and technicians transitioning into supervisory positions.
- Finally, cross-cutting roles such as principal consultants, financial modelling specialists, instructors, and supervisors provide strategic, economic, and knowledge-transfer support throughout the lifecycle, demonstrating that the core competencies and job profiles identified across original stakeholder categories remain relevant and simply migrate or elevate in responsibility as projects move from concept to decommissioning and end-of-life management. This continuity underscores the strategic importance of building deep talent pools in these recurring roles to support the rapid and sustainable scaling of the BESS industry.

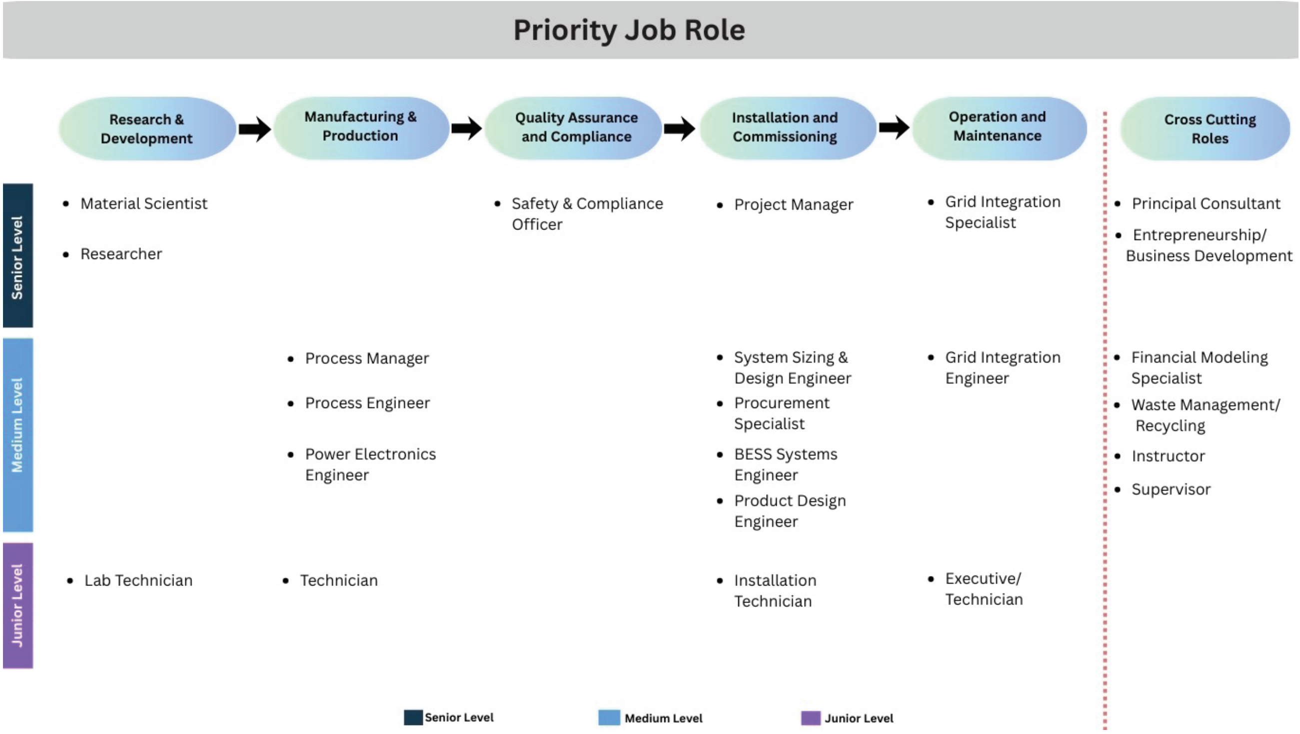
Key priority job roles have been identified from the consolidated job roles identified as part of the BESS skill gap analysis, based on the following criteria:

- Current availability of skilled professionals in each job role.
- The pool of expertise and experience available in industry and academia was considered.
- Evaluation of the impact and significance of job role in the overall operational efficiency and growth prospect of the BESS sector.
- Job roles which are likely to be in high demand in the short term and are critical for BESS sector growth.

### 8.2.2 Priority job roles in the BESS sector

Based on the above-mentioned criteria, following job roles have been identified as priority across the value chain (Figure 8.1) as identified in the skill gap analysis study. The priority job roles have been categorized in 5 value chain categories namely R&D, manufacturing & production, quality assurance & compliance, installation & commissioning and operation & maintenance as per their sectoral demand in terms of experience, ranging from junior to senior level. Some of the priority job roles are cross-cutting in nature, and they have been treated separately. Training curricula development is recommended to address demand of these priority job roles.

Further to this, deep electrochemistry knowledge, BMS hardware and embedded software mastery, thermal management simulation, compliance with UN38.3/IEC/UL standards, and hands-on familiarity with coating–calendaring–formation processes are some important themes which are in high demand. Moreover, pairing of cross-functional demands including IATF 16949 expertise, data analytics for predictive maintenance, and sustainability metrics for second-life applications. In this context, key insights from the survey of the employment portals are as follows:



| | Research & Development | Manufacturing & Production | Quality Assurance and Compliance | Installation and Commissioning | Operation and Maintenance | Cross Cutting Roles |
|---|---|---|---|---|---|---|
| Senior Level | Material Scientist<br>Researcher | | Safety & Compliance Officer | Project Manager | Grid Integration Specialist | Principal Consultant<br>Entrepreneurship/ Business Development |
| Medium Level | | Process Manager<br>Process Engineer<br>Power Electronics Engineer | | System Sizing & Design Engineer<br>Procurement Specialist<br>BESS Systems Engineer<br>Product Design Engineer | Grid Integration Engineer | Financial Modeling Specialist<br>Waste Management/ Recycling<br>Instructor<br>Supervisor |
| Junior Level | Lab Technician | Technician | | Installation Technician | Executive/ Technician | |

**FIGURE 8.1**: Priority job roles in the BESS sector by experience level

1. BMS engineers and ESS engineers are the most high-demand roles.
2. Manufacturing engineers are in strong demand due to India's gigafactory build-out.
3. Recycling and second-life applications are emerging as a niche but fast-growing segment.
4. Demand is balanced across the value chain—from R&D to after-sales service—indicating a maturing industry ecosystem.

As the sector grows, several professional roles—such as battery technicians, BMS engineers, EMS programmers, safety officers, recycling engineers, and grid-integration specialists—are rapidly emerging and can be developed upon the current expertise already present in the workforce. At the same time, new job opportunities are expected to expand across the BESS value chain, covering cell manufacturing, module and pack assembly, testing, transport logistics, installation and commissioning, predictive maintenance, and end-of-life management. By leveraging existing skills, the system can benefit from reduced training time and cost, while targeted skill creation ensures the development of a resilient and future-ready BESS workforce.

## 8.3 Strategic Recommendations for Workforce Development

The strategy outlined measures required to address the surging demand for skilled professionals across the value chain in the BESS sector. Critical insights observed in the skill gap analysis also suggested a few actions on priority. Some of the specific issues are recommended in the order of priority ranging from immediate attention to long-term strategy.

### *Immediate actions (0–6 months)*

1. Implement a phased roadmap with immediate awareness & short-term technical training course programmes
2. Establish critical role pipelines focusing on BESS value chain across all stakeholder categories.
3. Basic understanding of BESS through short awareness courses (1–2 days) are must for financial institutions, C&I consumers and at the ITI/polytechnic level.
4. Create emergency training programmes for the DISCOMs who are lacking trained staff.
5. Strengthening faculty capacity through nationwide upskilling programmes focused on BESS technologies, high-voltage safety, battery management systems, and grid applications. Training of ITI/polytechnic faculty members is necessary to meet immediate demand for training instructors on battery energy storage and technician requirements, respectively in the sector.
6. Introduce mandatory BESS certification for installers, designers, and technicians to ensure safety, quality, and industry-standard practices. Update outdated training materials and re-train trainers to ensure relevance to current conditions.
7. Integrate BESS skilling into existing government schemes, such as RDSS, PMSGMBY to strengthen DISCOMs/and other organizational capabilities in grid planning, operation, and energy storage integration.

### *Short-term strategy (6–12 months)*

1. Ensure inclusive workforce development by promoting women's participation, creating safe training environments, and expanding training access to rural and industrial regions.
2. Development of high-quality training programmes in ITI/polytechnic with a focus on hands-on practice and internship is the need of the hour. In this context, short-term skilling programmes on specific areas such as BESS site assessment, designing, planning, BMS, EMS, installation, testing & commissioning, O&M, testing, diagnosis & repairing, safety, recycling of different NSQF level are highly recommended.

3. Build standardized national BESS curricula through collaboration among the Ministry of Power, MNRE, AICTE, UGC, and NCVET to address training fragmentation and quality training content tailored to manufacturing, installation & commissioning, O&M and financial sectors.
4. Training tools and e-learning platforms for BESS sector trainees may be planned and developed in consultation with academic, OEM and C&I sectors.

### *Medium-term strategy (12–18 months)*

1. Modernize academic curricula to cover contemporary battery technologies.
2. Create standardized competency frameworks addressing the lack of uniform procedures.
3. Establish degree programmes in energy storage at university level.
4. Promote industry–academia partnerships by establishing regional "learning factories" to bridge practical experience gap.
5. Integrate manufacturers/OEMs in national skilling efforts for BESS and leverage their support in equipment, training kits, trainers, and structuring learning contents.
6. Accelerate enabling policies and investment frameworks immediately to convert the highly sensitive, services-led job multiplier into reality from 2027 onwards. India's battery storage opportunity is overwhelmingly services-driven; align education, industry, and policy accordingly for maximum employment impact.
7. Upgrade training infrastructure in ITIs and polytechnics through dedicated funding for specialized equipment such as battery cyclers, thermal chambers, and testing laboratories.

### *Long-term vision (18+ months)*

1. Develop BESS Centres of Excellence (CoE) for advanced R&D and specialized skills development in key industrial clusters.
2. Develop high-quality training curricula and contents for all stakeholders in BESS value chain.
3. Create national talent pipeline with the government and industry support.
4. ITIs/polytechnics require BESS-specific laboratory infrastructure such as battery cyclers, thermal chambers, or diagnostic tools needed for modern battery training. Financial provision for setting up BESS specific practical labs in selected ITI or polytechnic is recommended.
5. Insufficient number of accredited labs for large-format BESS testing delaying projects. Boosting up the number of advanced testing labs for EMS/BMS testing, testing of second-life batteries and recycling processes at reasonable testing cost is recommended.
6. Once developed, literature should be reviewed and updated annually to prevent obsolescence and the emergence of new gaps.
7. Integrate a free, standardized model for BESS financial and technical calculations.
8. Safety protocols evolve rapidly and must be updated on a regular, defined cycle.
9. For long-term impact, systematic training should be provided to academic trainers.
10. Academic research is often misaligned with current industry needs; research requirements should be industry-driven, time-bound, and focused on implementation.

## 8.4 BESS Skilling Policy Prospects

The Ministry of Power (MoP) and the Ministry of New and Renewable Energy (MNRE) are promoting energy storage frameworks and skill development initiatives in India. The MoP released a framework promoting indigenous manufacturing, R&D, quality, and sustainability in BESS. Further to this, draft amendments mandate fire safety audits and training for fire officials for BESS, with guidelines from the Directorate General of Fire Safety (DGFS). A policy setting targets for energy storage integration with renewables (e.g., 1% in 2023–24 rising to 4% by 2029–30) creates demand for trained professionals.

Moreover, recent policy directives from MoP of using 20% local content for VGF-funded BESS projects builds on prior rules requiring an indigenous energy management system for BESS projects will encourage local manufacturing. However, this requires enhanced number of skilled industry-ready manpower to take up the benefits as envisaged by the government.

In view of the evolving power system characterized by higher renewable energy penetration, peak demand variability, and the need for grid flexibility, targeted policy interventions are essential. MoP's flagship schemes such as the Revamped Distribution Sector Scheme (RDSS) may incorporate energy storage as a focused area for capacity building support. This would facilitate enhancement of institutional capabilities within DISCOMs in areas such as system planning, techno economic evaluation, procurement frameworks, and operational deployment of energy storage solutions. Mainstreaming energy storage within RDSS capacity building components would strengthen DISCOM preparedness for future distribution network requirements and support the broader national objectives of reliable, resilient, and sustainable power systems.

These policies aim to create jobs in R&D, manufacturing, O&M, and grid integration. Adequate technical expertise to be boosted through training covering BESS design (sizing, configuration), system analysis, grid integration, and operational maintenance.

Through the skill gap analysis, two major bottlenecks were identified in the present skilling ecosystem which are inadequacy of infrastructure and unavailability of standard BESS curricula at the national level.

Most BESS trainees receive limited hands-on exposure to real-world BESS commissioning, integration, and safety procedures while undergoing training. While immediate lab-facility development research laboratories within academic institutions can be upgraded to act as regional BESS testbeds for hands-on training.

Across the value chain, stakeholders felt that the lack of infrastructure and facilities, unavailability of high-quality training courses, high costs and financial constraints are major deterrents for BESS adoption. In this context, jointly designed certification programmes between academia and industry can enhance employability and bridge the skills gap. Based on the skill gap findings, high quality, standard BESS curriculum is to be followed across academic bodies and training institutes for quick BESS adoption. Structured, open access certification courses on BESS may be offered through NPTEL, Swayam and other e-learning platforms for interested mid-career professionals across the BESS value chain supported by innovative training tools. Such courses would enable existing staff to upskill, obtain certification, and build relevant competencies. This would create a win–win situation—employees gain new skills and career mobility, employers reduce training costs, and engineering graduates can obtain certification and begin their careers in the BESS sector.

The content of the curriculum may vary as per the requirement of the trainees at different levels covering important topics as mentioned earlier in the report, training duration and the mode of training. Hence, urgent need was felt to develop national level curricula for BESS trainings through multi-stakeholder collaborations

(MoP, MNRE, NPTI, sector skill council, etc., and other relevant government entities), and approved by the competent authorities–(a) AICTE for engineering institutes, IITs; (b) UGC for universities; and (c) NCVET (National Council for Vocational Education and Training). The industry aligned trainings can be conducted by various training institutes.

In order to cater to diverse stakeholders, different duration of standard skilling programmes may be introduced at engineering institutions and at vocational level training institutes, such as

1. One-day training curricula/workshop for senior officials of DISCOMs, C&I, financial institutions/auditors, etc., primarily to orient them regarding the value of BESS adoption and benefits thereof along with the revenue models where necessary.
2. 3–5 days theory/lab-based training curricula for O&M officials in DISCOMs to provide technical support to mid-career professionals for upskilling in the new areas to facilitate BESS adoption in industries and DISCOMs.
3. 30 days training curricula for ITI/polytechnic students with on-the-job training as it will facilitate regular flow of trained technicians in BESS projects implementation.
4. 6 months course at engineering institutions to ensure formal education of engineers to ensure R&D, designing BESS projects, quality assurance, system design, grid integration while carrying out BESS implementation.

All these curricula should be developed through multi-stakeholder consultation focusing on the industry's need in a standardized way and should be adequately supported with relevant content and learning facilities. Hybrid courses may also be introduced to attract participation of mid-career industry professionals. More women participation may be encouraged in BESS courses to bring gender equality to the sector.

While setting up facilities in the existing training institutes is encouraged, OEMs may be roped in initially as their domain knowledge can support national skilling efforts by providing equipment, trainers, and structured learning content.

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# ANNEXURE

## Annexure 1: Assumptions in the Job Estimation Methodology

| Assumptions | | |
|---|---|---|
| **Description** | **Value** | **Unit** |
| BESS Installed Capacity | | |
| BESS Installed Capacity in 2025 | 1 | GWh |
| BESS Installed Capacity in 2030 (Base) | 181 | GWh |
| BESS Installed Capacity in 2030 (Optimistic) | 208 | GWh |
| BESS Installed Capacity in 2030 (Pessimistic) | 160 | GWh |
| Installed Capacity Addition YoY (Base) | 36 | GWh |
| Installed Capacity Addition YoY (Optimistic) | 42 | GWh |
| Installed Capacity Addition YoY (Pessimistic) | 32 | GWh |
| **BESS Manufacturing** | | |
| Localized Manufacturing in 2025 | 0 | GWh |
| Localized Manufacturing in 2030 (Base) | 130 | GWh |
| Localized Manufacturing in 2030 (Optimistic) | 150 | GWh |
| Localized Manufacturing in 2030 (Pessimistic) | 115 | GWh |
| Localized Manufacturing Addition YoY (Base) | 26 | GWh |
| Localized Manufacturing Addition YoY (Optimistic) | 30 | GWh |
| Localized Manufacturing Addition YoY (Pessimistic) | 23 | GWh |
| **Jobs Generated** | | |
| Manufacturing | 50 | jobs per GWh |
| Installation and Commissioning | 400 | jobs per GWh |
| Operations and Maintenance | 150 | jobs per GWh |
| Indirect Jobs | 40 | jobs per GWh |
| **Life Cycle of Jobs** | | |
| Manufacturing | 20 | years |
| Installation and Commissioning | 2 | years |
| Operations and Maintenance | 15 | years |
| Indirect Jobs | 10 | years |

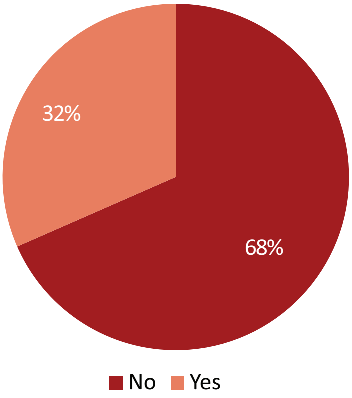
# Annexure 2: Stakeholder Insights based on Survey Questionnaire Data

As part of the initiative to assess the readiness, capacity, and challenges associated with Battery Energy Storage Systems (BESS) in India, an extensive online survey was conducted covering a diverse set of stakeholder groups. The survey received responses from over 150 organizations, including academic and research institutions, IITs, engineering colleges, technical training institutes (ITIs), renewable energy companies, industrial enterprises, consultancy organizations, and electricity distribution companies (DISCOMs).

## Distribution Companies (DISCOMs)

### i. Overview of Past Experience with ESS

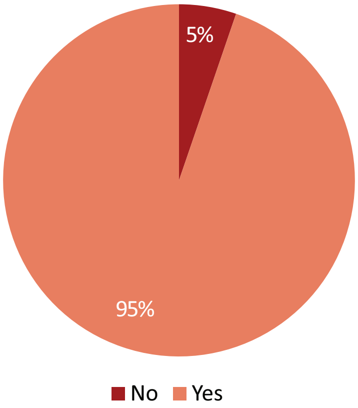
An assessment of 38 DISCOM responses shows that only 32% have previously worked on energy storage–related projects, while a significantly larger proportion—68% respondents reported having no prior experience with ESS. Among those with experience, most engagements were linked to large-scale utility BESS projects, supplemented by limited participation in pilot projects, renewable energy–BESS hybrid systems, and a few instances of standalone BESS or PSP-based solutions.



### ii. DISCOM Awareness, Familiarity, and Readiness for BESS

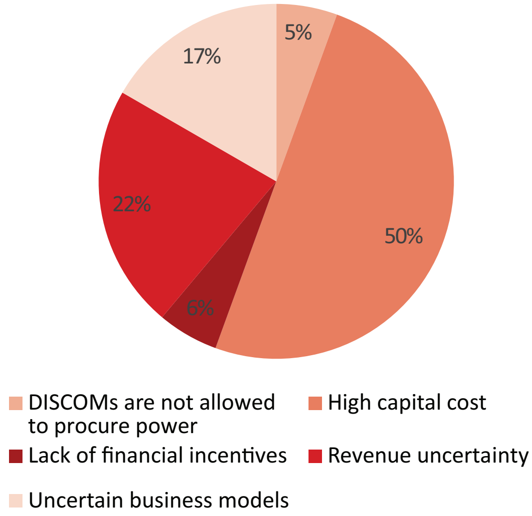
### a. Awareness of BESS and Its Applications

The survey results show that the awareness of BESS among DISCOMs is extremely high. Over 95% of respondents reported being aware of BESS and its applications, indicating that storage is well-recognized across the distribution sector. Only a single respondent indicated unfamiliarity, suggesting that the conceptual understanding of BESS has already achieved broad penetration, even though practical exposure varies.



### b Familiarity with BESS Technology

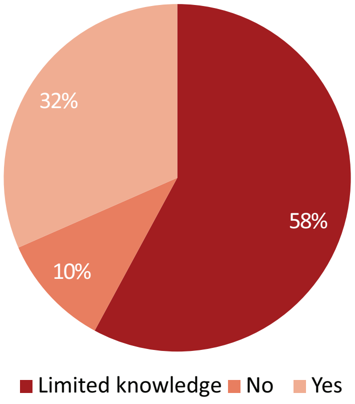
Despite near-universal awareness, the depth of familiarity with BESS technology differs across utilities. Approximately 26% of respondents from DISCOMs reported expert-level familiarity, reflecting strong internal technical capacity in some DISCOMs, particularly among those already engaged in pilot or large-scale storage projects. A majority of respondents (around 50%) indicated a moderate understanding, showing good foundational knowledge but limited hands-on experience. Another 26% described their familiarity as basic, and around 3% reported being unfamiliar with BESS technology. This distribution highlights the need for targeted technical capacity-building to strengthen operational-level competencies.

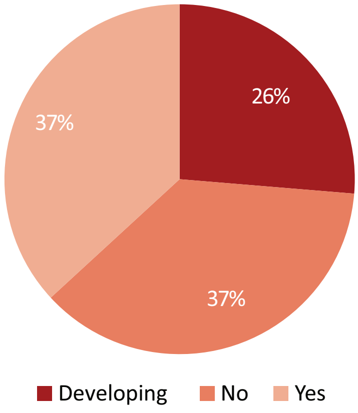


## iii. DISCOM Technical Capacity, Challenges, and Preparedness for BESS

### a Technical Expertise in BESS System Design, Sizing, and Grid Integration

The survey shows that a majority of DISCOMs currently lack strong technical expertise related to BESS. Approximately 58% of respondents indicated that their organizations have limited knowledge in system design, sizing methodology, or grid integration of storage solutions, with 10% respondents having indicated no technical expertise, while only 32% reported having adequate technical capabilities in these areas. This distribution highlights that although BESS is gaining strategic importance across the power sector, most DISCOMs are still at an early stage of technical preparedness and require extensive capacity strengthening to independently plan or execute BESS projects.





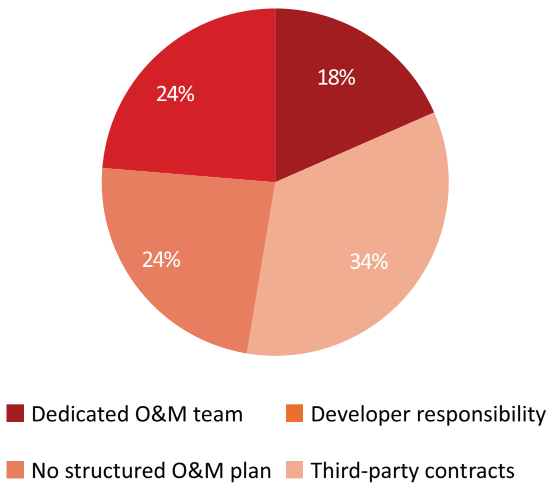
The survey responses reveal that DISCOMs face multiple capacity gaps across the entire lifecycle of a BESS project. About 70% respondents identified system sizing and optimization as a significant challenge, indicating uncertainties in designing storage systems suited for specific load profiles and operational requirements. Around 55% mentioned that managing charge and discharge cycles is difficult, while roughly 60% expressed challenges related to grid integration, particularly in understanding interconnection requirements and performance under varying grid conditions. Additionally, 50% respondents also highlighted complexities associated with frequency and voltage impacts, and a similar percentage found safety protocols, O&M planning, and performance guarantee assurance challenging.

Standard operating procedures (SOPs) for BESS remain underdeveloped in many DISCOMs. Only 63% of respondents stated that they have either established or are in the process of developing SOPs for BESS integration. Meanwhile, 37% reported having no SOPs in place, which indicates a lack of formalized process for safety, commissioning, operating, and maintenance of storage assets.

### iv. Operation, Maintenance and Safety

### a O&M, Safety, Monitoring, and Disposal Practices for BESS

DISCOMs currently follow a mixed approach for the operations and maintenance (O&M) of BESS projects, with significant dependence on external agencies. About 34% of respondents rely on developer responsibility for O&M, while another 24% depend on third-party contracts. Only 18% of DISCOMs have their own dedicated O&M teams, showing limited internal capability for long-term asset management. Additionally, 24% reported having no structured O&M plan at all, indicating operational gaps and insufficient preparedness for managing BESS installations. Overall, the responses suggest that most DISCOMs have not yet built in-house expertise for BESS O&M.



### b Key Barriers in Planning BESS Disposal and Recycling

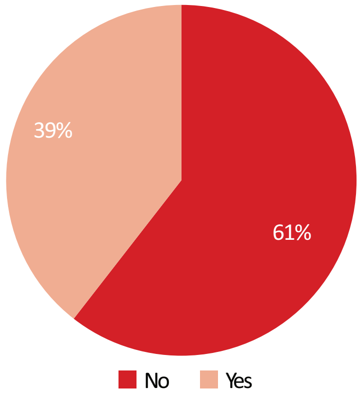
Among respondents lacking disposal strategies, the most frequently cited barrier was lack of clear recycling policies, mentioned by about 50% of DISCOMs. Another 35% pointed to limited recycling infrastructure, particularly the absence of certified recyclers and logistical challenges related to safe battery transport. The remaining 15% highlighted general regulatory uncertainty or internal institutional gaps. The results clearly show that the policy and infrastructure ecosystem for BESS end-of-life management is still underdeveloped, directly affecting DISCOM preparedness.

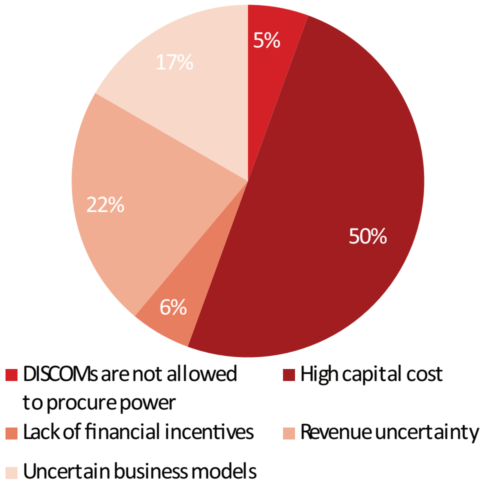
## v. Financial and Regulatory Considerations for BESS

### a Funding and Financial Barriers

The survey reveals that a majority of DISCOMs—around 61%—have not received any funding or subsidies for BESS projects whereas about 39% of DISCOMs reported having received some form of funding or subsidy, indicating limited access to financial support mechanisms.

Among those without financial support, the most frequently reported challenge is high capital costs, cited by about 53% of respondents. Additional financial hurdles include revenue uncertainty affecting roughly 23% of DISCOMs; lack of financial incentives; and DISCOMs are not allowed to procure power, mentioned by about 6%. Approximately 12% highlighted uncertain business models as a deterrent to moving forward with BESS deployment.





### b Awareness of Regulatory Frameworks

Approximately 55% DISCOMs stated that they are aware of the regulatory framework for BESS implementation. Conversely, about 45% lack such awareness, implying a significant information gap within the sector. This lack of clarity on regulations may be contributing to slow progress in evaluating or adopting energy storage projects at the distribution level.

### c Regulatory Challenges

DISCOMs reported a wide spectrum of regulatory hurdles that complicate BESS implementation. The most prominent among these is the issue of market mechanisms for BESS utilization, cited by 45% respondents. Another major concern is the tariff structure, mentioned by about 21% respondents, which indicates uncertainty regarding cost recovery and revenue models. Licensing and approvals emerged as a challenge for nearly 34% of DISCOMs, reflecting procedural complexities and unclear compliance pathways.

### c Experience with Structuring PPAs and ESSAs

The survey responses indicated that only about 39% of DISCOMs have experience in structuring Power Purchase Agreements (PPAs) or Energy Storage Service Agreements (ESSAs) for BESS projects. The remaining 61% lacked such experience, which highlights a critical capacity gap in contractual and commercial aspects of energy storage deployment. DISCOMs that have tested procurement arrangements appear better positioned to evaluate BESS feasibility, while those without experience may require targeted institutional capacity-building.

### vi. Training Needs and Capacity Building for BESS

#### a Current Status of BESS Training among DISCOM Staff

Survey results indicate that a majority of DISCOM respondents (around 53%) have not received any formal training on BESS. Only a limited number of staff from a few DISCOMs (primarily BSES Rajdhani, BSES Yamuna, and Kerala State Electricity Board) reported exposure to BESS-related programmes. The widespread absence of structured training highlights a significant capability gap across distribution utilities, with most personnel lacking familiarity with emerging storage technologies, system integration challenges, and operational practices.

#### b Key Barriers to Capacity Development

Among DISCOMs without prior training, several systemic challenges were consistently identified. Lack of available training programmes emerged as the most common barrier, reported by nearly 80% of untrained respondents. This was followed by high cost of training and limited institutional support, each affecting 50–60% of respondents. Time constraints were also cited by around 40% of utilities, particularly those with limited manpower and high operational responsibilities. Together, these barriers reflected structural limitations in both training supply and organizational readiness.

#### c Preferred Mode, Duration, and Types of Training

Most respondents, approximately 57%, expressed preference for residential training which they believed offers better engagement and focused learning. Another 43% showed preference for non-residential or hybrid (theory+practical) formats, favouring flexibility and the ability to combine conceptual learning with practical exposure. A smaller share, roughly 10%, indicated preference for long-term programmes (upto 30 days), particularly for deeper technical modules such as system design and financial modelling.

In terms of training delivery, in-person workshops and blended learning (online+in-person) were the most preferred formats, chosen by 37% and 24% of respondents, respectively. Very few opted for fully online courses, indicating a clear preference for interactive, practice-oriented learning.

#### d Gender Representation in the BESS Workforce

The survey also captured gender distribution within energy storage divisions. 18% DISCOMs reported female representation below 10%, while 29% respondents indicated 10–25% female representation whereas 10% respondents indicated 26% to 50% female workforce in their offices. Only a few respondents cited female ratios above 50%. Despite this, nearly all DISCOMs indicated willingness to nominate female staff for training, with most estimating 1 to 5 or 6 to 10 female participants, and a smaller number indicating above 10 participants. This suggests scope for targeted gender-focused inclusion measures in capacity-building initiatives.

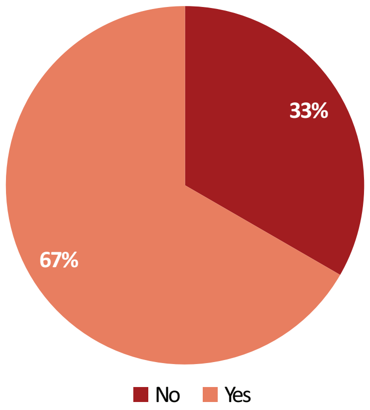
Overall, the analysis highlights a substantial and urgent need for systematic BESS capacity building across Indian DISCOMs. While awareness and interest are high, formal training exposure remains limited. DISCOMs strongly favour structured, practical, and techno-financial training delivered through residential or hybrid formats.

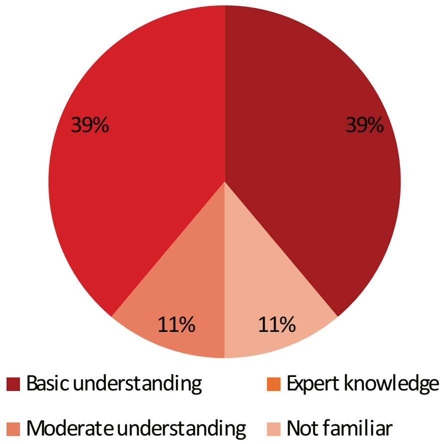
## C&I and Industry Associations

### i. Awareness & Interest of BESS

Awareness of BESS is relatively strong, with 67% of C&I respondents stating that they are aware of BESS and its applications. However, depth of knowledge remains limited. Only 11% report expert-level understanding, and about 39% possess only basic familiarity, while 11% have moderate technical awareness. Notably, 39% of organizations have no familiarity at all.

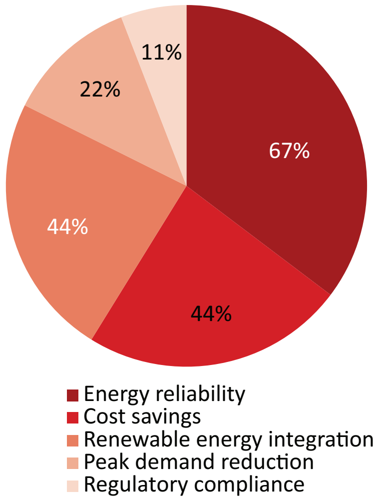
This pattern is typical of the C&I sector, where energy management is often outsourced or deprioritized unless it directly affects production uptime or regulatory compliance. The limited familiarity suggests that many organizations still view BESS as a specialized technology requiring external expertise.





The sector continues to demonstrate high dependence on diesel generators (DGs). Approximately 75% of respondents use generators during power outages, confirming that DGs remain the default backup solution for business continuity. Only 25% do not rely on generators, usually due to internal power plants, robust captive systems, or limited operational sensitivity to outages.

C&I consumers are primarily motivated by operational and economic benefits when considering BESS adoption:



- 67% cited energy reliability as their main driver, reflecting concerns over grid instability affecting production processes, IT systems, or service continuity.
- 44% pointed cost savings, driven by high peak tariff charges, diesel expenditure, and operational inefficiencies.

- 44% highlighted renewable energy integration, especially industries investing in rooftop solar but constrained by intermittency.
- 22% identified peak demand reduction, often influenced by high demand charges and the need for better load management.
- 11% cited regulatory compliance, mainly industries operating under renewable purchase obligations (RPOs) or sustainability mandates.

These responses confirmed that C&I organizations are primarily interested in the operational resilience and cost-efficiency benefits of storage, rather than participating in grid services—common in more advanced markets.

Around 78% of organizations have previously evaluated or implemented BESS, while 22% have not explored it formally. This shows growing interest but also significant gaps in structured assessment.

Among those with prior experience:

- 79% used BESS for backup power, indicating that reliability remains the number one business requirement.
- 21–29% used it for load shifting, peak shaving, and renewable energy integration, demonstrating early awareness of economic optimization opportunities.
- 21% explored frequency regulation, though this remains a niche use case in the C&I landscape due to unclear market mechanisms.

**ii. Technical Capabilities and Readiness:**

- The survey shows that 89% of organizations have an established energy management team, indicating a relatively strong institutional base to adopt advanced energy solutions.
- However, despite high internal energy management capacity, only 44% of organizations have conducted a BESS feasibility study, demonstrating that more than half of the organizations are still at a preliminary stage of evaluating energy storage solutions.
- Lithium-ion batteries emerged as the most familiar technology, with 67% of organizations reporting awareness. Lead-acid batteries were familiar to 28% organizations, while Sodium-ion technology was known to 22% organizations. Only 11% organizations had exposure to flow batteries, indicating limited industry-wide understanding of alternatives or emerging chemistries.
- Only 39% organizations reported having full internal expertise in BESS system design, sizing, and grid integration. A larger proportion—33% organizations—reported limited knowledge, while 22% organizations reported no expertise at all.
- When asked about expected technical challenges, the organizations collectively identified multiple recurring problem areas:
  - » System sizing and optimization – highlighted by 44% of organizations
  - » Charge and discharge cycle management – cited by 33%
  - » Power electronics and control systems – reported by 50%
  - » Safety protocols and hazard management – cited by 22%
  - » Performance guarantees and reliability concerns – mentioned by 39%

These quantified responses show that the technical challenges cut across all stages of BESS evaluation—design, implementation, operation, and long-term performance.

- Only 33% of organizations reported having staff trained in energy storage technology.
  - Among organizations without trained staff:
  - 39% planned to train existing staff
  - 17% planned to rely on external consultants
  - 16% planned to hire new staff
  - 28% had not decided at the time

### iii. Financial Readiness, Challenges, and Regulatory Barriers for BESS Implementation

- 44% organizations have explored financing options for BESS. 56% organizations have not yet undertaken any form of financial evaluation or structured funding assessment for BESS projects. This highlights an overall lack of clarity, preparedness, and confidence in the financial viability of storage technologies.
- 72% organizations expressed the need for financial or technical assistance to implement BESS. This widespread requirement demonstrates significant dependency on external support during early deployments. Furthermore, it also shows that organizations understand the complexity of BESS projects and need structured guidance for implementation.
- Based on the survey responses, 33% of the respondents highlighted licensing and approval requirements as the most significant regulatory barrier to implementing BESS, while 22% pointed to the absence of clear market mechanisms for storage utilization as a key challenge limiting revenue generation and commercial viability. Additionally, 17% organizations reported a lack of standard guidelines for BESS procurement, performance, and safety compliance, and 5% raised concerns regarding an unclear tariff structure for grid-connected storage operations. The remaining 17% provided incomplete or ambiguous inputs, indicating an overall low level of regulatory awareness within the sector.

### iv. Training Needs and Capacity Gaps for BESS Implementation

The survey responses indicated a significant training deficit across organizations, with 67% reporting that neither they nor their staff have received any formal training on BESS. The primary barriers to accessing training included a lack of available training programmes (46%), time constraints (23%), high training costs (23%), and limited institutional support (15%). Despite these constraints, 82% of the total respondents indicated that technical training would enhance their ability to implement BESS projects, demonstrating a strong willingness to build capacity.

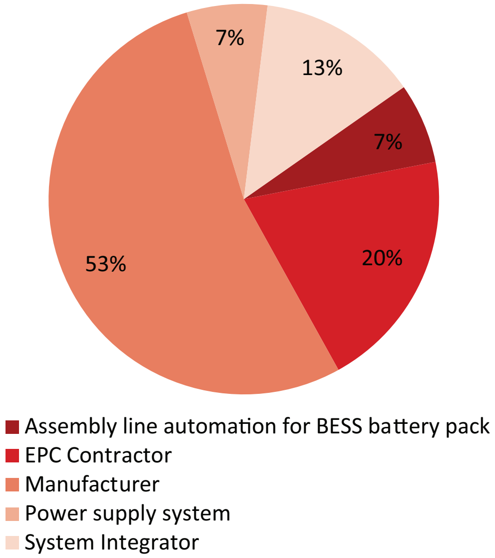
Regarding training preferences, 60% of the respondents expressed a preference for residential training, while 40% preferred non-residential formats. When it comes to the types of training, long-term (upto 30 days) and short-term (upto 7 days) were highlighted by 27% and 13% of organizations, respectively and 1-day workshops were preferred by approximately 20% of the respondents, reflecting the need for rapid skill enhancement among operational teams.

When asked about the specific training content required, the survey shows broad interest across a range of technical and managerial subjects. The most requested topics were BESS sizing and design (60%), O&M best practices (67%), feasibility assessment (53%), procurement and contract management (47%), and financial modelling (47%). Safety and end-of-life disposal were also significant concerns, with 40% of organizations indicating a need for training in these areas. Regulatory compliance emerged as an additional priority, requested by 40% of respondents, indicating gaps in understanding national standards, safety codes, and applicable CEA/CEA-grid guidelines.

## OEMs, System Integrators and Installers

### i. Experience and Expertise in BESS

The survey reveals a diverse representation of organizations involved in the BESS value chain, with manufacturers forming the largest group at 53% organizations, followed by EPC contractors at 20%, system integrators at 13%, and a smaller share comprising companies involved in specialized services such as assembly-line automation and power supply systems.



In terms of solution offerings, majority of respondents are engaged in utility-scale BESS, with 47% reporting specialization in large-scale storage deployments. This indicates strong industry maturity in grid-scale and utility-level storage applications. Meanwhile, 27% respondents work on C&I BESS, 13% on residential BESS, and 20% on microgrids, demonstrating an emerging but growing market focus on decentralized storage solutions. Hybrid renewable energy plus storage capability is also notable, with 13% offering hybrid RE+BESS solutions—highlighting increasing integration of storage with solar and wind projects for reliable power supply and flexibility services.

Battery chemistry analysis shows an overwhelming dominance of lithium-ion technology, used by 87% of surveyed organizations. This reinforces Li-ion's position as the current market standard for both utility-scale and behind-the-meter applications. However, there is also emerging diversity in chemistries—Sodium-ion batteries are used by 20%, indicating early industrial uptake of next-generation alternatives. Flow batteries are being deployed by only one manufacturer (7%), showing limited but growing interest in long-duration storage technologies.

### ii. Technical Capability and Implementation of BESS

Survey responses showed that a significant proportion of organizations involved in the BESS value chain are actively engaged in full-cycle project delivery. Approximately 80% respondents provide end-to-end BESS solutions including design, integration, installation, commissioning, and O&M. Another 7% provide partial services, while 13% do not offer complete turnkey solutions—highlighting that while the ecosystem is maturing, not all companies possess complete vertical capabilities.

### a In-house Technical Expertise

Organizations exhibiting diverse in-house technical strengths:

- 40% had grid integration expertise, a critical skill for utility-scale deployment.
- 20% reported expertise in BMS development (battery management systems), indicating growing domestic capability in this high-value subsystem.
- 13% reported expertise in BESS system design.
- 7% possessed in-house power electronics, thermal storage expertise and battery-cell technology development, showing early-stage progress in cell manufacturing innovation.

These capabilities collectively reflect an ecosystem that is strongest in integration, BMS, and power electronics—but still limited in upstream capabilities such as cell manufacturing and testing automation.

### b Technical Expertise Required for Better BESS Execution

Despite internal strengths, organizations identified several areas where additional technical capacity is needed:

- System sizing and design, power electronics and control systems and performance optimization were needed by 47% respondents, demonstrating a gap in high-tech engineering skills.
- Grid integration expertise was needed by 33%, even though many already possess partial capability—indicating the complexity of India's grid-interconnection requirements.
- Safety and fire protection were desired by 40%, reflecting increasing demand for operational excellence and compliance with emerging safety norms.
- BESS qualification and test requirements were highlighted by automation companies—suggesting the need for national testing standards and certified protocols.

### c Grid Integration Experience and Challenges

As per the surveys, only 33**%** companies had actual field experience integrating BESS into the grid. Among these, nearly all reported significant challenges.

**Key Issues Encountered:**

- Technical integration issues were reported by 50% of the experienced respondents, indicating widespread difficulty in synchronizing BESS with grid protection systems, SCADA, metering, and communication protocols.
- Lack of standardized procedures affected 30%, highlighting the absence of uniform national guidelines for commissioning, testing, and operational handover.
- Grid stability concerns were raised by 20%, primarily by organizations working on large-scale or industrial BESS applications.

The prevalence of integration problems underscores the need for standardized grid codes, interconnection guidelines, and certification protocols for BESS deployment across states and utilities.

## iii. Manpower and Skill Requirements

### a Shortage of Skilled Manpower

The survey reveals a significant shortage of skilled manpower across the BESS industry, with nearly 73% of organizations reporting insufficient trained personnel for executing energy storage projects. The most commonly cited shortages are in installation and commissioning, needed by 60% of respondents, followed by BESS system design at 47%. Several companies also highlighted gaps in grid integration (33%), operations and maintenance (33%), and safety and compliance roles (27%). These trends indicate that organizations require both engineering-level and technician-level talent to meet the growing complexity of BESS deployment.

### b Desired Educational Qualifications

The survey indicates a diverse preference for educational backgrounds depending on job roles. Around 33% of organizations prefer ITI or technician-level certifications, especially for installation, commissioning, and O&M functions. Meanwhile, 27% favour diploma or B.Tech/B.E. graduates in electrical or power engineering for system design, grid integration, and battery-related functions. Mechanical diploma holders are relevant for specific O&M tasks but are less broadly in demand. These insights highlight the need to develop training programmes that can cater to multiple qualification levels.

### c Industry Interest in Hiring Trained Professionals

There is a strong and growing interest across the sector in hiring trained BESS professionals, with 73% organizations confirming they would recruit candidates trained under a structured programme. A little over 33% of employers prefer freshly trained professionals, while 47% are open to hiring both fresh and experienced candidates. This demonstrates the industry's readiness to absorb new talent, suggesting that industry-aligned training programmes will immediately translate into employment opportunities.

### d Gender Diversity in the Energy Storage Workforce

Gender participation in the energy storage workforce remains extremely low. More than 73% of the surveyed organizations indicated that female employees make up less than 25% of their workforce, with many reporting women's participation below 10%. Only one organization reported a female participation rate exceeding 50%. When asked about training participation, about 40% of the companies expect to nominate only 1–5 female participants, 13% expect to nominate 6–10 female participants, and 47% expect none at all. This highlights a significant gender gap and presents an opportunity for targeted interventions to improve inclusivity in the sector.

## iv. Supply Chain, Manufacturing and Procurement

### a Key Supply Chain Constraints

Across companies, the most common supply chain constraints are cost fluctuations and import dependence, reported by nearly 27% and 40% of the respondents, respectively. Cost volatility is especially challenging for companies relying on imported lithium, cobalt, and specialty chemicals. A smaller but notable share of organizations highlighted regulatory barriers (SRF Company) and logistical issues (Sunrise CSP India), pointing to challenges not only in sourcing but also in cross-border movement of energy storage components. Overall, the responses indicate an ecosystem vulnerable to global supply shocks, currency fluctuations, and import regulations.

## v. Operation, Maintenance and Safety

### a Provision of O&M Services

A majority of surveyed organizations (approximately 67%) reported that they do provide O&M services for BESS installations. These include EPC contractors, system integrators, and manufacturers who support grid-connected and C&I BESS deployments. A smaller proportion of roughly 33%, mainly technology providers or component manufacturers, do not currently offer O&M services, primarily because their services stop at supply, manufacturing, or system design.

### b Key O&M Challenges

Among those offering O&M support, the most dominant challenge, reported by nearly 53% of the respondents, is the lack of trained personnel capable for carrying out BESS-specific maintenance activities. This shortage affects companies across the value chain, particularly EPC contractors and system integrators. A smaller share of organizations reported battery degradation monitoring as a challenge, reflecting growing difficulty in managing ageing batteries, thermal management, and predicting end-of-life. Additionally, one respondent noted high component replacement costs, highlighting the economic burden associated with BESS O&M.

### vi. Training Needs and Capacity Building for BESS Implementation

The survey responses indicated a significant training deficit across organizations, with 80% reporting that their staff had not received any formal training on BESS. The primary barriers to accessing training include a lack of available training programmes (53%), time constraints (13%), high training costs (20%), and limited institutional support (20%). Despite these constraints, 73% of the total respondents indicated that technical training would enhance their ability to implement BESS projects, demonstrating a strong willingness to build capacity.

Regarding training preferences, 47% of the respondents expressed a preference for residential training, while 53% preferred non-residential formats. When it comes to the type of training, long-term programmes were highlighted by 33% of the organizations and short-term trainings were preferred by 20% and hands-on practical modules were preferred by 7%. Meanwhile, 1-day workshops were preferred by approximately 27% of the respondents, reflecting the need for rapid skill enhancement among operational teams.

When asked about specific training content requirement, the survey showed broad interest across a range of technical and managerial subjects. The most requested topics were BESS sizing and design (47%), O&M best practices (27%), feasibility assessment (47%), procurement and contract management (47%), and financial modelling (33%). Safety and end-of-life disposal were also significant concerns, with 47% of organizations indicating a need for training in these areas. Regulatory compliance emerged as an additional priority, requested by 33% of the respondents, highlighting gaps in understanding national standards, safety codes, and applicable CEA/CEA-grid guidelines.

In terms of preferred formats, the survey revealed diverse expectations—20% of organizations preferred in-person workshops, 13% preferred blended learning (online+offline), 7% favoured on-the-job training, and 20% preferred webinars or fully online sessions. This reflects the need for both flexibility and immersive practical exposure depending on organizational roles.

## Financial Institutions

Among surveyed financial institutions, 50% reported having previously financed RE projects, primarily rooftop solar, commercial and industrial (C&I) systems, and residential solar installations. The remaining 50% have not yet financed any RE-related projects, indicating a mixed but emerging level of engagement with the clean-energy financing landscape.

The institutions that had financed RE projects showed 100% involvement in rooftop solar, C&I, and residential solar portfolios. No institution reported financing utility-scale solar, wind, biomass, or hybrid RE systems, suggesting RE exposure remains limited to small and medium-scale distributed solar.

Only half of the institutions confirmed funding electrical infrastructure projects, while the remaining half did not participate in this sector. This indicates that grid-related or distribution-level project financing exposure is not uniform across institutions.

### i. Experience and Challenges in BESS Financing

A range of challenges emerged from the responses provided by financial institutions. Half of the institutions cited uncertainty around revenue models, revealing a major knowledge gap regarding how BESS projects generate financial returns. Similarly, 50% pointed to difficulties in conducting risk assessments, reflecting concerns about technology maturity, performance reliability, lifecycle uncertainties, and overall project bankability. Additionally, 25% institutions identified high capital costs and issues related to battery disposal as barriers, highlighting apprehensions about significant upfront investments and end-of-life management responsibilities. Another 25% noted regulatory challenges, suggesting that evolving policies and lack of clarity in compliance requirements continue to hinder financing decisions.

Institutional confidence in assessing the financial viability of BESS projects varies evenly across respondents. An equal share (25% each) reported being *'very confident'*, '*confident'*, '*somewhat confident'*, and '*not confident'*. This evenly-distributed confidence spectrum indicates inconsistent internal expertise across institutions and reinforces the need for targeted capacity-building initiatives to strengthen financial evaluation capabilities for emerging technologies like BESS.

### ii. Technical Aspects of BESS in Financing

The survey results indicated low technical familiarity among financial institutions. Only 25% respondents reported having a '*basic understanding'* of key BESS technical parameters, while the remaining 75% stated they were '*not familiar'*. This shows that technical capacity gaps are widespread, which may influence banks' willingness to finance BESS projects.

Many banks cited multiple technical challenges in evaluating BESS projects:

- 50% of the respondents who answered this question identified battery chemistry, technology types, efficiency, degradation rates, energy capacity, and discharge rates as difficult to assess.
- 25% identified safety and environmental concerns, project implementation timelines, supplier agreements, and performance guarantees.
- Another 25% provided no technical comments, further reinforcing limited technical confidence within the sector.

Only 25% of the surveyed institutions mandate performance guarantees from BESS technology suppliers or system integrators. The majority (75%), on the other hand, do not require such assurances.

### iii. Training Exposure and Barriers to Training

None of the participating institutions have received any formal training on BESS financing. The key barriers cited include time constraints (reported by 75% of the respondents), limited institutional support (25%), and a lack of available training programmes (25%). This pattern indicates that institutional systems and training opportunities have not matured sufficiently to support BESS-related capacity building.

Despite low exposure, 50% of the respondents indicated that technical training on BESS would improve their ability to finance such projects, while the other half did not see an immediate need. The institutions interested in capacity building expressed a desire for training modules on technical aspects of BESS, financial modelling, risk assessment, regulatory frameworks, and case studies of successful BESS financing. These preferences underline the need for structured, application-oriented training content.

Training format preferences varied, but almost half of the respondents favoured blended learning combining online and in-person sessions, while 25% preferred exclusively online courses and another 25% preferred in-person workshops. This indicates that institutions are receptive to multiple learning modes, with a slight preference towards flexible blended formats.

### iv. Challenges in Financing BESS Projects

The financial institutions anticipate multiple challenges based on their understanding of the sector. These include concerns about uncertain revenue models (reported by 50%), lack of clear regulations (50%), high upfront capital costs (25%), and difficulties in risk assessment (25%). These anticipated barriers highlight systemic uncertainties in the financing landscape for emerging technologies like BESS.

## ITI and Training Institutes' Readiness for BESS/ESS Education

### i. Training Course and Infrastructure

Over 86% of the respondent institutions offered at least one trade connected to electrical, mechanical, renewable energy, or EV technologies. Electrical trades dominated, with almost every institute offering courses such as electrician, fitter, and wireman. Mechanical trades—such as motor vehicle mechanic, diesel mechanic, and refrigeration & air conditioning—are also well represented.

Renewable energy-related courses (mainly solar PV and solar technician) are offered by approximately 14% of the institutions. A few institutes (about 5–7%) reported coverage of advanced areas such as green hydrogen, EV maintenance, and industrial robotics, indicating emerging diversification.

#### a Availability of BESS-specific Courses

Across all surveyed institutions, it was observed that none of the institutions (10–14%) currently offer structured courses on BESS. This reflects a substantial curriculum gap, even among institutes that teach renewable energy or electrical trades. One or two institutes mentioned exposure to solar plants or EV-related content, but these do not constitute formal BESS courses.

#### b Inclusion of BESS/ESS in Existing Training Modules

Only 19% of the institutions responded that they include BESS-related topics within existing trades (mostly in electrician, solar technician, or EV mechanic courses). However, this inclusion is typically partial and limited to basic battery concepts, not comprehensive BESS trainings such as system design, integration, safety, or diagnostics. An overwhelming majority of 81% reported that BESS/ESS is not included in any formal trade module.

#### c Availability of Technical Infrastructure (Labs, Equipment, Tools)

Infrastructure to support ESS/BESS training is extremely limited. About:

- 52% of institutes have no dedicated equipment or lab facilities for BESS/ESS.
- 10% have only basic electrical or mechanical apparatus.
- 5–10% have partial facilities, often linked to solar or EV training.

One institute noted having both electrical and mechanical workshops, while only one or two reported partial infrastructure such as basic testing tools. Overall, training infrastructure for BESS remains insufficient across institutions.

### d Curriculum Alignment with Advancements in ESS/BESS

Only 33% of institutions reported that their curriculum is updated in line with emerging technologies in the BESS/ESS sector. A small number mentioned partial updates (e.g., EV-related modules), but these are not comprehensive. The remaining 67% acknowledged that their curriculum does not reflect technological advancements such as battery safety protocols, energy management systems, or grid-integrated storage.

### e Availability of Courses on Battery Manufacturing, Testing, Maintenance, Battery Management, and Safety

Nearly all respondents indicated that training in advanced battery domains is absent. Only one institute reported offering BESS-focused courses covering battery technology, system design, grid integration, investment analysis, and O&M, thereby representing less than 5% of the total responses.

For the rest:
- 95% provide no training in battery manufacturing or maintenance.
- Where battery-related content exists, it is limited to basic coverage within electrician or electronics trades.

This highlights a critical skills gap for India's evolving battery and storage workforce.

### ii. Industry Collaboration in the BESS/ESS Sector

Institutional linkages with the BESS/ESS industry are extremely limited. Over 90% of the institutes reported having no collaboration with any company or industry in the energy storage space. Only one institution indicated an association—with a public sector entity—suggesting that structured partnerships for curriculum development, training, or equipment support are rare. The absence of such collaborations highlights a major gap between training institutions and emerging industry needs in the BESS and ESS sector.

### a Placement Assistance in the BESS/ESS Sector

Placement support specifically targeting the BESS/ESS sector is also very low. More than 85% of institutions had not provided placement assistance in this domain, reflecting limited employer engagement and low visibility of energy storage as a career pathway. Only a minority (around 10–14%) offered some form of placement support, demonstrating a need for stronger ecosystem linkages to improve employability outcomes.

### b Key Challenges in Implementing BESS/ESS Training Programmes

Institutions highlighted several barriers to introducing or expanding BESS/ESS-related training. The most frequently cited challenges include:
- Infrastructure gaps
- Limited student awareness
- Lack of advanced training options or curriculum modules
- Unavailability of relevant courses
- Raw material or equipment shortages
- Faculty readiness issues

### c Gender Representation in Energy Storage Divisions

Where institutions reported female participation data, representation is low.

The findings show that:
- Nearly 43% of institutions have less than 10% female participation in energy-related training or activities.
- Around 5% fall in the 10%–25% range.
- 5% institutions reported a significantly higher female ratio (26%–50%), indicating isolated improvements.

## IITs, Engineering Institutions, Research Institutions

### i. General Information

#### a Familiarity with Energy Storage Technologies

Across all surveyed institutions, the level of familiarity with energy storage technologies is generally high. Approximately 55% respondents indicated that they are familiar in detail, while another 34% reported being somewhat familiar. Only around 11% of respondents stated that they are not at all familiar, suggesting that the overall baseline awareness within academic and technical institutions is strong.

#### b Primary Reasons for Seeking Energy Storage Training

The motivation to seek training was driven by multiple overlapping factors, with career advancement emerging as the most dominant driver across approximately 74% of respondents. Academic research was cited by nearly 53%, particularly from universities, IITs, and technical institutes. Entrepreneurship and startup aspirations motivated about 49%, reflecting the growing innovation ecosystem around battery technology and clean energy. Industry compliance and regulatory needs were highlighted by around 57%, mostly from institutes aligned with industrial training or skill development. A smaller but notable proportion (28%) mentioned personal interest, suggesting a growing curiosity in emerging green technologies.

### ii. Training Needs and Expectations

#### a Preferred Training Format

Preferences for training formats showed a strong inclination towards mixed-mode delivery. Nearly 50% preferred hybrid training (online plus practical labs), reflecting a desire for theoretical grounding combined with hands-on exposure. Another 30% favoured in-person classroom training, especially institutions involved in vocational and technical skill development. Online live sessions were preferred by around 15–20%, mostly by research teams and working professionals, whereas self-paced e-learning was chosen by about 5–7%, primarily among institutions with flexibility constraints. Overall, the demand clearly leans towards formats that combine instructor-led learning with practical experience.

#### b Topic Preferences for Training Curriculum

Training topics saw extensive interest across nearly all categories. Basics of Energy Storage Technologies (BEST) was selected by almost 100% of respondents. Design and manufacturing of ESS attracted close to 85–90%, while grid integration and energy management was preferred by around 80–85%. Similarly, safety, maintenance, and recycling of batteries saw interest from nearly 75–80%, reflecting the importance of operational safety and lifecycle management. Policies and regulations were requested by nearly 60–65%, whereas business and investment opportunities captured interest from 50–55%, especially from entrepreneurship-driven institutions and engineering colleges.

### iii. Practical Exposure and Industry Collaboration

#### a Interest in Industry Visits and Hands-on Training

Interest in industry exposure is overwhelmingly high, with around 95–97% respondents expressing willingness to participate in industry visits, hands-on engagement, and real-world demonstrations at storage companies or labs. Only a few institutions (less than 3–5%) indicated no interest, mostly due to logistical constraints. This reflects a strong recognition that practical exposure is essential for mastering this rapidly evolving technology domain.

### b Key Challenges Foreseen in Implementing Energy Storage Technologies

Across the academic, engineering, IIT, and research institutions, multiple barriers were identified. The most frequently cited challenges include:

- Cost-related constraints (high deployment costs, cost of implementation, financial constraints) were mentioned by over 26% respondents.
- Infrastructure gaps, such as lack of labs, hardware, and practical facilities, accounted in around 26% of responses.
- Technological limitations (battery life, indigenous manufacturing gaps, advanced technology knowledge) were noted by approximately 19%.
- Policy and regulatory barriers appeared in about 11% of responses, especially from universities and public institutions.
- Awareness and skill shortages (including lack of trained manpower and long learning curves) comprised roughly 15% of the challenges.
- Environmental and sustainability concerns, including disposal management, accounted for about 4%.

Overall, the challenges indicated that the sector faces both technical readiness gaps and systemic institutional constraints, with financial and infrastructure bottlenecks being the most dominant.

### c Factors Influencing Decision to Enrol in an Energy Storage Training Programme

Respondents were allowed to choose multiple options. The quantified ranking shows:

- Cost of training was selected by around 55% of the institutions.
- Certification and career opportunities influenced approximately 60% of the respondents.
- Practical hands-on learning was highlighted by about 58%.
- Expert faculty influenced around 51%.
- Industry collaboration was selected by nearly 55%.

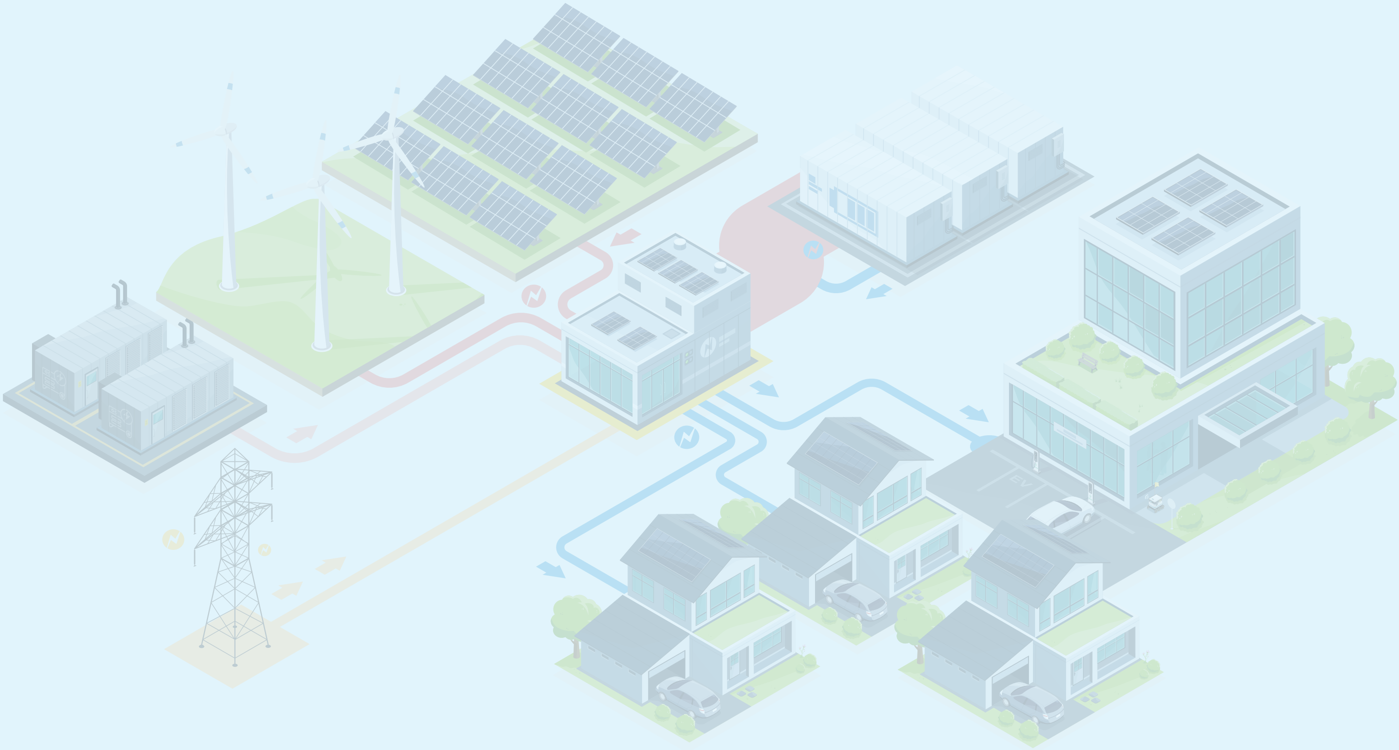
This distribution showed that institutions highly valued affordable, career-oriented, and practice-driven training, complemented by expert-led and industry-integrated modules. Cost is also among the strong determining factors.

### d Ratio of Female Employees in Energy Storage Divisions

The participation of women in the ESS roles remains low with some statistics mentioned below.

- Less than 10% female representation was reported by over 43% of institutions.
- 10%–25% representation was seen in around 13% of the responses.
- 26%–50% representation was noted in nearly 21%.
- More than 50% female representation appeared in only about 9% of the cases.

The data indicates that energy storage remains a male-dominated field, though a few institutions demonstrate encouraging gender diversity.



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