सत्यमेव जयते

NITI Aayog

Report on
"Developing Chemistry agnostic standards for energy storage technologies"

May, 2024

Acknowledgements

This report has been prepared under the guidance of Dr. V. K. Saraswat, Member (Energy), NITI Aayog. A technical group was created under Sh. Rajnath Ram, Adviser (Energy), NITI Aayog, with members Sh. M. A. K. P. Singh, Member (Hydro), CEA, Sh. Kuldeep Rana, Scientist E, MNRE, Sh. Neeraj Kushwaha, Asst. Director, BIS, Dr. AS Prakash, Sr. Principal Scientist, CSIR-Central Electro Chemical Research Institute, Karaikudi, Sh. Yogesh Sharma, Professor, Energy Storage Laboratory (ESL), IIT Roorkee, Dr. Raman Vedarajan, Senior Scientist, International Advanced Research Centre for Powder Metallurgy & New Materials (ARCI), Hyderabad, Sh. Abhijit Datta, AGM, Chakr Innovation, Sushri Abhilasha Meena, Chakr Innovation, Sh. P M Nanda, Greenko, Dr G Ganesh Das Chief - Collaboration & Innovation, TATA Power, Sh. Bhupesh Verma Manager, India Energy Storage Alliance, Dr. Deepanjan Majumdar, Office of Member (Energy), NITI Aayog and Sh. Manoj Kumar Upadhyay, Dy Adviser (Energy), NITI Aayog as Member Secretary for the group.

We acknowledge all other stakeholders who contributed in finalization of the Report on “Developing Chemistry agnostic standards for energy storage technologies ".

डॉ. वी.के. सारस्वत
Dr. V.K. Saraswat
सदस्य
Member
Tele : 23096566, 23096567
Fax : 23096603
E-mail : vk.saraswat@gov.in

सत्यमेव जयते

भारत सरकार
नीति आयोग, संसद मार्ग
नई दिल्ली–110 001
Government of India
NATIONAL INSTITUTION FOR TRANSFORMING INDIA
NITI Aayog, Parliament Street
New Delhi-110 001

FOREWORD

The challenge posed to welfare of the planet by the climate change has necessitated increasing global efforts to limit temperature increase to 1.5 °C above pre-industrial levels as enunciated in the Paris Agreement. Ambitious climate action commitments have been made by nations across the world in the form of National Determined Contributions (NDCs) and long-term low carbon development strategies. India's updated NDCs reaffirms our commitment to reducing the Emissions Intensity of our GDP by 45 percent by 2030 and achieving 50% non-fossil fuel-based electricity capacity.

India has set a target to install 500 GW Renewable Energy (RE) by 2030. The RE is variable and intermittent in nature, which requires integration of resources like energy storage for removing intermittency and making it a more reliable source of energy for the grid and the consumer. India's EV market is expected to grow at a CAGR of 49% from 2022 to 2030. India is taking rapid strides towards achieving 30% EV market share by 2030. As per a NITI Aayog and RMI study, the battery storage demand will be ranging from 109 GWh/per year to 338 GWh/per year by 2030.

Battery energy storage technologies, with their diverse chemistries, materials, and operational characteristics, are at the forefront of this energy transition. However, the lack of standardized testing and certification procedures for these varied technologies poses a significant barrier to their commercialization. Current standards are often limited to specific chemistries and applications, hindering the evaluation and certification of new chemistries for energy storage applications, whether in electric mobility or stationary storage.

In response to this challenge, this report, "Developing Chemistry Agnostic Standards for Energy Storage Technologies," proposes a transformative approach. By adopting a chemistry-agnostic framework for standards, we can aim to evaluate all energy storage technologies based on universal technical and safety parameters, regardless of their chemical composition. This shift not only streamlines the standardization process but also facilitates the commercialization of new and potentially more sustainable energy storage solutions. Furthermore, standards can be designed to encourage the use of readily available materials within India, fostering resource efficiency. A flexible framework also encourages innovation and attracts investment in the domestic energy storage research, development, and manufacturing ecosystem.

As we move forward, the development of chemistry-agnostic standards for energy storage technologies will be instrumental in realizing our climate goals and securing a sustainable energy future for India. I congratulate all who have contributed in the preparation of this report.

(Dr. V K.Saraswat)

स्वच्छ भारत
एक कदम स्वच्छता की ओर

Contents

Tables

Executive Summary

India has made ambitious climate commitments and net-zero emission target by 2070. India is aiming to reduce **Emissions Intensity** of its GDP by **45 percent** from 2005 level and achieve about **50 percent cumulative electric power installed capacity** from non-fossil fuel-based energy resources by 2030.

As a part of commitment, the share of Renewable Energy (RE) is likely to increase significantly, but these renewable sources are inherently variable, weather dependent. The intermittencies of RE pose challenge to grid stability and reliability of electricity supply. Energy storage can act as a bridge between renewable energy generation and electricity demand. During periods of high renewable energy production, excess power can be captured and stored in the system and the stored energy can then be released back into the grid during peak demand hours, ensuring a reliable and stable power supply. The energy storages will become a game-changer in driving India's energy transition.

All the emerging Battery Energy Storage (BES) technologies have different chemistries, materials, and operating characteristics. This necessitates the requirement of different standards and protocols to ensure safety, performance, and reliability of these nascent technologies. A variety of battery energy storage is currently designed for consumer electronics or for vehicle usage. Likewise, grid storage conditions can be quite different from the conditions for use in vehicle transportation, which might mean that a different technology could be the preferred stationary storage technology.

A significant barrier to commercializing innovative battery energy storage technologies lies in the lack of standards, standardized testing and certification procedures. Most of the existing standards are limited to specific chemistries and their application. Consequently, neither can new chemistries be evaluated for battery energy storage, nor can any current application in Electric mobility or stationary storage be certified with these chemistries using these existing standards. As the world in general and India in particular has taken initiative for transitioning to a greener future, several new energy storage technologies are being researched upon, developed, and rapidly progressing towards commercialization. Making standards for each new technology for every application is not only time consuming but also requires a certain level of expertise within the standardising agencies.

To overcome this hurdle and unlock the potential of these niche technologies, India needs to adopt a chemistry agnostic approach to standards. This framework would evaluate all energy storage technologies based on universal technical and safety parameters, regardless of their type.

This shift offers several benefits:

1. **Enabling Diverse Technologies**: The commercialization of new, potentially more sustainable energy storage solutions.

2. **Resource Utilization**: Standards can be designed to encourage the use of readily available materials within India.
3. **Innovation and Growth**: A flexible framework fosters innovation and attracts investment in domestic energy storage research, development, and manufacturing ecosystem.

This report puts forward the technical and safety parameters necessary to establish a set of standards within this framework that are agnostic to chemistry. A sample template for such a standard is also proposed. Furthermore, it recommends flexible interpretations and adjustments of current application standards to ease the incorporation of new energy storage technologies into electric vehicles (EVs) and stationary energy storage systems within the given framework.

From this report, the following key recommendations have emerged:

(a) Formulation of Chemistry Agnostic Standards and notification of guidelines for their use: India lacks energy storage standards that are agnostic to specific chemistries and technologies. This poses a challenge for evaluating and integrating the diverse range of emerging technologies. A range of Technical and Safety Parameters suitable for Chemistry Agnostic Standards have been identified based on examination of existing standards. A draft template for developing chemistry agnostic standards for energy storage has been developed in BIS format. This template can be utilized for development of standards & certifications. It is recommended that BIS develops and notifies the use of these standards within a period of 3-4 months.

(b) Modification of existing standards for application specific testing of emerging Energy Storage technologies: India's existing application standards for energy storage technology (like AIS038, IS039, AIS040, AIS041, AIS048, AIS049, AIS156, AIS039, etc.) inherently impede certification of emerging energy storage technologies (EST). BIS needs to review and suitably modify these standards, aligning them with the proposed modifications for facilitating application specific testing and certification of emerging Energy Storage technologies within a period of 3-4 months.

Additionally, Indian conditions require operation in ambient temperature in the range of -20 to 60°C. The following safety requirements need to be adhered to:

i. All technologies should ensure safety and accepted performance in these conditions.
ii. In case technologies cannot inherently function safely with acceptable performance in these conditions, additional thermal management systems need to be mandated.

(c) Update Standards for Connectivity to the Grid: CEA Safety Standards and CEA (Technical Standards for Connectivity to the Grid) Regulations need to be suitably updated to cover ESS and other technologies like electrolysers for Green Hydrogen. The Technical Standards may also cover the 'Performance Standards' for different services as well as 'Operation and Maintenance Standards' for ESS facilities.

(d) Establishing the Test Beds for Emerging Energy Storage Technologies: India's energy storage sector, vital for clean energy integration, suffers from a lack of centralized testing infrastructure data base. This fragmentated approach leads to unreliable data, hinders innovation due to inconsistent testing protocols, and limits collaboration due to a lack of transparent data sharing. The existing central testing and certification agencies, such as International Centre for Automotive Technology (ICAT) and Automotive Research Association of India (ARAI) under the **Ministry of Heavy Industries (MHI),** lack the necessary equipment and facilities to handle the full range of technical parameters associated with evolving energy storage technologies. This translates to inaccurate and incomplete testing, hindering the development and commercialization of reliable storage solutions.

Upgrading the existing **testing facilities** and establishing new ones require significant resources. By leveraging government resources and private sector expertise, PPPs model can be explored to establish **high-end testing infrastructure**. This collaborative approach will ensure efficient resource allocation and faster development of the testing infrastructure.

It is also recommended that BIS needs to develop dashboards for **centralized testing infrastructure** and include infrastructure, equipment's, type of test, timelines, testing process, fee, trained manpower, online application, testing tracking, result and certification to facilitate the energy storage manufacturers, startups, innovators etc.

(e) Capacity Building: Developing a skilled workforce through targeted training programs for personnel by BIS in co-ordination with the different user ministries (MHI, Power, MNRE, Transport etc.). This may ensure expertise in handling the intricacies of diverse energy storage technologies. By investing in capacity building via these partnerships, India can create a robust ecosystem that fosters innovation and development in the crucial energy storage sector. This, in turn, will unlock the true potential of clean energy integration, paving the way for a sustainable energy future.

By embracing chemistry agnostic standards, India can overcome the limitations of current technologies and accelerate its clean energy transition. This will enable the development of a robust and sustainable domestic energy storage industry, ultimately contributing to achieving its NDC targets and building a cleaner energy future.

CHAPTER 1

1. Background

1.1 India's Climate Commitments

India's historical cumulative emissions from 1850 to 2019 amount to less than 4 percent of cumulative carbon dioxide emissions of the world from the pre-industrial era, despite being home to 17 per cent of the world's population. Even today India's annual per capita emissions remain less than half of the global average (IEA- CO2 Emission in 2023 report).

At the 26th session of the **Conference of the Parties (COP26)** to the United Nations Framework Convention on Climate Change (UNFCCC) held in Glasgow, United Kingdom, India expressed to intensify its climate action by presenting to the world five nectar elements *(Panchamrit)* of India's climate action. The updated Nationally determined contributions (NDCs) translate the '*Panchamrit*' commitment announced at COP 26 into enhanced climate targets. The update is also a step towards achieving India's long-term goal of reaching **net-zero by 2070.**

As per the updated NDC, India now stands committed to reduce **Emissions Intensity** of its GDP by **45 percent by 2030**, from 2005 level and achieve about **50 percent cumulative electric power installed capacity** from non-fossil fuel-based energy resources by 2030. This also takes forward the Hon'ble Prime Minister's vision of sustainable lifestyles and climate justice to protect the poor and vulnerable from adverse impacts of climate change. The updated NDC reads "To put forward and further propagate a healthy and sustainable way of living based on traditions and values of conservation and moderation, including through a mass movement for **'LIFE'– 'Lifestyle for Environment'** as a key to combating climate change". The decision on enhanced NDCs demonstrates India's commitment at the highest level for decoupling of economic growth from greenhouse gas emissions.

There are many possible pathways that can be taken up to achieve NZ 2070 emissions at a national level; however, there exist some barriers and uncertainties that may affect them. For India, a lot will depend on the pace of innovation in emerging technologies, the extent to which citizens are able or willing to change their behaviour, the availability of sustainable alternatives in addition to the extent and effectiveness of technology transfers and support, financial investments, and capacity building through international cooperation.

The role of Renewable Energy (RE) in Energy Transition and Net Zero:

i. The share of renewable energy (excluding hydro) in installed capacity as on 31st March, 2024 was 143.64 GW. This is expected to increase to 500 GW by 2030 and more than 1200 GW by 2047. Furthermore, as we move towards net zero, the share of renewable energy will continue to increase.
ii. In the given landscape, the role of energy storage particularly battery energy storage and other types of storage are also expected to multiply.

Therefore, it is important to develop Chemistry Agnostic Standards for different types of storages for increased penetration of RE. In the next chapter, the critical role of energy storage in driving energy transition has been detailed.

CHAPTER 2

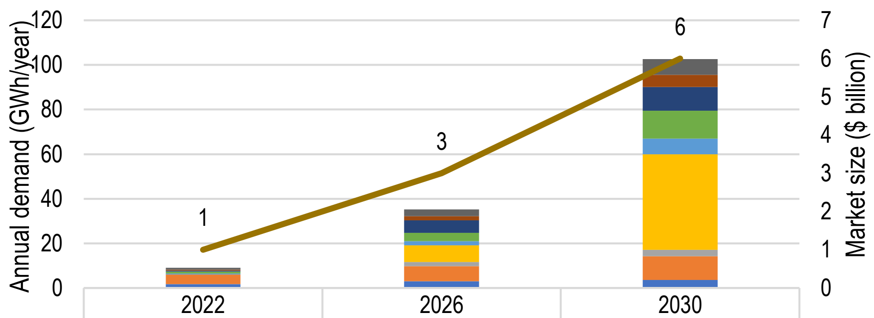
2. Energy storage - a critical role for driving India’s energy transition

Renewable sources are inherently variable, generating power based on weather conditions. This intermittency poses a significant challenge to grid stability and reliable electricity supply. The core challenge with renewable energy is its inability to consistently match electricity demand. Solar panels produce no power at night, and wind turbines are dependent on wind speeds. This variability can lead to grid instability and power outages if not addressed. Energy storage systems act as a bridge between renewable energy generation and electricity demand. During periods of high renewable energy production, excess power can be captured and stored in these systems. This stored energy can then be released back into the grid during peak demand hours, ensuring a reliable and stable power supply. Thus, energy storage will emerge as a game-changer, playing a critical role in driving India's energy transition.

The Central Electricity Authority’s (CEA) Optimal Generation Mix 2029-30" latest optimal generation mix report indicates that India will need at least 41.7 gigawatt (GW)/208.3 gigawatt-hour (GWh) of Battery Energy Storge System (BESS) and 18.9GW of Pump Hydro System in the 2029-30. In a different study by NITI Aayog and RMI, the battery storage demand ranges from 109 GWh/per year to 338 GWh/per year.

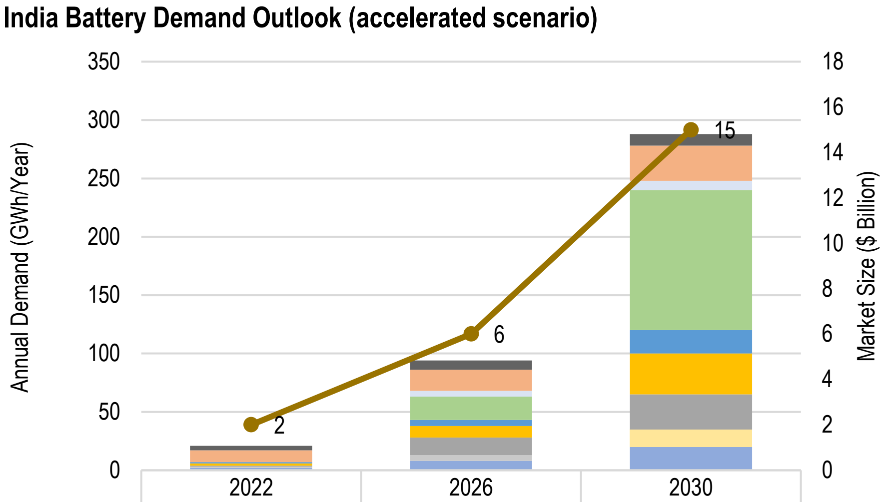
Table 1: NITI Aayog & RMI 2022 battery demand outlook (conservative scenario)

India Battery Demand Outlook (conservative scenario)



	2022	2026	2030
Passenger EVs	1	3	7
Commercial EVs	0	2	5
E 2-wheeler/3-wheeler	0	6	11
E-buses	1	4	12
Freight	0	2	7
Stationary storage (grid scale)	0	8	43
Behind the meter (Residential + Commercial)	0	2	3
Consumer electronics	4	7	11
Rail + Defense	2	3	4
Market size	1	3	6

Table 2: NITI Aayog & RMI 2022 battery demand outlook (accelerated scenario)



	2022	2026	2030
Rail + Defense	4	8	10
Consumer Electronics	10	18	30
Behind-the meter (Res + Comm)	0	5	8
Stationary Storage (Grid-scale)	0	20	120
Freight	1	5	20
E-buses	2	10	35
E 2-wheeler/3-wheeler	1	15	30
Commercial Evs	1	5	15
Passenger Evs	2	8	20
Market Size	2	6	15

Also, energy storage technology can facilitate greater penetration of renewables into the grid without compromising power quality or security and hence facilitate a faster transition away from traditional fossil fuel-based energy reserves.

Additionally, energy storage offers significant economic benefits in the context of India's energy transition. By storing excess renewable energy and releasing it during peak demand periods, energy storage reduces dependence on expensive peak power plants, leading to cost savings for consumers and utilities. Moreover, energy storage systems allow for participation in electricity markets by enabling optimized power dispatch based on real-time prices. This facilitates a more dynamic and efficient electricity market, potentially leading to lower overall power costs.

Beyond just energy storage, energy storage systems offer a multitude of benefits for grid management:

i. **Grid Balancing and Ancillary Services:** Energy storage systems can participate in electricity markets, providing real-time frequency and voltage regulation, crucial for grid stability.

ii. **Deferring Infrastructure Upgrades**: By storing excess renewable energy, energy storage systems can reduce peak demand, potentially delaying the need for expensive transmission and distribution infrastructure upgrades.
iii. **Cost Optimization**: Energy storage can be used strategically to reduce reliance on expensive peak power plants and minimize congestion costs on the grid.
iv. **Firming Up Renewables**: Batteries can compensate for the intermittency of renewables, ensuring reliable power supply.
v. **Decarbonization**: Integrating renewables with energy storage displaces fossil fuel generation.

Thus, energy storage is not simply a technological solution, but a key enabler for India's clean energy transition.

2.1 Energy Storage Technologies and its and Types

Technologies use a diverse nature of energy storage today - pumped hydro, concentrated solar thermal, capacitors, Lead Acid batteries, Lithium-ion batteries, etc. - which find diverse nature of application from large scale storage for energy generation purpose to short duration applications like mobility and devices. According to the form of storage energy, technologies can be broadly classified as mechanical, electrochemical, thermal and electrical. The following Table 3 & 4 give a detailed outline of the different types of storage technologies being envisaged and the corresponding maturity levels, respectively.

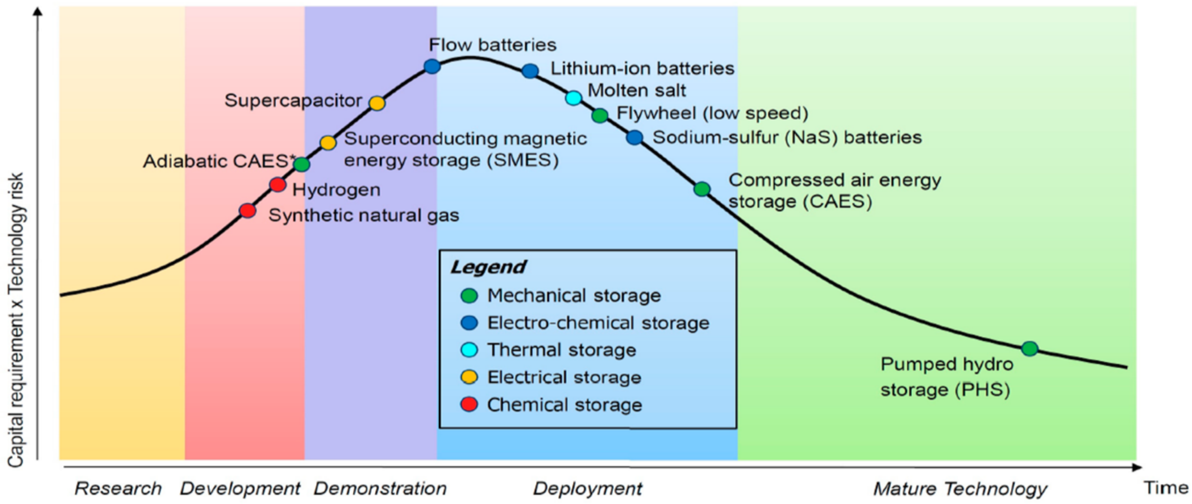
Table 3: Types of storage technologies

Mechanical	Electrochemical	Thermal	Electrical	Chemical
Pumped Hydro Storage (PHS)	Lead Acid Batteries, Advanced Lead Acid (Lead Carbon, Bipolar Lead Acid)	Sensible – Molten Salt, Chilled Water	Super Capacitors	Power-to-Power (Hydrogen Fuel Cell, etc)
Compressed Air Energy Storage	Lithium Batteries (LCO, LMO, LFP, NMC, LTO, NCA)	Latent – Ice Storage	Superconducting Magnetic Energy Storage (SMES)	Power-to-Gas
Flywheel Energy Storage	Flow Batteries (ZnBr, Vn Redox)	Thermochemical Storage		
Solid Gravity Energy Storage	Sodium Ion (NaS, $NaNiCl_2$)	Phase Change Materials		
	Aluminium, Iron and Zinc Air batteries			

LCO-Lithium-Cobalt-Oxide, NCA-Nickel-Cobalt-Aluminum, NMC-Nickel-Manganese Cobalt, LMO – Lithium Manganese Oxide, LFP– Lithium Iron Phosphate, LTO - lithium-titanium-oxide

Source: Study on Advanced Grid-Scale Energy Storage Technologies by Department of Hydro and Renewable Energy, IIT Roorkee, October, 2023

Table 4: Technology Maturity Level



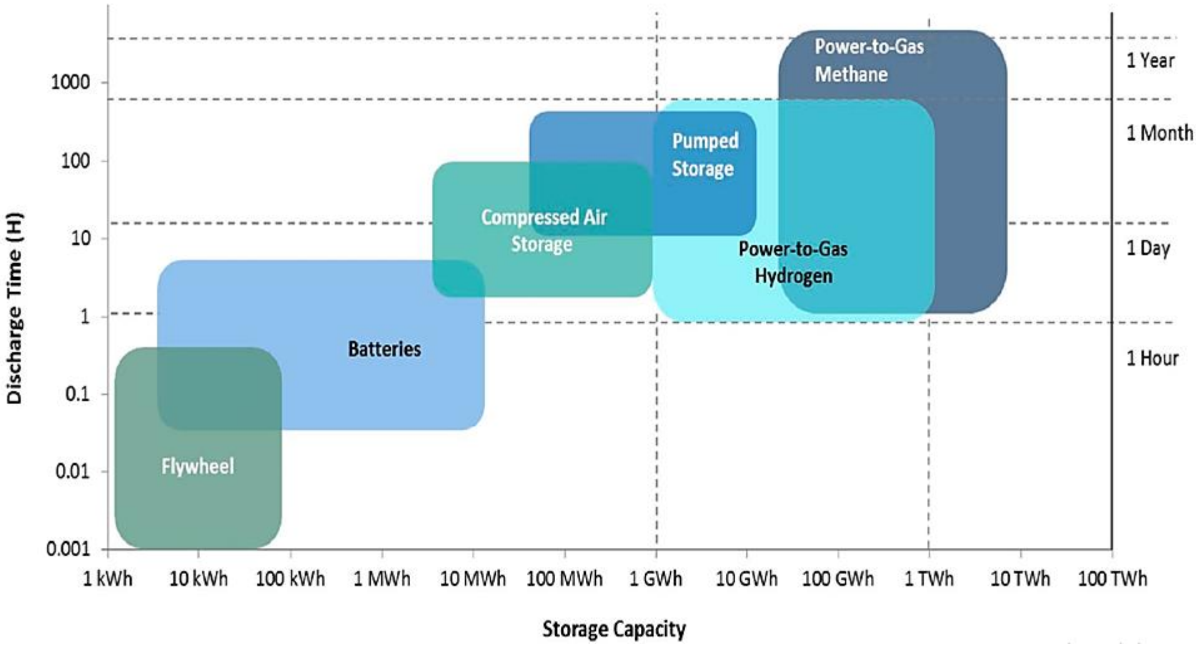
Source: Source: Study on Advanced Grid-Scale Energy Storage Technologies by Department of Hydro and Renewable Energy, IIT Roorkee, October, 2023

2.2 Capacity of Storage Technologies

In Table 5 the storage capacities for different technologies have been illustrated. It is evident from the illustrations that PHS, is the most ancient, mature technology, and comprises of majority of the installed storage technology globally. While PHS is not a battery technology and does not involve the use of specific chemicals, it does provide a way to store energy in the form of potential energy, using water as the medium. PHS or in other terms water battery includes the interaction with VRE (Variable Renewable Energy) ensuring power availability and robustness of clean energy transition strategy. Large scale, long-term storage, which will be required for seasonal backup or as energy security reserves in the absence of fossil fuels, will require a different technology. Hydrogen storage has the potential to fulfil this role and, therefore, the future grid is likely to be one where hydrogen plays a significant and crucial role, not in competition but in concert, alongside various other storage technologies. Moreover, power to hydrogen and power to methane technologies are still at the nascent stages of research and deployment.

Battery storage technology or Electrochemical storage technology plays a significant role starting from grid ancillary services, electric vehicles to consumer electronics and acts as one of the major pillars for electrical energy storage. However, battery storage technology has limitations in terms of storage capacity and so is not suitable for every application. An increasing level of policy and regulatory support, combined with the rapid advances in energy storage technology and significant cost declines are creating enabling conditions for a rapid growth of the electric mobility market. According to RMI's research and Bloomberg New Energy Finance's (BNEF's) analysis, the global demand for lithium-ion batteries is expected to reach more than 2.8 TWh annually by 2030, with a vast majority of that demand serving electric transportation. Similar momentum is emerging in Energy Storage System (ESS) applications. Investment in stationary energy storage globally reached US$ 6.3 billion in 2020. It is expected to continue at a rapid pace reaching US$22 billion by 2025 and more than US$30 billion by 2030.

Table 5: Capacity of Storage technologies



Source: Study on Advanced Grid-Scale Energy Storage Technologies by Department of Hydro and Renewable Energy, IIT Roorkee, October, 2023

2.3 Emerging Battery Storage Technologies

Lithium-ion batteries have been the dominant energy storage technology for many years due to their high energy density, long cycle life, and other advantages. However, there are limitations to lithium-ion batteries, such as the risk of thermal runaway, limited availability of raw materials, and high costs applications. As a result, there is an increasing interest in exploring alternative energy storage technologies, such as flow batteries, sodium-ion batteries, aluminium air batteries, zinc-air batteries, and hydrogen fuel cells, among others. Flow batteries are popular for both utility scale and residential applications, such as vanadium (e.g. Ultra Energy) and zinc bromine systems (e.g. Redflow). Other emerging technologies include iron flow batteries, zinc air batteries, aluminium air batteries; and power system technologies like vehicle to grid (V2G) and vehicle to everything (V2X) applications. The following Table 6 exhibit a vivid idea on the emerging battery storage technologies.

Table 6: Emerging Storage technologies (Beyond Li-ion)

Cell Schematics	Advantages	Drawbacks	Applications	Major Developments
Flow Battery	• Offers very long cycle life because anolyte and catholyte are stored in external tanks • High power and voltage delivery performance	• Low specific energy • Requires special housing for thermal safety • High system costs currently	• Long-duration storage; typically used for stationary applications such as power backup (replacing diesel generators, transmission and distribution upgrades, etc.)	• ESS Inc. announced a deal in fall 2021 to supply 2 GWh of iron flow batteries to utilities through the US, and v n begun operations to sell iron flow batteries in Europe. • VFlow Technologies has announced two trial projects to use vanadium redox flow batteries to support EV charging in South Korea and Australia
Sodium Sulphur	• Very high cycle life • Good specific energy • Low input material costs; cost competitive with traditional LiBs • Uses environmentally benign materials	• High temperatures required for operation raise safety concerns and require special housing • Currently high system costs	Long-duration storage; grid support applications	• NGK Insulators already supplies commercial sodium-sulphur batteries for grid-scale storage; commissioned a long-duration storage test project in 2021 with BASF in Belgium • Material research for advanced electrolytes that inhibit dendrite growth is ongoing at University of Texas in Austin
Sodium Ion	• Low material cost for sodium, more abundant and	• Currently in initial commercialisation phase,	• Grid-scale storage	• Reliance New Energy Solar announced acquisition of Faradion Ltd., a UK-based battery maker specialising in sodium-ion technology; it plans to use the technology

	sustainably sourced • Allows easy and safe transport without loss of performance • Low tendency for dendrite growth on charging	has not achieved scale • Relatively lower energy density and cycle life performance		for a domestic manufacturing plant in Gujarat • CATL announced first-gen sodium-ion battery in 2021 which can offer up to 160 Wh/kg energy density and fast charging; aims at target 200 Wh/kg
Zinc Air	• High theoretical energy density • Higher safety performance compared with incumbent LiBs • Low-cost materials for the electrodes allow lower overall manufacturing cost	• Technology has not reached mass market penetration; currently expensive to manufacture rechargeable zinc-air batteries • India has limited zinc reserves	• Small consumer electronics • Potential use in long duration storage	• Technology still in R&D phase (advanced materials research)
Aluminium Air	• High theoretical energy density, lightweight • Easily recyclable cell raw	• Technology still in early R&D stage • Typically nonrechargeable , so battery replacement	• Long-range EVs and unmanned air vehicles (UAVs)	• Technology still in R&D phase (advanced materials research)

	material • Not susceptible to thermal runaway • India has abundant aluminium reserves	stations need to be built out if the technology achieves commercialisati on		
Superca pacitors	• Very high cycle life • Good specific energy • Low input material costs; cost competitive with traditional LiBs • Uses environmenta lly benign materials	• High temperatures required for operation raise safety concerns and require special housing • Currently high system costs	• Fast-response grid support applications • Medical devices and consumer electronics	• Researchers at companies are developing different materials, such as various carbon materials, mixed-metal oxides, and conducting polymers for supercapacitor electrodes. Advances in carbon-based materials, namely graphene, can increase the energy density to nearly the level of batteries

Source: Study by NITI Aayog and RMI, 2020

Given the significant role and scale of energy storage, availability of critical material used in energy storage technology will become a major challenge in the long run. Hence, new and diverse energy storage technologies need to be adopted. With their distinctive advantages, these diverse technologies will become economically, technologically and environmentally more suited in some applications than others. Standards which would facilitate testing and certification, are hence required to not only keep up with the pace of innovation but also to facilitate commercialization and deployment of these new and emerging energy storage technologies. In this regard, the commonly available standards relating to Energy storage that intend to cover multiple technologies and chemistries, have been reviewed in the next chapter

CHAPTER 3

3. Key findings of the review of Standards on Testing and Certification for Energy Storage

The commonly available standards relating to Energy storage that intend to cover multiple technologies and chemistries, have been reviewed for their technical scope and safety requirements.

The key findings are as follows:

i. Most of the standards are specific to a particular chemistry and a particular application. India is transitioning to a greener future, several new energy storage technologies are emerging and progressing towards commercialization. Making standards for each new technology for every application is not only time consuming but also requires a certain level of expertise within the standard making agencies. An inaccurate evaluation procedure or a delayed release of new standards will not only bias the market acceptance towards a particular technology but also halt research and development in the emerging technologies.

ii. Some of the standards are not limited by the application. They cover many chemistries (e.g. IS6303 for Primary Batteries), but the parametric testing conditions are neither generic nor extendable to include new chemistry or technologies. Not all the emerging technologies or chemistries can be accommodated within these standards with appropriate amendments. Also, some of the standards that are used for certification of products and applications running on energy storage like Electric mobility (e.g. AIS156, AIS038, AIS039, etc.), do not specifically mention a particular technology or chemistry like Secondary Lithium ion, but the testing procedure and evaluation criteria are well defined.

iii. Almost in all the standards on energy storage systems (e.g. IS17092, IEC62933-1, IEC62933-2, IEC62933-3, etc.), an Energy Storage System has been defined to be an electrically rechargeable system. This very definition excludes chemistries and technologies which can be charged and recharged non-electrically (e.g. pumped hydro, fuel cells, mechanically rechargeable primary batteries, etc.).

iv. In terms of safety and performance, most of the environmental testing procedures and conditions have been adopted from global standards suited for applications of energy storage systems in non-Indian conditions. India, being a geographically diverse country and facing climatic variations hence, technologies certified by these standards might not be suitable in terms of safety and performance in actual Indian conditions. There is also non-uniformity in these test conditions among the existing standards.

Some of the clauses and sections which limit the scope of the reviewed standards to cover a wider range of chemistries and technologies are noted below:

Table 7: IS 6303 - Primary Batteries— General

Clause/ Section	Details	Limitations
Scope	This standard specifies requirements to standardize primary batteries with respect to their electrochemical system, dimensions, nomenclature, terminal configurations, markings, test methods, typical performance, safety, and environmental aspects. The objective of this standard is to benefit primary battery users, device designers and battery manufacturers by ensuring that batteries from different manufacturers are interchangeable according to standard form, fit and function. Furthermore, to ensure compliance with the above, this part specifies standard test methods for testing primary cells and batteries.	This standard is limited to only dry cell or batteries. It does not include primary flow batteries like metal air flow batteries or hydrogen fuel cells
Clause 3.3	Definition - Dry (Primary) Battery	
Clause 3.5	Definition - End-point Voltage (EV)	Discharge can be terminated if any of following condition is reached depending upon type of energy storage technology: a) End Point Voltage b) End Point Current c) End Point Power
Clause 4.1.4 - Table 3	Standardized Electrochemical systems	It does not include primary flow batteries like metal air flow batteries or hydrogen fuel cells
Clause 6.7	Activation time	Generic formula or procedure of finding activation time which is extendable to other primary batteries is not provided

Clause 6.1 Table 4	Conditions for Storage before and during discharge Testing	Discharge conditions do not include high temperature or low temperature testing as required by Indian conditions

Table 8: IS 16048-1 – Secondary Cells and Batteries Containing Alkaline or Other Non-acid Electrolytes — Secondary Sealed Cells and Batteries for Portable Applications Part 1 Nickel-cadmium.

Clause/Section	**Details**	**Limitations**
Title	Secondary cells	It does not include primary batteries or hydrogen fuel cells
Title	Sealed cells	It does not include flow batteries
Scope	Specific to Ni-Cd and small power applications like portable	It is specific to Ni-Cd Systems
Clause 7.1	Charging procedure for test purposes	This procedure is not applicable for primary battery batteries as it cannot be electrically charged
Clause 7.3.3	Discharge performance at –18 °C	Some batteries may not perform at this temperature
Clause 7.3.4	Discharge performance for rapid charge cells (R cells)	It is not applicable for primary battery batteries as it cannot be electrically charged
Clause 7.5	Endurance	This procedure is not applicable for primary battery batteries as it cannot be electrically charged
Clause 7.6	Charge acceptance at constant voltage	
Clause 7.7	Overcharge	It is not applicable for non-electrically recharging batteries

Table 9: IS 17092– Electrical Energy Storage Systems: Safety Requirements

Clause/Section	Details	Limitations
Clause 3.2	Definition - Energy Storage (ES) System — Equipment that receives electrical energy and then provides a means to store that energy in some form for later use in order to supply electrical energy when needed. EES are classified into mechanical, electrochemical, chemical, electrical and thermal energy storage systems, as shown in Fig. 1.	Although this clause, covers most of the chemistries that can be classified into electrically rechargeable type, but it is not applicable for primary batteries. It does not cover all types of the energy storage systems.
Clause 3.2 (a)	Electrochemical energy storage system — Consists of a secondary (rechargeable) battery electrochemical capacitor, flow battery or hybrid battery-capacitor system that stores electrical energy and any associated controls or devices that can provide the stored electric energy upon demand.	Although this clause, covers most of the chemistries that can be classified into electrically rechargeable type, but it is not applicable for primary batteries. It does not cover all the electrochemical energy storage system
Clause 3.2 Examples	Electrochemical Input Energy - Charger	This example is limited to secondary systems and does not cover electrically not rechargeable systems.
Clause 3.16	Ambient Temperature – 35 ± 5 degrees	Inconsistency in the values when compared with other standards
Clause 24.2	Ambient Temperature – 35 ± 5 degrees	Inconsistency in the values when compared with other standards

IEC 62933-1 - Electrical energy storage (EES) systems – Part 1: Vocabulary: The limitations in this part of standard are the same as that of IS17092.

Table 10: IEC 62933-2- Electrical energy storage (EES) systems – Part 2-1: Unit parameters and testing methods – General specification

Clause/Section	**Details**	**Limitations**
Clause 6.2.2.2	Input active power test	This clause is limited to secondary systems and does not cover non-electrically rechargeable systems.
Clause 6.2.3	Roundtrip efficiency test	This clause is limited to secondary systems and does not cover non-electrically rechargeable systems.
Clause 6.2.4	Expected service life test	This clause is limited to secondary systems and does not cover electrically not rechargeable systems.
Clause 6.2.5	System response test, step response time and ramp rate	This clause is limited to secondary systems and does not cover non-electrically rechargeable systems.
Clause 6.2.6	Auxiliary power consumption test	This clause is limited to secondary systems and does not cover non-electrically rechargeable systems.
Clause 6.2.7	Self-discharge of EES system test	This clause is limited to secondary systems and does not cover non-electrically rechargeable systems.
Clause 6.4.6.3	Operating cycle test (input and output power operating test)	This clause is limited to secondary systems and does not cover non-electrically rechargeable systems.
Clause 6.4.8	Available energy test	This clause is limited to secondary systems and does not cover non-electrically rechargeable systems.
Annex C	Back-to-back test method for EES system	This clause is limited to secondary systems and does not cover non-electrically rechargeable systems.

Table 11: IEC 62933-3- Electrical energy storage (EES) systems – Part 3-1: Planning and performance assessment of electrical energy storage systems – General specification

Clause/Section	**Details**	**Limitations**
Clause 5	Planning of EES Systems – rated input and output power	This clause is limited to secondary systems and does not cover non-electrically rechargeable systems.
Clause5.4, Table1	Main electrical parameters of EES systems	This clause is limited to secondary systems and does not cover non-electrically rechargeable systems.
Clause 5.4.9	End-of-service life values	This clause is limited to secondary systems and does not cover electrically not rechargeable systems.

CHAPTER 4

4. Need for Chemistry Agnostic Standards

All the emerging Battery Energy storage technologies have different chemistries, materials, and operating characteristics. As reviewed in the previous chapter, the available standards that cover electrical energy storage and multiple battery chemistries are also limited by their very scope and cannot be applied to the new emerging technologies. This necessitates the requirement of different standards and protocols to ensure the corresponding safety, performance, and reliability of the emerging technology. Against this backdrop, experts, and technical teams, experience a variety of problems regarding application of such technologies:

i. Different technologies respond to a particular use case (applications) differently, and so testing is needed for many of the use cases and often in the country where the storage will be deployed at scale.
ii. The use cases for energy storage are complex, particularly for the broad range of electric system configurations in developing economies.
iii. Potential lack of quality across battery technology providers is sometimes difficult to determine initially.
iv. Because of the above issues, the users, like discoms, EV manufacturers, solar power producers etc. are unable to incorporate different chemistry technologies for energy storage in their system. Further, they are also uncertain about acquiring the storage capacity and treating them as an asset for investment.
v. A variety of battery storage is currently designed for consumer electronics or for vehicle usage. Like the issue above, grid storage conditions can be quite different from the conditions for use in vehicle transportation, which might mean that a different technology could be the preferred stationary storage technology.
vi. With the advancement in R&D, new storage technologies are announced within short time spans as a breakthrough with both significant funding and an appealing potential. These emerging technologies (gravity, liquid air, geothermal, thermal) do not have testing standards or commissioning protocols.

To address these limitations and gaps, a chemistry agnostic framework of standards for energy storage would be vital. An assorted set of these common standards and protocols should be designed, preferably demonstrating the suitability of the storage-type for the target application. This format hereby appeals for a chemistry agnostic approach and applicable for most of the emerging chemistries or technologies that are progressing towards commercialization within the next 5-10 years. Other standards may include testing protocols, durability requirements, and regulatory compliance measures. Moreover, the protocols should contain the essence to attract technology transformation and future R&D prospects, enabling the most appropriate technological utilization.

In the subsequent section, the technical parameters and safety requirements for technologies for various energy storage have been examined and suitable parameters common for different storage technologies have been recommended.

CHAPTER 5

5. Chemistry Agnostic Parameters

The various Chemistry Agnostic Parameters detailed in this chapter are based on analysis of existing standards and literature survey of research publications and certification standards. Any Energy storage technology can fundamentally be defined by the following operational parameters:

5.1 Technical Parameters

A total of 23 parameters have been identified which need to be defined in terms of their operability in energy storage technology. These parameters are independent of chemistry or technology and hence agnostic in nature. For simplicity of understanding, these technical parameters and specifications can be grouped as follows, to include in chemistry agnostic standard:

i. **Electrical**

Electrical specifications include definitions on voltage, power, state of charge, capacity, and standard parameters of operation for charging and discharging, etc.

ii. **Time**

This includes parameters that specify time during operation like average duration for charging and discharging.

iii. **Performance**

This includes parameters on performance and operational energy losses like round trip efficiency, etc.

iv. **Size and Weight**

This includes parameters like energy density that indirectly indicate the size and weight of the system.

v. **Life**

This includes parameters that specify life like cycle life, service life, calendar life, etc.

vi. **Environmental**

This includes the specifications of ambient environmental conditions of temperature and humidity during storage and operation.

All 23 parameters have been defined with their standard units of measurement. The following table displays the range of each technical parameter, their type, and units of measurement for different chemistries and technologies:

Table 12: Chemistry Agnostic Technical parameters

Sr. No.	Type	Parameters	Unit
1.	Electrical	Operating Voltage	Volt (V)
2.	Electrical	Nominal Voltage	Volt (V)
3.	Electrical	Peak Power – Electrical Charging [1]	Watt (W)
4.	Electrical	Peak Power – Electrical Discharging	Watt (W)
5.	Electrical	End Point of Operation- Electrical Charging [1]	Volt (V) or Ampere (A) or Watt (W)
6.	Electrical	End Point of Operation- Electrical Discharging	Volt (V) or Ampere (A) or Watt (W)
7.	Electrical	State of Charge or State of Energy	%
8.	Time	Average Discharge Duration	Min or h
9.	Time	Average Charge Duration	Min or h
10.	Electrical	Maximum Storage Capacity	Wh
11.	Electrical	Maximum Deliverable Capacity	Wh
12.	Size and Weight	Energy Density	Wh/kg & Wh/L
13.	Performance	System Round Trip Efficiency	%

14.	Performance	Cell Round Trip Efficiency (Ah and Wh efficiencies)	%
15.	Electrical	Standard Parameter- Electrical Charging (Constant Voltage. Constant Current), constant power, CC-CV [1]	Volt (V) or Ampere (A)
16.	Electrical	Standard Test Parameter- Electrical Discharging or capacity tests (Constant Voltage or Constant Current, constant power)	Volt (V) or Ampere (A)
17.	Life	Life during Cycling	Nos. of charge/discharge cycle
18.	Life	Life during Operation/Service	hours or days or years
19.	Life	Life during Non-Operation/Storage (Calander life)	hours or days or years
20.	Environmental	Ambient Temperature – Operation (Charge or Discharge)	°C
21.	Environmental	Ambient Temperature - Storage	°C
22.	Environmental	Ambient Humidity – Operation (Charge or Discharge)	% RH

23.	Environmental	Ambient Humidity - Storage	% RH

Notes:
[1] Applicable only for Electrically rechargeable Chemistries

Definition of Technical Parameters and their ranges: All parameters except system round trip efficiency have been defined for a unit cell which is the smallest unit of the technology/chemistry which generates electrical energy.

Operating Voltage: The range of voltages within which the unit cell is designed to function properly and safely.

Nominal Voltage: Suitable approximate value of voltage used to identify the voltage of a unit cell.

Peak Power- Electrical Charge: It refers to the unit cell's maximum absorbable input power capacity during short -duration fast- charging situations without compromising safety.

Peak Power- Electrical Discharge: It refers to the unit cell's maximum deliverable output power capacity during short-duration high-demand situations without compromising safety.

End Point of Operation- Charge: It refers to the state or condition of the unit cell when it reaches a certain predefined level of charge when a charging operation needs to be stopped.

End Point of Operation- Discharge: It refers to the state or condition of the unit cell when it reaches a certain predefined level of discharge when a discharging operation needs to be stopped.

State of Charge: It is the remaining charge as a percentage of the maximum charge stored under operating conditions as declared by the manufacturer.

State of Energy: It is the remaining energy as a percentage of the maximum stored energy under operating conditions as declared by the manufacturer.

Average Discharge Duration: The time from the commencement of discharge until the unit cell's end point operation is reached.

Average Charge Duration: The time from the commencement of charge until the unit cell's end point operation is reached.

Maximum Storage Capacity: The maximum amount of energy that a unit cell can store.

Maximum Deliverable Capacity: The maximum amount of energy that a unit cell can deliver during standard electrical discharge.

Energy Density: The maximum amount of energy that the unit cell can deliver per unit weight.

Cell Round Trip Efficiency: It refers to the ratio of the energy output from the unit cell when it is discharged compared to the energy input required to recharge it. In simpler terms, it measures how effectively a cell can store and then release energy.

System Round Trip Efficiency: It refers to the ratio of the energy output from the battery energy storage system (BESS) when it is discharged compared to the energy input required to recharge it. It includes all the losses in the BESS, including auxiliary systems and power conversion units.

Standard Discharge Voltage-Constant Voltage (CV) Discharge: It refers to the Voltage conditions in which a unit cell needs to be discharged to determine and validate its characteristic technical parameters.

Standard Discharge Current-Constant Current (CC) Discharge: It refers to the Current conditions in which a unit cell needs to be discharged to determine and validate its characteristic technical parameters.

Standard Charge Voltage-Constant Voltage (CV) Charge: It refers to the Voltage conditions in which a unit cell needs to be charged to determine and validate its characteristic technical parameters.

Standard Charge Current-Constant Current (CC) Discharge: It refers to the Current conditions in which a unit cell needs to be charged to determine and validate its characteristic technical parameters.

Life Cycle: It is the number of charge-discharge cycles in standard operation until acceptable degradation in performance without compromising safety.

Life during Operation/service: It is the time in hours in standard operation until acceptable degradation in performance without compromising safety.

Life during Non-Operation /Storage: It is the time in years for storage in manufacturer defined conditions without compromising safety and acceptable degradation in performance in standard operation post storage.

Ambient Temperature- Charge Operation: It is the manufacturer defined range of ambient temperature within which the unit cell can be charged without compromising safety.

Ambient Temperature- Discharge Operation: It is the manufacturer defined range of ambient temperature within which the unit cell can be discharged without compromising safety.

Ambient temperature- Storage: It is the manufacturer defined range of ambient temperature within which the unit cell can be stored without compromising safety.

Ambient Humidity- Charge Operation: It is the manufacturer defined range of ambient humidity within which the unit cell can be charged without compromising safety.

Ambient Humidity- Discharge Operation: It is the manufacturer defined range of ambient humidity within which the unit cell can be discharged without compromising safety.

Ambient Humidity- Storage: It is the manufacturer defined range of ambient humidity within which the unit cell can be stored without compromising safety.

The following table lists all the defined technical parameters with their range of values. Their reference sources and assumptions made for their theoretical calculations have been noted wherever applicable.

Table 13: Ranges of Chemistry Agnostic Technical parameters

Sr. No.	Technical Parameter	Metal Ion	Lead Acid	Redox Flow	Metal Air Flow	Metal Sulphur	Hydrogen Fuel
1.	Operating Voltage (in V)	1.5-4.31 [4][5]	1.7-3 [6]	1-2.4 [7]	0.5-2.5	0.9-2.6	0.6-0.8
2.	Nominal Voltage (in V)	2.4-3.7 [4][5][6]	2.2 [5]	1.4-1.6 [7]	1.2-1.4	1.25-2.3	0.6-0.8
3	Peak Power - Electrical Charge (in Watt)	0.2-18 (max: 5Ah, 3.6V, 1C charge) [12]	1-180 (max: 180Ah, 2V, 0.5C charge) [11]	Up to 135 (max: 95Ah, 1.4V, 1C charge) [13]	NA [2]	66-1390 [14]	NA [2] [10]
4.	Peak Power- Electrical Discharge (in Watt)	1-90 (max 5Ah,3.6V 5C discharge) [12]	2-360 (max 180Ah, 2V 1C discharge) [11]	Up to 135 (max 95Ah, 1.4V 1C discharge)	2-100 [31]	50-1100 [14]	7-125 (Power density: Upto 2.5 W/cm^2

				[13]			Sze: 5-50cm^2) [10]
5.	End Point-Charge (in V)	Up to 4.5 [5]	Up to 3 [6]	Up to 1.65 [7]	NA [3]	Up to 2.3	NA [3]
6.	End Point-Discharge	Upto 2V [4][5]	1.75V [6]	0.8V [7]	1W [31]	0.9V	0.6V
7.1.	State of Charge (in %)	0-100	0-100	0-100	0-100	0-100	0-100
7.2	State of Energy (in %)	0-100	0-100	0-100	0-100	0-100	0-100
8.	Average Discharge Duration (in h)	0.1-8 (min: 0.125C max: 10C) [18] [19]	5 [15]	4-12 [17]	3-12 [31]	5-50 [16]	9-10 [20]
9.	Average Charge Duration (in h)	0.1-8 (min: 0.125C max: 10C) [18][19]	14-16 [15]	6-24 [17]	0.05-0.5 [39]	4-5 [16]	0.25-0.5 [39]
10.	Maximum Storage Capacity (Wh)	0.1-23 (max: 5Ah, charge Voltage: 4.5V)	3-540		100-400 [31]	120-260 [31]	

11.	Maximum Deliverable Capacity (Wh)	0.095- 21 (Cell Round trip max: 95%)	2.25-405		70-360 [31]	100-250 [31]	
12.	Energy Density (Wh/kg) [32]	100-350 [21][22]	40-60	25-35 [31]	80-4000 [31]	1274-2600 [31]	100-300 [31]
13.	Cell Round Trip Efficiency (%)	85-95	70-85	60-65	80-95	85-95	50-70
14.	System Round Trip Efficiency (%) [34]	50-70	50-65	55-60	70-80	65-85	30-60 [35]
15.1.	Standard Discharge Voltage - Constant Voltage Discharge	NA [36]	NA [36]		1.0-1.4V		0.6-0.7V
15.2.	Standard Discharge Current - Constant Current Discharge	35 mA-5A [37]	1 A- 180 A [37]		NA [36]		NA [36]
16.1.	Standard Charge Voltage - Constant Voltage Charge	NA [36]	NA [36]		NA [36]		NA [36]
16.2.	Standard Charge Current - Constant Current Charge	10mA- 2.5 A	0.3 A- 60 A		NA [36]		NA [36]

17.	Operation/ Service Cycle (in Charge-Discharge cycle)	300-5000	500	10000 [33]	100-2000 [33]	50-5000 [33]	
18.	Operation/ Service Life (in hours)	1200-4000	~2500	40000-12000 [33]	3000-10000 [33]	250-25000 [33]	
19.	Storage/ non-operating life (in years)	5-10	2-5	20-100 [33]	10-15 [33]	5-15 [33]	5-10
20.1	Ambient Temperature – Charge Operation	-20 to 60°C [31]	-20 to 60°C	10 °C to 40 °C [26]	10°C to 60 °C [38]	-50°C to 400°C [27][28]	10 to 60 °C [38]
20.2	Ambient Temperature – Discharge Operation	-20 °C to 60°C [31]	-20°C to 60°C	10°C to 40 °C [26]	10°C to 60 °C [31]	-50 °C to 400°C [27][28]	50°C to 200°C
21.	Ambient Temperature – Storage	-40°C to 50°C [31]	-40°C to 50°C		-20°C to 60 °C [31]		
22.1	Ambient Humidity – Charge Operation	65±20 %RH [31]	50±15% RH		5-95%RH (no condensation)	50±15 %RH	40-100%RH [30]

22.2	Ambient Humidity – Discharge Operation	65±20 %RH [31]	50±15% RH		5-95 %RH (no condensation)	50±15 %RH	40-100%RH [30]
23.	Ambient Humidity – Storage	65±20 %RH [31]	50±15% RH		5-95 %RH (no condensation)	50±15 %RH	

(References are enclosed in Annexure VI)

Notes:

[2] As Metal Air Flow and Hydrogen Fuel Cell cannot be electrically charged, therefore Peak power during Charge condition is Not Applicable (NA) to both the chemistries.

Peak values have been found from as far as commercially available largest size of unit cells in each chemistry.

[3] For Metal air flow, end point power is calculated as 0.01 times maximum deliverable output power.

[31] Claimed in academic/corporate research reports. Not validated by standard laboratories yet

[32] Chemistry dependent values

[33] Claimed in academic/corporate research. Not validated by standard laboratories yet

[34] Losses in the auxiliary systems and power conversion units have been assumed to be around 20% in a round trip (10% each in charge and discharge)

[35] Losses in the auxiliary systems and power conversion units have been assumed to be around 10% as there are no losses in mechanical recharging.

[36] Based upon the characteristic discharging/charging nature of the chemistries either a constant voltage or constant current mode is applicable. The other mode is hence marked as Not Applicable (NA) in the matrix.

[37] In constant current Charge and discharge, values have been found for commercially available cells with 1C and C/3 rates respectively (AIS-156)

[38] Represents conditions for non-electrical or mechanical charging.

[39] As Metal Air Flow and Hydrogen Fuel Cell cannot be electrically charged, therefore mechanical Charge/refilling duration is considered for both the chemistries.

5.2 Safety Requirements

Safety Requirements in energy storage depend upon the end application (e.g. electric mobility or stationary storage). On deliberation of the purpose, acceptance, and testing conditions by the sub-group of experts, the consensus was that all chemistries or technologies to be used in these respective application areas are expected to ensure safety against fire, explosion, hazardous chemical release, or safety against electrical shock either as a unit cell or in configuration of an energy storage system (ESS). These requirements during normal operation or abuse are defined by the following 15 parameters:

i. Vibration
ii. Mechanical Drop/Impact/Crush
iii. Mechanical Shock
iv. Over discharge/forced discharge Protection
v. Over Charge Protection (for only electrically rechargeable cells)
vi. Thermal Shock and Temperature Cycling
vii. Over Temperature Protection
viii. Thermal Propagation/runaway
ix. External Fire Resistance
x. Ingress Protection
xi. Short Circuit Protection
xii. Isolation Resistance
xiii. Withstand Voltage
xiv. Insulation Resistance
xv. Battery Management System

The applicable testing conditions and the acceptance criteria for each of the above parameters have been detailed in the following table:

Table 14: Test condition and acceptance criteria of Safety parameters/ requirements

Sr. No.	Test for	Acceptance Criteria	Test Condition-Mobility	Test Condition-Stationary
1.	Vibration	No fire, No leakage, No explosion	As per AIS 156 (Cat. L), AIS038 (Cat. M&N)	As per IEC 60086-5, UL1973
2.	Mechanical Drop/Impact/ Crush	No fire, No leakage, No explosion	As per AIS 156 (Cat. L), AIS038 (Cat. M&N)	As per IEC 62619, UL1973, IEC62660
3.	Mechanical Shock	No fire, No leakage, No explosion	As per AIS 156 (Cat. L), AIS038 (Cat. M&N)	As per IEC 60086-5, UL1973

4.	Over discharge/forced discharge Protection	No fire, No leakage, No explosion	As per AIS 156 (Cat. L), AIS038 (Cat. M&N)	As per IEC 62619, IEC60086-5, UL1973
5.	Over Charge Protection (for only electrically rechargeable cells)	No fire, No leakage, No explosion	As per AIS 156 (Cat. L), AIS038 (Cat. M&N)	As per IEC 62619, UL1973
6.	Thermal Shock and Temperature Cycling	No fire, No leakage, No explosion	As per AIS 156 (Cat. L), AIS038 (Cat. M&N)	As per IEC 60086-5, UL1973
7.	Over Temperature Protection	No fire, No leakage, No explosion	As per AIS 156 (Cat. L), AIS038 (Cat. M&N)	As per UL 1973
8.	Thermal Propagation/runa way	No fire, No leakage, No explosion	As per AIS 156 (Cat. L), AIS038 (Cat. M&N)	As per IEC 62619, UL1973
9.	External Fire Resistance	No fire, No leakage, No explosion	As per AIS 156 (Cat. L), AIS038 (Cat. M&N)	As per IEC 62619, UL1973
10.	Ingress Protection	No fire, No leakage, No explosion	As per AIS 156 (Cat. L), AIS038 (Cat. M&N)	As per IEC 60529
11.	Short Circuit Protection	No fire, No leakage, No explosion	As per AIS 156 (Cat. L), AIS038 (Cat. M&N)	As per IEC 62619, UL1973
12.	Isolation Resistance	No fire, No leakage, No explosion	As per AIS 156 (Cat. L), AIS038 (Cat. M&N)	As per IEC 60950
13.	Withstand Voltage	No fire, No leakage, No explosion	As per AIS 156 (Cat. L), AIS038 (Cat. M&N)	As per IEC 60950

14.	Insulation Resistance	No fire, No leakage, No explosion	As per AIS 156 (Cat. L), AIS038 (Cat. M&N)	As per IEC 60950
15.	Battery Management System	Existence of Microprocessor/ controller based intelligent management	As per AIS 156 (Cat. L), AIS038 (Cat. M&N)	As per IEC 62619

Notes:

Category L includes 2 Wheelers and 3 Wheelers,
Categories M&N include 4 Wheelers (passenger, commercial, trucks, etc. but excludes trailers)

All the applicable test conditions in the above table refer to respective application standards like AIS 156, AIS038, AIS039 for their requirements of safety. However, the conditions and testing procedures mentioned in these standards are implicitly chemistry specific.
Hence, in the following tables, the respective sections in these standards which need to be amended are listed. These amendments need to be made to ensure that the safety requirements and their corresponding tests in these application standards also become chemistry agnostic and can be used for the certification of emerging battery chemistries when used in these applications. A chemistry agnostic standard as attached in the draft template would comprise of the technical parameters and safety requirements generic enough to evaluate the technology independently of its application. The application specific standards with the amendment mentioned would ensure chemistry agnostic evaluation of the technology in the application with its specific requirements.

Required Amendment or Adaptive interpretation of application specific standards for technology development, validation, and Certification

(a) Standard No. AIS 156

Scope of Standard:

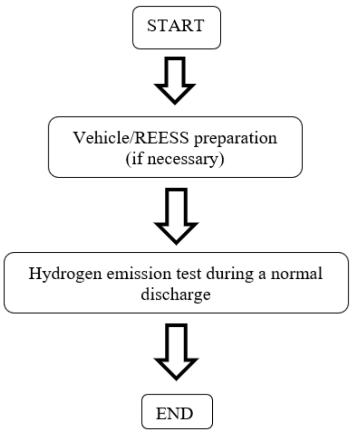
SPECIFIC REQUIREMENTS FOR L CATEGORY ELECTRIC POWER TRAIN VEHICLES

Table 15: Amendment/Adaptive interpretation of AIS156

Clause	**Existing Clause**	**Amendment/Adaptive Interpretation**
2.6	"Conductive connection" means the connection using connectors to an external power supply when the REESS is charged.	"Conductive connection" means the connection using connectors to an external power supply when the REESS is *electrically* charged.

2.7	"Coupling system for charging the REESS" means the electrical circuit used for charging the REESS from an external electric power supply including the vehicle inlet or a permanently affixed charging cable.	"Coupling system for *electrically* charging the REESS" means the electrical circuit used for *electrically* charging the REESS from an external electric power supply including the vehicle inlet or a permanently affixed charging cable.
2.14	"Electric power train" means the electrical circuit which includes the traction motor(s), and may include the REESS, the electric energy conversion system, the electronic converters, the associated wiring harness and connectors, and the coupling system for charging the REESS.	"Electric power train" means the electrical circuit which includes the traction motor(s), and may include the REESS, the electric energy conversion system, the electronic converters, the associated wiring harness and connectors, and the coupling system if *applicable* for *electrically* charging the REESS.
2.23	"High voltage bus" means the electrical circuit, including the coupling system for charging the REESS that operates on high voltage.	"High voltage bus" means the electrical circuit, including the coupling system *if applicable* for *electrically charging* the REESS that operates on high voltage.
2.34	"Removable REESS" means a REESS that by design can be taken out from the vehicle by the vehicle user for off-board charging.	"Removable REESS" means a REESS that by design can be taken out from the vehicle by the vehicle user for off-board charging *which can be done both electrically or mechanically*.
2.36	"Service disconnect" means the device for deactivation of the electrical circuit when conducting checks and services of the REESS, fuel cell stack, etc.	"Service disconnect" means the device for deactivation of the electrical circuit when conducting checks and services of the REESS, fuel cell stack, *flow cell stack*, etc.
2.46	*None*	"Metal air flow cell" means a cell characterized by the spatial separation of the electrodes and the movement of the energy storage fluids.
2.47	*None*	"State of energy" is the remaining energy as a percentage of the maximum available energy under operating conditions as declared by the manufacturer.
2.48	*Energy Capacity (Wh)*	*The total amount of electrical energy that can be stored in a unit metal air flow cell*
5.1.3.3(b)	On-board isolation resistance monitoring system together with a warning to the driver if the isolation resistance drops below the minimum required value. The isolation resistance between the high voltage bus of the coupling system for charging the REESS and the electrical chassis need not be monitored, because the coupling system for charging is only energized during charging of the REESS. The function of the on-board isolation	On-board isolation resistance monitoring system together with a warning to the driver if the isolation resistance drops below the minimum required value. The isolation resistance between the high voltage bus of the coupling system for *electrically* charging the REESS and the electrical chassis need not be monitored, because the coupling system for charging is only energized during charging of the REESS. The function of the on-board isolation resistance monitoring system shall be confirmed as described in Annex 6.

	resistance monitoring system shall be confirmed as described in Annex 6.	
5.1.3.4	Isolation resistance requirement for the coupling system used to charge the REESS	Isolation resistance requirement for the coupling system used to charge the REESS *electrically*
	For the coupling system (used to charge the REESS and intended to be conductively connected to the grounded external AC power supply) the isolation resistance shall be at least 1 MΩ when the charger coupler is disconnected. During the measurement, the REESS may be disconnected.	For the coupling system (used to *electrically* charge the REESS and intended to be conductively connected to the grounded external AC power supply) the isolation resistance shall be at least 1 MΩ when the charger coupler is disconnected. During the measurement, the REESS may be disconnected.
5.4.1		*Determination of hydrogen emissions during electrical charging*
5.4.2		*Determination of hydrogen emissions during discharging*
5.4.2.1		*During a normal discharge procedure in the conditions given in Annex 7, hydrogen emissions shall be below 125 g during 5 h, or below 25 x t2 g during t2 (in h)*
6.7	Overcharge Protection	Overcharge Protection *(Applicable only for electrically chargeable REESS)*
Annex 7	DETERMINATION OF HYDROGEN EMISSIONS DURING THE CHARGE PROCEDURES OF THE REESS (See 5.4.2.)	DETERMINATION OF HYDROGEN EMISSIONS DURING THE *ELECTRICAL* CHARGE PROCEDURES OF THE REESS (See 5.4.1.2.)
Annex 7 - Fig 7.1	Determination of hydrogen emissions during the charge procedures of the REESS	Determination of hydrogen emissions during the *electrical* charge procedures of the REESS

Fig 7.2		**Figure 7.2** **Determination of hydrogen emissions during the discharge procedure of tl REESS** 
Annex 7 - Part 5	The test consists in the five following steps:	The test *for hydrogen emission while charging* consists in the five following steps:
Annex 7 - 5.1.1.	Initial charge of the REESS	Initial *electrical* charge of the REESS
		The test for hydrogen emission while discharging consists in the five following steps: *(a) Vehicle / REESS preparation;* *(b) Discharge of the REESS;* *(c) Determination of hydrogen emissions during a normal discharge*
		If the vehicle / REESS has to be moved between two steps, it shall be pushed to the following test area.
		Vehicle Based test
		Vehicle preparation
		The ageing of REESS shall be checked, proving that the vehicle has performed at least 300 km during seven days before the test. During this period, the vehicle shall be equipped with the traction battery submitted to the hydrogen emission test. If this cannot be demonstrated, then the following procedure will be applied.
		Initial mechanical charge of the REESS *The mechanical charge is carried out:* *(a) As per manufacturer guideline* *(b) In an ambient temperature between 293 K and 303 K.*
		Discharges of the REESS

		The procedure starts with the discharge of the REESS of the vehicle while driving on the test track at a steady speed of 70 per cent ± 5 per cent of the maximum speed of the vehicle during 30 minutes. Pre-discharge activation and Post-discharge deactivation, if required, shall be performed as per manufacturer guidelines.
		Discharging is stopped: *(a) When the vehicle is not able to run at 65 per cent of the maximum thirty minutes speed, or* *(b) When an indication to stop the vehicle is given to the driver by the standard on-board instrumentation, or* *(c) After having covered the distance of 100 km.* *After discharging is stopped, process of determining hydrogen emissions should be started.*
		Component Based Test *REESS preparation* *The ageing of REESS shall be checked, to confirm that the REESS has performed at least 5 standard cycles (as specified in Annex 8, Appendix 1).*
		Initial mechanical charge of the REESS *The mechanical charge is carried out:* *(a) As per manufacturer guideline* *(b) In an ambient temperature between 293 K and 303 K.*
		Discharge of the REESS *The REESS is discharged at 70 per cent ±5 per cent of the nominal power of the system.* *Stopping the discharge occurs when minimum SOC as specified by the manufacturer is reached.* *After discharging is stopped, process of determining hydrogen emissions should be started.*

Annex 8 - Appendix 1	**ANNEX 8 – APPENDIX 1** **PROCEDURE FOR CONDUCTING A STANDARD CYCLE** (See Annex 7, 3.2.1.) A standard cycle will start with a standard discharge followed by a standard charge. **Standard discharge:** Discharge rate: The discharge procedure including termination criteria shall be defined by the manufacturer. If not specified, then it shall be a discharge with 1C current. Discharge limit (end voltage): Specified by the manufacturer Rest period after discharge: Minimum 30 min Standard charge: The charge procedure including termination criteria shall be defined by the manufacturer. If not specified, then it shall be a charge with C/3 current.	A standard cycle will start with a standard discharge followed by a standard electrical o mechanical charge whichever applicable. **Standard discharge:** Discharge rate: The discharge procedure including termination criteria shall l defined by the manufacturer. Discharge with 1C current if Constant Current (CC) discharge applicable. If Constant Voltage (CV) discharge is applicabl then it should be discharged at the standard discharge voltage. Discharge limit (end voltage or end power or end current): Specified by the manufacturer Rest period after discharge: Minimum 30 min Standard electrical charge: The charge procedure including termination criteria shall l defined by the manufacturer. Charge with C/3 current if Constant Current (CC) charge applicable. If Constant Voltage (CV) charge is applicable, then should be charged at the standard charge voltage. Standard mechanical charge: Specified by the manufacturer
Annex 8G	OVERCHARGE PROTECTION	OVERCHARGE PROTECTION *(Applicable only for electrically chargeable REESS)*
Annex 8G - 3.2		Discharging
		At the beginning of the test, all relevant main contactors shall be closed.
		A *constant current* discharge shall be performed if *applicable* with at least 1/3 C rate but shall not exceed the maximum current within the normal operating range as specified by the manufacturer.
		A constant voltage discharge shall be performed if applicable with at least standard discharge voltage rate but shall not exceed the maximum voltage within the normal operating range as specified by the manufacturer.
		The discharging shall be continued until the tested-device (automatically) interrupts or limits the discharging. Where an automatic interrupt function fails
		to operate, or if there is no such function then the discharging shall be continued until the tested-device is discharged to 25 per cent of its nominal voltage level *or end point power is reached as described by the manufacturer.*
AIS156	SOC	*SOC or SOE*

(b) Standard No. AIS 039

Scope of Standard:

Battery Operated Vehicles - Measurement of Electrical Energy Consumption

Table 16: Amendment/Adaptive Interpretation of AIS039

Clause	Existing Clause	Amendment/Adaptive Interpretation
3.3	The first charging of the battery shall be carried out as per para 3.5 below, if not already done.	The first charging (electrical or mechanical) of the battery shall be carried out as per para 3.5 below, if not already done.
3.5	Initial charge of the battery	
	Charging the battery consists of the following procedures. NOTE: "Initial charge of the battery" applies to the first charge of the battery, at the reception of the vehicle. In case of several combined tests or measurements, carried out consecutively, the first charge carried out shall be an "initial charge of the battery" and the following may be done in accordance with the "normal charge" procedure.1	Charging the battery consists of the following procedures. NOTE: "Initial charge of the battery" applies to the first charge of the battery *be it electrical or mechanical*, at the reception of the vehicle. In case of several combined tests or measurements, carried out consecutively, the first charge carried out shall be an "initial charge of the battery" and the following may be done in accordance with the "normal charge" procedure.1 *The initial mechanical charge of the REESS is carried out:* *(a) As per manufacturer guideline* *(b) In an ambient temperature between 293 K and 303 K.*
3.5.2.1	Normal charge procedure	**Normal *electrical* charge procedure**
3.5.2.2	End of charge criteria	**End of *electrical* charge criteria**
3.5.2.3	*None*	***Normal mechanical charge procedure***
		The initial mechanical charge of the REESS is carried out: *(a) As per manufacturer guideline* *(b) In an ambient temperature between 293 K and 303 K.*
4	Test conditions	NA for Metal air flow as standard discharge is done at CV and not at Constant Current
5.4.3	Charge of the battery	*Electrical* Charge of the battery

	The vehicle shall be connected to the mains within 30 minutes after the conclusion of the Driving Cycle. The vehicle shall be charged according to normal charge procedure (Refer clause 3.5.1.2 above). The energy measurement equipment, placed between the mains socket and the vehicle charger, measures the charge energy E delivered from the mains as well as its duration. Charging is stopped after 24 h from the previous end of charging time to. NOTE In case of any power disruptions during charging, the 24 h period shall be exceeded according to the disruption duration. The maximum total Power disruption of 30 minutes duration is allowed irrespective of the number of failures. Validity of the charge shall be discussed between the technical services of the approval laboratory and the vehicle's manufacturer.	The vehicle shall be connected to the mains within 30 minutes after the conclusion of the Driving Cycle. The vehicle shall be charged according to normal charge procedure (Refer clause 3.5.1.2 above). The energy measurement equipment, placed between the mains socket and the vehicle charger, measures the charge energy E delivered from the mains as well as its duration. Charging is stopped after 24 h from the previous end of charging time to. NOTE In case of any power disruptions during charging, the 24 h period shall be exceeded according to the disruption duration. The maximum total Power disruption of 30 minutes duration is allowed irrespective of the number of failures. Validity of the charge shall be discussed between the technical services of the approval laboratory and the vehicle's manufacturer.
		The Energy E for mechanically chargeable metal air flow battery or cell will be calculated according to electrical energy capacity multiplied by weight of anode consumed. For more info refer manufacturer guidelines.

(c) Standard No. AIS 038

Scope of Standard

Part I: Safety requirements with respect to the electric power train of motor vehicles of categories M and N, as defined in Rule 2 (u) of CMVR.

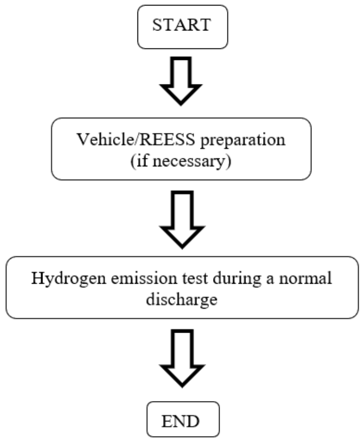
Part II: Safety requirements with respect to the Rechargeable Electrical Energy Storage System (REESS), of motor vehicles of categories M and N, as defined in Rule 2 (u) of CMVR.

Table 17: Amendment/Adaptive Interpretation AIS038

Clause	Existing Clause	Amendment/Adaptive Interpretation
2.5	"Cell" means a single encased electrochemical unit containing one positive and one negative terminal, which exhibits a voltage differential across its two terminals and used as rechargeable electrical energy storage device.	"Cell" means a single encased electrochemical unit containing one positive and one negative terminal, which exhibits a voltage differential across its two terminals and used as rechargeable (both mechanical and electrical) electrical energy storage device.
2.6	"Conductive connection" means the connection using connectors to an external power supply when the REESS is charged.	**"Conductive connection"** means the connection using connectors to an external power supply when the REESS is *electrically* charged.
2.8	"Coupling system for charging the REESS" means the electrical circuit used for charging the REESS from an external electric power supply including the vehicle inlet.	**"Coupling system for *electrically* charging the REESS"** means the electrical circuit used for *electrically* charging the REESS from an external electric power supply including the vehicle inlet.
2.12	"Electric power train" means the electrical circuit which includes the traction motor(s), and may include the REESS, the electric energy conversion system, the electronic converters, the associated wiring harness and connectors, and the coupling system for charging the REESS.	**"Electric power train"** means the electrical circuit which includes the traction motor(s), and may include the REESS, the electric energy conversion system, the electronic converters, the associated wiring harness and connectors, and the coupling system *if applicable* for *electrically* charging the REESS.
2.25	"High voltage bus" means the electrical circuit, including the coupling system for charging the REESS that operates on high voltage.	**"High voltage bus"** means the electrical circuit, including the coupling system *if applicable* for *electrically charging* the REESS that operates on high voltage.

2.36	"Service disconnect" means the device for deactivation of the electrical circuit when conducting checks and services of the REESS, fuel cell stack, etc.	**"Service disconnect"** means the device for deactivation of the electrical circuit when conducting checks and services of the REESS, fuel cell stack, *flow cell stack*, etc.
2.54		***"Metal air flow cell"*** *means a cell characterized by the spatial separation of the electrodes and the movement of the energy storage fluids.*
2.55		***"State of energy" is t****he remaining energy as a percentage of the maximum available energy under operating conditions as declared by the manufacturer.*
5.1.3.3 (b)	In fuel cell vehicles, DC high voltage buses shall have an on-board isolation resistance monitoring system together with a warning to the driver if the isolation resistance drops below the minimum required value of 100 Ω/V. The function of the on-board isolation resistance monitoring system shall be confirmed as described in Annexure VI. The isolation resistance between the high voltage bus of the coupling system for charging the REESS, which is not energized in conditions other than that during the charging of the REESS, and the electrical chassis need not to be monitored.	In fuel cell vehicles, DC high voltage buses shall have an on-board isolation resistance monitoring system together with a warning to the driver if the isolation resistance drops below the minimum required value of 100 Ω/V. The function of the on-board isolation resistance monitoring system shall be confirmed as described in Annexure VI. The isolation resistance between the high voltage bus of the coupling system for *electrically* charging the REESS, which is not energized in conditions other than that during the charging of the REESS, and the electrical chassis need not to be monitored.
5.1.3.4	Isolation resistance requirement for the coupling system for charging the REESS	Isolation resistance requirement for the coupling system used for charging the REESS *electrically*
	For the vehicle conductive connection device intended to be conductively connected to the grounded external AC power supply and the electrical circuit that is galvanically connected to the vehicle conductive connection device during charging of the REESS, the isolation resistance between the high voltage bus and the electrical chassis shall comply with the requirements of	For the vehicle conductive connection device intended to be conductively connected to the grounded external AC power supply and the electrical circuit that is galvanically connected to the vehicle conductive connection device during *electrically* charging of the REESS, the isolation resistance between the high voltage bus and the electrical chassis shall comply with the requirements of paragraph 5.1.3.1. when the conductive connection is disconnected and the

	paragraph 5.1.3.1. when the conductive connection is disconnected, and the isolation resistance is measured at the high voltage live parts (contacts) of the vehicle conductive connection device. During the measurement, the REESS may be disconnected.	isolation resistance is measured at the high voltage live parts (contacts) of the vehicle conductive connection device. During the measurement, the REESS may be disconnected.
5.4.2		***Determination of hydrogen emissions during electrical charging***
5.4.3		***Determination of hydrogen emissions during discharging***
5.4.3.1		*During a normal discharge procedure in the conditions given in Annex 7, hydrogen emissions shall be below 125 g during 5 h, or below 25 x t2 g during t2 (in h)*
6.7	Overcharge protection	Overcharge protection *(Applicable only for electrically chargeable REESS)*
Annex 8	DETERMINATION OF HYDROGEN EMISSIONS DURING THE CHARGE PROCEDURES OF THE REESS (See 5.4.2.)	DETERMINATION OF HYDROGEN EMISSIONS DURING THE *ELECTRICAL* CHARGE PROCEDURES OF THE REESS (See 5.4.1.2.)
Annex 7 - Fig 8.1	Determination of hydrogen emissions during the charge procedures of the REESS	Determination of hydrogen emissions during the *electrical* charge procedures of the REESS

Fig 8.2		**Figure 8.2** **Determination of hydrogen emissions during the discharge procedure of REESS** 
Annex 8 - Part 5	The test consists in the five following steps:	The test *for hydrogen emission while charging* consists in the five following steps:
Annex8 5.1.1.2.	**Initial charge of the REESS**	**Initial *electrical* charge of the REESS**
Annex 8 - 5.3.		*The test for hydrogen emission while discharging consists in the five following steps:* *(a) Vehicle / REESS preparation;* *(b) Discharge of the REESS;* *(c) Determination of hydrogen emissions during a normal discharge* *If the vehicle / REESS has to be moved between two steps, it shall be pushed to the following test area.* ***Vehicle Based test.*** ***Vehicle preparation*** *The ageing of REESS shall be checked, proving that the vehicle has performed at least 300 km during seven days before the test. During this period, the vehicle shall be equipped with the traction battery submitted to the hydrogen emission test. If this cannot be demonstrated, then the following procedure will be applied.*

		Initial mechanical charge of the REESS *The mechanical charge is carried out:* *(a) As per manufacturer guideline* *(b) In an ambient temperature between 293 K and 303 K.* ***Discharges of the REESS*** *The procedure starts with the discharge of the REESS of the vehicle while driving on the test track at a steady speed of 70 per cent ± 5 per cent of the maximum speed of the vehicle during 30 minutes. Pre-discharge activation and Post discharge deactivation, if required, shall be performed as per manufacturer guidelines.* *Discharging is stopped:* *(a) When the vehicle is not able to run at 65 per cent of the maximum thirty minutes speed, or* *(b) When an indication to stop the vehicle is given to the driver by the standard on-board instrumentation, or* *(c) After having covered the distance of 100 km.* *After discharging is stopped, process of determining hydrogen emissions should be started.* ***Component Based Test*** ***REESS preparation*** *The ageing of REESS shall be checked, to confirm that the REESS has performed at least 5 standard cycles (as specified in Annex 8, Appendix 1).* ***Initial mechanical charge of the REESS*** *The mechanical charge is carried out:* *(a) As per manufacturer guideline*

<table>
<tr><td></td><td></td><td> (b) In an ambient temperature between 293 K and 303 K. Discharge of the REESS The REESS is discharged at 70 per cent ±5 per cent of the nominal power of the system. Stopping the discharge occurs when minimum SOC as specified by the manufacturer is reached. After discharging is stopped, process of determining hydrogen emissions should be started. </td></tr>
<tr><td>Annex 9 - Appendix 1</td><td> PROCEDURE FOR CONDUCTING A STANDARD CYCLE A standard cycle shall start with a standard discharge followed by a standard charge. The standard cycle shall be conducted at an ambient temperature of 20 ± 10 °C. <table>
<tr><td colspan="2">Standard discharge:</td></tr>
<tr><td>Discharge rate:</td><td>The discharge procedure including termination criteria shall be defined by the manufacturer. If not specified, then it shall be a discharge with 1C current for a complete REESS and REESS subsystems.</td></tr>
<tr><td>Discharge limit (end voltage):</td><td>Specified by the manufacturer</td></tr>
<tr><td colspan="2">For a complete vehicle, discharge procedure using a dynamometer shall be defined by the manufacturer. Discharge termination will be according to vehicle controls.</td></tr>
<tr><td>Rest period after discharge:</td><td>Minimum 15 min</td></tr>
<tr><td>Standard charge:</td><td></td></tr>
<tr><td colspan="2">The charge procedure shall be defined by the manufacturer. If not specified, then it shall be a charge with C/3 current. Charging is continued until normally terminated. Charge termination shall be according to paragraph 2. of Annexure IX Appendix 2 for REESS or REESS subsystem.</td></tr>
<tr><td colspan="2">For a complete vehicle that can be charged by an external source, charge procedure using an external electric power supply shall be defined by the manufacturer. For a complete vehicle that can be charged by on-board energy sources, a charge procedure using a dynamometer shall be defined by the manufacturer. Charge termination will be according to vehicle controls.</td></tr>
</table></td><td> A standard cycle will start with a standard discharge followed by a standard electrical or mechanical charge whichever applicable. Standard discharge: <table>
<tr><td>Discharge rate:</td><td>The discharge procedure including termination criteria shall be defined by the manufacturer.
Discharge with 1C current if Constant Current (CC) discharge is applicable. If Constant Voltage (CV) discharge is applicable, then it should be discharged at the standard discharge voltage.</td></tr>
<tr><td>Discharge limit (end voltage or end power or end current):</td><td>Specified by the manufacturer</td></tr>
<tr><td>Rest period after discharge:</td><td>Minimum 30 min</td></tr>
<tr><td>Standard electrical charge:</td><td>The charge procedure including termination criteria shall be defined by the manufacturer.
Charge with C/3 current if Constant Current (CC) charge is applicable. If Constant Voltage (CV) charge is applicable, then it should be charged at the standard charge voltage.</td></tr>
<tr><td>Standard mechanical charge:</td><td>Specified by the manufacturer</td></tr>
</table></td></tr>
<tr><td>Annex 9G</td><td>OVERCHARGE PROTECTION</td><td>OVERCHARGE PROTECTION (Applicable only for electrically chargeable REESS)</td></tr>
<tr><td>Annex 9H - 3.2</td><td></td><td>Discharging</td></tr>
<tr><td></td><td></td><td>At the beginning of the test, all relevant main contactors shall be closed.</td></tr>
<tr><td></td><td></td><td>A constant current discharge shall be performed if applicable with at least 1/3 C rate but shall not exceed the maximum current within the normal operating range as specified by the manufacturer.</td></tr>
</table>

		A constant voltage discharge shall be performed if applicable with at least standard discharge voltage rate but shall not exceed the maximum voltage within the normal operating range as specified by the manufacturer.
		The discharging shall be continued until the tested-device (automatically) interrupts or limits the discharging. Where an automatic interrupt function fails to operate, or if there is no such function then the discharging shall be continued until the tested-device is discharged to 25 per cent of its nominal voltage level or end point power is reached as described by the manufacturer.
Annex 9H - 3.3		**Standard *electrical or mechanical* charge and observation period**
		Directly after termination of the discharging the tested-device shall be charged with a *standard electrical or mechanical* charge as specified in Annex 8, Appendix 1 if not inhibited by the tested-device.
		The test shall end with an observation period of 1 h at the ambient temperature conditions of the test environment.
AIS038	SOC	SOC or SOE

CHAPTER 6

6. Recommendations

India lacks energy storage standards that are agnostic to specific chemistries and technologies. This poses a challenge for evaluating and integrating the diverse range of emerging technologies. A range of Technical and Safety Parameters suitable for Chemistry Agnostic Standards have been identified based on examination of existing standards. A draft template for developing chemistry agnostic standards for energy storage has been developed in the BIS format. This template can be utilized for development of standards & certifications. It is recommended that BIS develops and notifies the use of these standards within a period of 3-4 months.

6.1 Modification of existing standards for application specific testing of emerging Energy Storage technologies:

India's existing application standards for energy storage technology (like AIS038, IS039, AIS040, AIS041, AIS048, AIS049, AIS156, AIS039, etc.) inherently impede certification of emerging energy storage technologies (EST). The BIS needs to review and suitably modify the standards, aligning them with the proposed modifications for facilitating application specific testing and certification of the emerging Energy Storage technologies within a period of 3-4 months.

Additionally, Indian conditions require operation in ambient temperature of -20 to 60°C. The following safety requirements need to be adhered to:

i. All technologies should ensure safety and accepted performance in these conditions.
ii. In case technologies cannot inherently function safely with acceptable performance in these conditions, additional thermal management systems need to be mandated.

6.2 Quality and Standards for Connectivity to the Grid:

CEA Safety Standards and CEA (Technical Standards for Connectivity to the Grid) Regulations needs to be suitably updated to cover ESS and other technologies like electrolysers for Green Hydrogen. The Technical Standards may also cover the ‘Performance Standards’ for different services as well as ‘Operation and Maintenance Standards’ for ESS facilities.

6.3 Establishing the Testing Infrastructure for Emerging Energy Storage Technologies:

India's energy storage sector, vital for clean energy integration, suffers from a lack of centralized testing infrastructure data base. This fragmentation leads to unreliable data, hinders innovation due to inconsistent testing protocols, and limits collaboration due to a lack of transparent data sharing. More so, existing central testing and certification agencies, such as

International Centre for Automotive Technology (ICAT) and Automotive Research Association of India (ARAI) under the **Ministry of Heavy Industries (MHI),** lack the necessary equipment and facilities to handle the full range of technical parameters associated with evolving energy storage technologies. This translates to inaccurate and incomplete testing, hindering the development and commercialization of reliable storage solutions.

Upgrading existing **testing facilities** and establishing new ones require significant resources. By leveraging government resources and private sector expertise, PPPs can facilitate the establishment of **high-end testing infrastructure**. This collaborative approach ensures efficient resource allocation and faster development of the testing infrastructure, enabling India to keep pace with the rapid advancements in energy storage technologies.

It is recommended that BIS needs to establish a **centralized testing infrastructure** dashboard for infrastructure, equipment's, type of test, timelines, testing process, fee, trained manpower, online application, testing tracking, result and certification to facilitate the energy storage manufacturers, startups, innovators etc.

6.4 Capacity Building:

Developing a skilled workforce through targeted training programs for personnel by BIS in co-ordination with the different user ministries (MHI, Power, MNRE, Transport etc.) in these centralized facilities is essential. This ensures expertise in handling the intricacies of diverse energy storage technologies. By investing in capacity building via these partnerships, India can create a robust ecosystem that fosters innovation and development in the crucial energy storage sector. This, in turn, will unlock the true potential of clean energy integration, paving the way for a sustainable energy future.

6.5 *The Template for Chemistry Agnostic Standards* has been developed as below that can be utilised by BIS in developing the standards:

Template for Chemistry Agnostic Standard

Part I Metal Air Flow Battery

Part II Metal ion, Metal Sulfur and Lead acid

Part III Fuel cells

Part IV Pumped Hydro

Part I of the standard is as below. This template may be used to develop the other parts of the standard.

CONTENTS

1. **Scope**
2. **Normative references**

3. **Terms and definitions**
4. **Abbreviated terms**
5. **Nomenclature**
6. **Descriptive overviews of the flow battery**
    - 6.1.**Indicative Diagram of a metal air flow battery (MAFB)**
    - 6.2.**Component descriptions of a MAFB**
7. **General Test conditions**
    - 7.1.**Accuracy of measuring instruments**
        - 7.1.1. **Voltage measurement**
        - 7.1.2. **Current measurement**
        - 7.1.3. **Power measurement**
        - 7.1.4. **Electric energy measurement**
        - 7.1.5. **Temperature measurement**
        - 7.1.6. **Mass measurement**
        - 7.1.7. **Time measurement**
    - 7.2. **Ambient temperature**
    - 7.3.**Ambient Humidity**
8. **General Test procedures for performance**
    - 8.1. **Determination of maximum deliverable output power**
    - 8.2. **Determination of maximum input auxiliary power**
    - 8.3. **Determination of energy capacity density**
    - 8.4.**Determination of energy capacity density during Standard Discharge**
    - 8.5.**Determination of energy capacity density during Peak Power Discharge**
    - 8.6. **Determination of efficiency**
9. **Other general aspects**
    - 9.1.**Identification labels and Markings**
    - 9.2.**Electrical Specifications**
10. **Safety tests**
    - 10.1. **Transport**
        - 10.1.1. **Impact**
        - 10.1.2. **Vibration**
        - 10.1.3. **Climate temperature cycle**
        - 10.1.4. **Leaving half used batteries**
    - 10.2. **Misuse**
        - **10.2.1. Crush test**
        - 10.2.1. **External short circuit**
        - 10.2.2. **Over discharge**
        - 10.2.3. **Free fall**
        - 10.2.4. **Reverse energy storage fluid flow direction**
        - 10.2.5. **Nail penetration test**
        - 10.2.6. **Reverse electrical loading**
11. **Transport, storage, disposal and environmental aspects**
12. **Packing and transport**
13. **Dismantling, disposal, and recycling**

1. Scope

This template standard relates to metal air flow battery (MAFB) that can be used in electrical energy storage (EES) applications, automobiles and provides the main terminology and general aspects of this technology, including terms necessary for the definition of unit parameters, test procedures, criteria for performance, environmental issues and ensure safety of Metal air flow batteries under intended use and reasonably foreseeable misuse. It also includes the description of MAFB.

2. References

Different tests, definitions and terminologies have been referred from following standards: IEC 62392-1, IEC 62392-2-1, IEC 62392-2-2, IS 6303-1, IEC 60086- 2, IEC 60086-5

3. Terms and definitions

3.1. Activation

Transition of MAFB from either OFF state or cold standby to ON state.

3.2. Activation time

The duration between the transition of MAFB from either OFF state or cold standby to ON state.

3.3. Air

Air is referring to the mixture of gases comprising of oxygen which is one of the reactants in the metal air flow battery's electrochemical reactions.

3.4. Air filter

A component designed to remove particulate matter and contaminants from the air before it enters the metal air flow stack enclosure

3.5.Air piping

A network of tubes or hoses used to circulate air back and forth between atmosphere to metal air flow stack enclosure. It may include various pipes, connectors, and other components that ensure the proper delivery of air to the enclosure

3.6.Air pump

A device used to circulate air back and forth between atmosphere to metal air flow stack enclosure.

3.7.Ambient temperature

Environmental temperature around a metal air flow battery

3.8. Auxiliary energy

Energy consumed by all the auxiliary equipment and components of the metal air battery support unit.

3.9.Average Discharge Duration

Average time on discharge which shall be met by a sample of batteries

3.10. **Cold standby**

State of MAFB in which no electrical power/energy is supplied from the POMC (Point of Main connection) to the external load and the MABSU is partially active to perform required functions

3.11. **Control Unit**

Electronic unit associated with a metal air flow battery which monitors and/or manages its state, calculates secondary data, reports that data and/or controls its environment to influence the metal air flow battery’s performance, state of energy and/or service life

3.12. **Discharge**

Operation during which a metal air flow cell/ stack when connected to an external electrical circuit results in electrochemical changes within the cell and releases electrical energy in that external electrical circuit

3.13. **End of Discharge**

End of discharge limit conditions specified by the manufacturer at which a discharge is terminated

3.14. **Enclosure**

The part enclosing the internal units and providing protection against direct contact from any direction of access

3.15. **Effective Electrical Output Power**

Electrical power output at the POMC (Point of Main connection) less by the electrical power input at the POAC (Point of Auxiliary Connection) of the MAFB

3.16. **Efficiency**

Effective Electrical Output Power per unit of electrical power output at the POMC of the MAFB

3.17. **Electrode**

The conducting body that contains active materials and through which current enters or leaves a metal air flow cell

3.18. **Energy storage fluid**

Fluid that contains active materials and flows through the metal air flow cell/stack, consisting of liquid, suspension or gas

3.19. **Energy storage fluid piping**

A network of tubes or hoses used to circulate energy storage fluid back and forth between fluid tank and metal air flow stack enclosure. It may include various pipes, connectors, and other components that ensure the proper and safe delivery of fluid to the enclosure

3.20. **Energy storage fluid pump**

A device used to circulate energy storage fluid back and forth between energy storage fluid tank and metal air flow stack enclosure

3.21. **Energy storage fluid tank**

Storage chamber for energy storage fluid. Its design should be at least IP65-compliant

3.22. **End point Power**

Specified value of the output power of the MAFB at which standard discharge is terminated

3.23. **Energy Capacity (Wh)**

The total amount of electrical energy that can be stored in a metal air flow cell

3.24. **Energy Capacity density**

The total amount of 2electrical energy that can be stored in the MAFB per unit weight of metal anode

3.25. **Fluid leakage**

Unplanned escape of fluids from a metal air flow cell, stack or MAFB

3.26. **Fluid system**

Components and equipment destined to store and circulate energy storage fluids, such as tanks, pipes, manual valves, electrical valves, pumps and sensors

3.27. **Forced ventilation**

Movement of air and its replacement with fresh air by mechanical means

3.28. **Fully discharged**

Condition (status) where, after a discharge process as specified by the manufacturer, the metal air flow battery reaches the end of discharge point

3.29. **Gas release**

Emission of gas from the metal air flow battery to the environment

3.30. **Heat exchanger**

A device designed to exchange heat between the metal air flow battery and its surroundings, helping to maintain an optimal temperature range for efficient operation and safety.

3.31. **Hot standby**

State of MAFB in which no electrical power/energy is supplied from the POMC to the external load and the MABSU is fully active to perform required functions.

3.32. **Input Auxiliary power**

Electrical power supplied to all the auxiliary equipment and components of the MABSU

3.33. **Interlock**

Circuit linking mechanical, electrical or other devices intended to make the operation of a piece of apparatus dependent on the condition or position of one or more others.

3.34. **Maximum ambient temperature**

Highest ambient temperature at which the MAFB is operable and should perform according to specified requirements

3.35. **Maximum input auxiliary power**

Highest level of power in watt that can be supplied to the MABSU and at which it is operable and performs according to specified conditions

3.36. **Maximum output power**

Highest level of power in watt that can be supplied by the MAFB and at which it is operable and performs according to specified conditions

3.37. **Metal**

The metal used as anode (negative electrode) can be made up of but not limited to metals like Aluminium, Iron, Lithium, Zinc and their alloys. In case of Aluminium, it should be compliant with EN 481-1, EN485-2, EN515, EN573-2.

3.38. **Metal air battery support unit (MABSU)**

Auxiliary units, such as heat exchanger, ventilation system, safety system, and control unit used in an MAFB, and which are not stacks and not power conversion system

3.39. **Metal air flow cell**

A cell characterized by the spatial separation of the electrodes and the movement of the energy storage fluids

3.40. **Metal air flow battery (MAFB)**

Two or more metal air flow cells electrically connected including all components for use in electrochemical energy unit such as metal air battery support unit and stack

3.41. **Minimum ambient temperature**

Lowest ambient temperature at which the MAFB is operable and should perform according to specified requirements.

3.42. **Natural ventilation**

Movement of air and its replacement with fresh air because of wind and/or temperature gradients

3.43. **Negative terminal**

Accessible conductive part provided for the connection of an external electrical circuit to the negative electrode of the cell

3.44. **Nominal Voltage**

Suitable approximate value of voltage used to identify the voltage of a battery.

3.45. **Non-operating state**

State of the MAFB when it is not performing any required function

3.46. **OFF-state**

State of the MAFB when it is not delivering electrical energy/power at POMC

3.47. **ON-state**

State of MAFB when it is actively delivering electrical energy/power at POMC

3.48. **Open circuit Voltage (OCV)**

Voltage across the terminals of a metal air flow battery when no current is flowing

3.49. **Operating state**

State in which the MABF performs the required functions and includes the ON-state, hot standby and cold standby states.

3.50. **Operational condition**

Activity or status where all the different elements of a complex activity such as electrochemical changes and MABSU are brought into a harmonious and efficient relationship.

3.51. **Output power**

Electrical power supplied by the metal air flow battery during discharge.

3.52. **Point of auxiliary connection (POAC)**

Reference point where the MABSU is connected to an external power source.

3.53. **Point of auxiliary measurement (POAM)**

Physical location in the MABSU where the energy absorbed from the external power source is to be measured/recorded

3.54. **Point of main connection (POMC)**

Reference point where the MAFB is connected to the final application point.

3.55. **Point of main measurement (POMM)**

Physical location in the (MAFB) circuit where the energy delivered from the stack is to be reproducibly measured/recorded

3.56. **Positive terminal**

Accessible conductive part provided for the connection of an external electrical circuit to the positive electrode of the cell

3.57. **Rated energy**

Manufacturer declared value of the energy content of the MAFB when discharged under specified (rated) conditions and measured at the POMM.

3.58. **Rated input auxiliary power**

Manufacturer declared value of input auxiliary power for a specific set of operating conditions of the MAFB and measured at the POAM.

3.59. **Rated maximum Output power**

Manufacturer declared highest output power level that the MAFB can deliver.

3.60. **Rated output power**

Manufacturer declared value of output power for a specific set of operating conditions of the MAFB

3.61. **Routine test**

Conformity test made on each individual item during or after manufacture

3.62. **Sensor**

Device which detects/ measures a physical property and records, indicates or responds to it

3.63. **Service life**

Duration from the time of MAFB commissioning test to the end of service life

3.64. **Short circuit current**

Maximum current which should be delivered by a MAFB into an external circuit with zero electrical resistance, or an external circuit which depresses the cell or battery voltage to approximately 0 volt.

3.65. **Shutdown**

Regulated or instantaneous shutdown of a MAFB triggered by the shutdown of the end application system, internal or external protection systems, or manual intervention.

3.66. **Stack**

Group of metal air flow cells, assembled in a contiguous form and usually connected electrically in series

3.67. **Standard Discharge**

A constant voltage discharge of a metal air flow cell/stack at standard discharge voltage as declared by the manufacturer.

3.68. **Standard Discharge voltage**

The voltage declared by the manufacturer at which standard discharge of a metal air flow cell/stack is to be carried out.

3.69. **Standby state**

State of MAFB in which no electrical power is supplied from the POMC to the external load and the MABSU is partially or fully active to perform required functions

3.70. **State of energy**

The remaining energy as a percentage of the maximum available energy under operating conditions as declared by the manufacturer.

3.71. **Type test**

Conformity test made on one or more items representative of the production.

4. Abbreviated terms

MABSU	Metal air battery support Unit
MAFB	Metal air flow battery
POAC	Point of auxiliary connection
POAM	Point of auxiliary measurement
POMC	Point of main connection
POMM	Point of main measurement

5. Nomenclature

Refer Annexure C (Clause 4.1.5) of IS 6303-1

6. Descriptive overview of the Metal Air Flow Battery

6.1. Indicative Diagram of a metal air flow battery (MAFB)

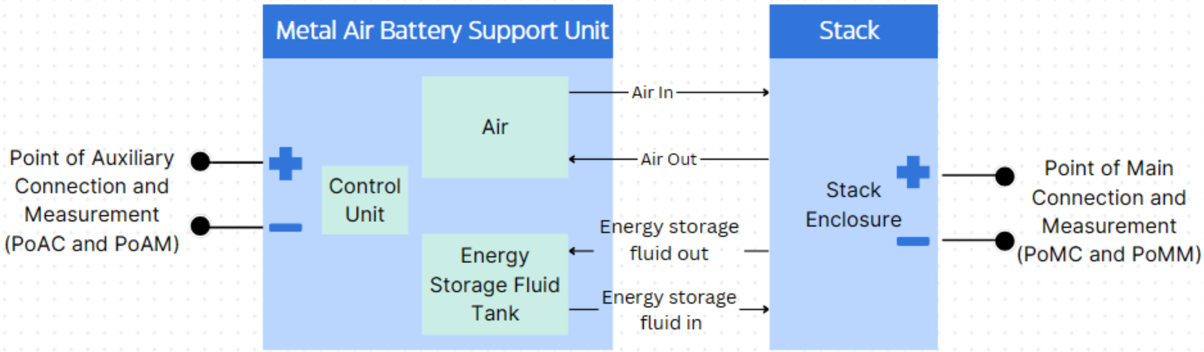


Figure 1 – Metal Air Flow battery (MAFB)

6.2. Component description of metal air flow battery (MAFB)

1. **Stack**
    1. Electrodes
    2. Enclosure
2. **Metal air Battery support Unit (MABSU)**
    1. Pump
    2. Tank
    3. Piping
    4. Air and air filter
    5. Sensors
    1. Energy storage fluids
    7. Heat exchanger
    8. Control Unit

7. General test conditions

7.1. Accuracy of measuring instruments

7.1.1. Voltage measurement

The instruments used shall be of an accuracy class equal to 0.5% or better. The internal resistance of the voltmeter used shall be at least 1 kohm/V.

7.1.2. Current measurement

The instruments used shall be of an accuracy class equal to 0.5% or better.

7.1.3. Power measurement

The instruments used shall be of an accuracy class equal to 0.5% or better.

7.1.4. Electric energy measurement

The instruments used shall be of an accuracy class equal to 1% or better.

7.1.5. Temperature measurement

The instruments used shall have a resolution of 0.5 K and the accuracy of the instruments shall be ±0.5K or better.

7.1.6. **Mass measurement**

The instruments used shall have a resolution of 1 gram and accuracy of the instruments shall be ±1 gram or better.

7.1.7. **Time measurement**

The instruments used shall have a resolution of 1s and the accuracy of the instruments shall be 1% of the measured time interval or better.

7.2. **Ambient temperature**

All tests of a MAFB shall be carried out at an ambient temperature of 27 °C ± 2 K unless otherwise specified in a test clause or agreed by the manufacturer and user. The ambient temperature shall be measured and reported.

7.3. **Ambient Humidity**

All tests of a MAFB shall be carried out at relative humidity of 60 ± 5 percent RH unless otherwise specified in a test clause or agreed by the manufacturer and user. The ambient humidity shall be measured and reported.

8. **General Test procedures for performance**

8.1.**Determination of maximum deliverable output power**

8.1.1. **General**

The maximum deliverable output power is affected by the discharge voltage, temperature, and the auxiliary power needs for the MAFB operation. Any maximum deliverable output power value determined is hence representative or applicable only to the specific operation condition of the MAFB.

The manufacturer's recommended procedures should be followed during metal air flow cell or battery preparation.

8.1.2. **Test procedures**

The test for determining the maximum deliverable output power shall be in accordance with the following procedures:

A Constant Voltage (CV) discharge shall be carried out at the POMC of the MAFB.

The conditions of all the components of the MABSU should be noted and as declared by the manufacturer in the ON state. The MABSU shall be supplied by a separate power source. The rating of the power source shall be greater than the maximum receivable input auxiliary power as declared by the manufacturer.

The voltage level selected for CV discharge is the voltage of a metal air flow cell multiplied by number of cells in series in the MAFB.

The test unit shall be discharged at constant voltage steps with each step of 5 minutes starting from Open circuit voltage to 0.2V multiplied by number of cells in series of the MAFB. The step size/interval shall be equal to 0.1V multiplied by number of cells in series of the MAFB.
The total time duration of the discharge shall be recorded. The voltage level at each step shall be kept constant to within ±0.5 % of the set value.
The ambient temperature of the MAFB shall be maintained at a constant temperature of 27 °C ± 2 K. The points within the MAFB indicative of the MAFB temperature shall be declared by the manufacturer and temperature at these points shall be recorded during the test.
The maximum deliverable output power value and voltage at the POMM and the corresponding auxiliary power supplied shall be recorded. The maximum deliverable output power value shall be accompanied with the corresponding voltage at the POMM and temperature of the MAFB.

8.2. **Determination of maximum input auxiliary power**

8.2.1. **General**

The maximum input auxiliary power is affected by the operating state, temperature, voltage and delivered output power of the MAFB. Any maximum input auxiliary power value determined is hence representative or applicable only to the specific operation condition of the MAFB.
The manufacturer's recommended procedures should be followed during metal air flow cell or battery preparation.

8.2.2. **Test procedure**

The test for determining the maximum input auxiliary power shall be in accordance with the following procedures:
A Constant Voltage (CV) discharge shall be carried out at the POMC of the MAFB.
The conditions of all the components of the MABSU should be noted and as declared by the manufacturer in the ON state. The MABSU shall be supplied by a separate power source. The rating of the power source shall be greater than the maximum input auxiliary power as declared by the manufacturer.
The voltage level selected for CV discharge is the voltage at which the maximum deliverable output power is recorded.
The test unit shall be discharged at constant voltage for 5 minutes during which the voltage shall be kept constant to within ±0.5 % of the set value.
The ambient temperature of the MAFB shall be maintained at a constant temperature of 27 °C ± 2 K. The points within the MAFB indicative of the MAFB temperature shall be declared by the manufacturer and temperature at these points shall be recorded.
The maximum input auxiliary power value at the POAM, delivered output power, current and voltage at the POMM and the corresponding auxiliary power supplied shall be recorded. The maximum input power value shall be accompanied with the corresponding voltage, delivered output power at the POMM and temperature of the MAFB.

8.3.**Determination of energy capacity density**

8.3.1. **Determination of energy capacity density during Standard Discharge**

8.3.1.1. **General**

This test is for determining the energy capacity density of the MAFB by measuring the total discharge energy output from the MAFB during standard discharge per unit weight metal anode.

The manufacturer's recommended procedures should be followed during metal air flow cell or battery preparation.

8.3.1.2. **Test procedures**

The test for determining the energy capacity shall be in accordance with the following procedures:

The total weight of the metal anode in each metal air flow cell/stack of the MAFB shall be measured before test.

A Constant Voltage (CV) discharge shall be carried out at the POMC of the MAFB at standard discharge voltage as declared by the manufacturer.

The conditions of all the components of the MABSU should be noted and as declared by the manufacturer in the ON state. The MABSU shall be supplied by a separate power source. The rating of the power source shall be greater than the maximum input auxiliary power as declared by the manufacturer.

The standard discharge voltage at the POMC shall be kept constant to within ±0.5 % of the set value throughout the duration of the test.

The delivered output power, current and voltage at the POMM shall be recorded in intervals of 1 second.

The test shall be carried out till the delivered output power falls to the end point power as declared by the manufacturer.

The energy capacity is the time summation/integration of the output power till end of point power. The energy capacity density is obtained by dividing the energy capacity with the total metal anode weight in kg.

The energy capacity shall be accompanied with the corresponding standard discharge voltage and maximum output power at POMM, end point power and temperature of the MAFB.

The ambient temperature of the MAFB shall be maintained at a constant temperature of 27 °C ± 2 K. The points within the MAFB indicative of the MAFB temperature shall be declared by the manufacturer and the temperature at these points shall be recorded during the test.

8.3.2. **Determination of energy capacity density during Peak Power Discharge**

8.3.2.1. **General**

This test is for determining the energy capacity density of the MAFB by measuring the total discharge energy output from the MAFB during peak power discharge per unit weight metal anode.

The manufacturer's recommended procedures should be followed during metal air flow cell or battery preparation.

8.3.2.2. **Test procedures**

The test for determining the energy capacity shall be in accordance with the following procedures:

The total weight of the metal anode in each metal air flow cell/stack of the MAFB shall be measured before test.
A Constant Voltage (CV) discharge shall be carried out at the POMC of the MAFB at the maximum deliverable output power voltage point obtained in 8.1.
The conditions of all the components of the MABSU should be noted and as declared by the manufacturer in the ON state. The MABSU shall be supplied by a separate power source. The rating of the power source shall be greater than the maximum input auxiliary power as declared by the manufacturer.
The standard discharge voltage at the POMC shall be kept constant to within ±0.5 % of the set value throughout the duration of the test.
The delivered output power, current and voltage at the POMM shall be recorded in intervals of 1 second.
The test shall be carried out till the delivered output power falls to the end point power as declared by the manufacturer.
The energy capacity is the time summation/integration of the output power till end of point power. The energy capacity density is obtained by dividing the energy capacity with the total metal anode weight in kg.
This energy capacity shall be accompanied with the corresponding discharge voltage and maximum output power at POMM, end point power and temperature of the MAFB.
The ambient temperature of the MAFB shall be maintained at a constant temperature of 27 °C ± 2 K. The points within the MAFB indicative of the MAFB temperature shall be declared by the manufacturer and the temperature at these points shall be recorded during the test.

8.4. **Determination of efficiency**

8.4.1. **General**

The efficiency of the MAFB is affected by the delivered output power and the input auxiliary power consumption during the discharge of the MAFB. Any energy efficiency determination is hence representative or applicable only to the MAFB at the specified power levels.
The temperature and conditions of the MABSU shall be recorded and reported.
The manufacturer's recommended procedures should be followed during metal air flow cell or battery preparation.

8.4.2. **Calculation**

Effective maximum output power = (maximum deliverable output power - maximum input auxiliary power)

E_{PMAX} = (Effective maximum output power)/ (maximum deliverable output power)

Where E_{PMAX} is the maximum efficiency obtained at maximum deliverable output power at a constant MAFB ambient temperature of 27 °C ± 2 K.

9. **Other general aspects**

9.1. **Identification labels and Markings**

9.1.1. **Name plate information**

The name plate/label(s) shall include the following information:

a) manufacturer's name,

b) serial number (optional),
c) date of commissioning (optional),
d) maximum DC voltage(V), current(A) and power(kW) in operation,
e) rated energy capacity density (kWh/kg),
f) transport weight (kg) (optional),
g) chemical type of battery (active materials shall be indicated),

9.1.2. Warning label information and location

The warning labels shall be placed at such a position that they are visible from any direction of approach to the MAFB where hazards can be present. The safety symbols and possibly associate information shall be explained and/or included in the MAFB instruction manual.

9.2. Electrical Specifications

Table 1 Electrical Specifications

Electrical Specifications	**Values**
Open Circuit Voltage	1.50 V -2.30V
End point Power	0.01*P_{0max}
Nominal Voltage	1.20 V
Energy Capacity Density	Greater than 1500 Wh/kg of metal anode at standard discharge Voltage
Activation time	< 1min
Standard discharge Voltage	1.20 V
Average Discharge Duration	Greater than 0.6*t hours at standard discharge voltage

*Above values are for Aluminum air flow battery

Where t is thickness of metal anode in mm for prismatic metal air flow cell, P_{0max} is maximum deliverable output power

10. Safety Tests

10.1. Transport

Table 2 Transport

Test	**Intended use simulation**	**Requirements**	**Procedure Reference**
Electrical test	Storage after partial use	No leakage, No fire, No explosion	IEC 60086-5, Clause 6.3.2.1
Environmental/ Mechanical tests	Transportation - Shock	No leakage, No fire, No explosion	AIS-156, Clause 6.4.2 and Annex 8D
	Transportation - Vibration	No leakage, No fire, No explosion	AIS-156, Clause 6.2 and Annex 8A

Climatic-temperature	Climatic-temperature cycling	No leakage, Nofire, No explosion	IEC 60086-5, Clause 6.3.2.4

10.2. **Misuse**

Table 3 Misuse

Test	**Intended use simulation**	**Requirements**	**Procedure Reference**
Electrical test	Incorrect Installation	No fire, No explosion	IEC 60086-5, Clause 6.4.2.1
	External short circuit	No fire, No explosion	IEC 60086-5, Clause 6.4.2.2
	Over discharge	No fire, No explosion	IEC 60086-5, Clause 6.4.2.3
Environmental test	Free fall	No fire, No explosion	IEC 60086-5, Clause 6.4.2.4
	Nail penetration test	No fire, No explosion	AIS 048, Clause 2.2.4
	Crust test	No fire, No explosion	~~IEC 62660-2, Clause 6.1.3~~
Human mistake	Reverse energy storage fluid flow direction	No fire, No explosion	

10.2.1. Crush Test

The test is performed to characterize cell responses to external load forces that may cause deformation. The test shall be performed as follows.

a) Perform the test at 100% State of Energy of cell.
b) The cell shall be placed on an insulated flat surface and be crushed with a crushing tool of round or semiconductor bar, or sphere or hemisphere with a 150mm diameter. It is recommended to use the round bar to crush a cylindrical cell, and the sphere for a prismatic cell. The force for the crushing shall be applied in direction nearly perpendicular to a layered face of positive and negative electrodes inside cell. The crushing tool shall be selected so that the cell is deformed nearly in proportion to the increase of crushing force.
c) The force shall be released when a deformation of 15% or more of initial cell dimension occurs, or the force of 20 times the weight of cell applied. The cells remain on test for 24 h.

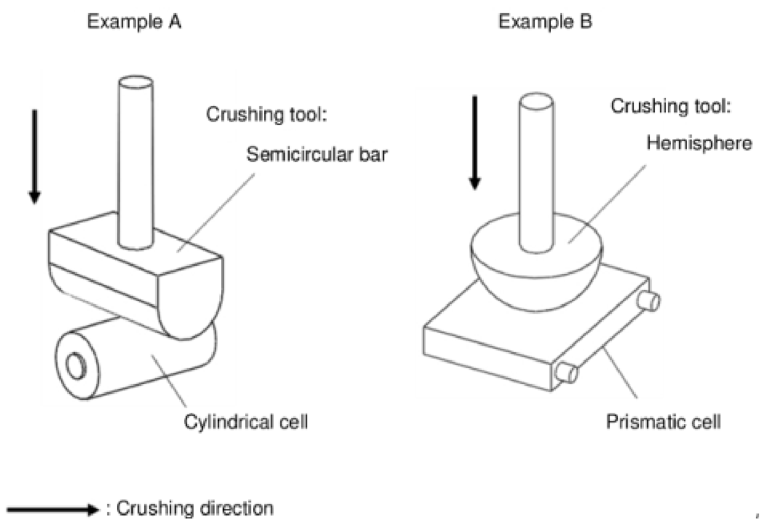


Figure 2 - Example of Crush test

11. **Transport, storage, disposal and environmental aspects**

11.1. **Packing and transport**

For protection against hazards, appropriate measures shall be taken, such as emptying the fluids from the stack or discharging before transportation, proper insulation of terminals and other protective measures as specified by the manufacturer to avoid any hazardous chemical changes during packing and transportation.

11.2. **Dismantling, disposal, and recycling**

For dismantling, disposal and recycling follow manufacturer guidelines.

12. **Safety requirements and protective measures**

12.1. **General**

The metal air flow battery differs from other batteries, in that a system for circulating the energy storage fluid is present. The fluid circulating system consists of tanks, pumps, piping, sensors and some safety-relevant devices.

From a chemical safety point of view, since fluid is contained in tanks, pipes and stacks, the sealing is an important factor. If there is also a possibility of any gaseous emissions as declared by the manufacturer, appropriate countermeasures shall be implemented.

12.2. **Short-circuits**

The electrical energy stored in an MAFB can be released in an uncontrolled manner due to short-circuiting the terminals. Because of its considerable level of energy and subsequent high current, the heat generated can melt metal, produce sparks, cause explosion, or vaporize fluid.

To avoid short-circuits protective devices such as insulation shrouds, fuses and circuit breakers shall be installed in a way that a short-circuit does not occur under any foreseeable conditions.

- For protective measures, the MAFB may mitigate a short-circuit fault which occurs outside stacks by stopping the supply of energy and fluids to the metal–air flow battery cells;
- stopping power conversion system and opening circuit breaker(s); and,
- interrupting the short-circuit current path by using fuses between stacks.

It is suggested that each stack has a fuse to break the short-circuit path. Specific location and quantity of fuses and/or circuit breakers shall be decided between the manufacturer and the system user in consideration of cell protection and system safety.

12.3. **Hazards of gaseous emissions**

12.3.1. **General**

Metal-air Flow batteries can produce gases in small quantities that can be flammable and/or corrosive in nature. The quantities produced depend on the operating conditions of the MAFB and their release to the environment shall be managed with adequate safety features (e.g. ventilation, absorption traps, scrubbers).

The gas emission and its mitigation shall be considered in the metal air flow battery design process. It is suggested to install necessary gas monitoring equipment with alarms and appropriate interlocks.

12.3.2. **Types of gases**

12.3.2.1. **Flammable gases**

The risk level of flammable gases increases if the following hazards coincide:

- accumulation of combustible gases,
- their mixture with oxygen,
- presence of ignition sources.

The MAFB shall have protective measures against the above hazards, including but not limited to:

- reduction in the generation and dilution of combustible gases,
- prevention of diffusion of gases outside the volume where they are generated
- elimination of ignition sources

12.3.2.2. **Corrosive gases**

The risk level of corrosive gases increases if the following hazards coincide:

- generation and accumulation of corrosive gases,
- human access to the vicinity of corrosive gases.

The MAFB shall have protective measures against the above hazards, including but not limited to:

- Construction of the system with corrosion-resistant material
- elimination and dilution of corrosive gases,

- collection of toxic gases by a scrubber
- limitation of human access.

12.3.3. **Ventilation**

12.3.3.1. **General**

The manufacturer shall specify the ventilation requirements for the compartment where the MAFB is installed. This specification shall involve the warning signs, operator access limitation, mitigation of static discharges, numbers of air exchanges in m^3/h required air flow patterns and exhaust direction. The safety requirements and procedures for personnel and user handling shall be specified. The manufacturer shall provide data and a measurement method used to determine the gas emission rating, and ventilation measures shall be implemented.

Ventilation is required to ensure the necessary thermal management and that no combustible or harmful gases reach a critical concentration level. The ventilation requirement shall be met by either one or a combination of the following methods:

- natural ventilation
- forced ventilation through the room or enclosure.

12.3.3.2. **Natural ventilation**

When natural ventilation is used, battery rooms or enclosures shall be equipped with an inlet and an outlet for the air with a minimum free opening area which meets the ventilation requirements.

12.3.3.3. **Forced ventilation**

When forced ventilation is used, gases which are released from the MAFB into the room or enclosure shall be expelled to the atmosphere using a ventilation system, which may combine an opening and fan. If forced ventilation is essential for the safe operation of the MAFB, then an appropriate interlock shall prevent its operation when the forced ventilation is not operating or has failed.

12.3.4. **Warning sign**

Appropriate warning signs which prohibit sparks, smoking, open flame, and electrostatic discharges shall be placed at the entrance of the hazardous area.

12.3.5. **Close vicinity to emissions**

The dilution of gases is not always fully achieved in the close vicinity of the exhaust of released gases or at the outlet of direct forced ventilation, therefore a safety distance from the outlet shall be observed. The dispersion of gases depends on the gas emission rate and the type of ventilation close to the source of emission.

12.4. **Hazard posed by liquids**

12.4.1. **General**

The impact of the energy system fluid involved in the MAFB leakage can be categorized in terms of toxicity, corrosiveness, environmental impacts, and flammability.

Since the energy storage fluids are flowing through the fluid system, there is a possibility that a leakage will continue unattended or unmitigated if the detection of the leakage and/or the protection against the leakage are inappropriate. In addition, fluids supplied to the stacks may be stored in the common tank in a large volume while:

- ensuring the sealing performance of the fluid system,
- incorporating corrosion resistance in the design and the material of the parts that come into contact with the energy storage fluids,
- detecting leakage and taking appropriate measures,
- preventing leakage to the surroundings, and,
- providing information and markings concerning the fluid.

12.4.2. **Detection of energy storage fluid leakage**

Leakage shall be detected by appropriate protection measures such as a leakage sensor. The detection and protective functions shall be verified appropriately.

The detection of the fluid shall initiate the necessary countermeasures such as stopping the pumps and closing the valves.

12.4.3. **Protective measures against leakage**

The MAFB must have a leakage collection provision such as a collecting tray (also known as collecting basin) under the tanks which is stable to the energy storage fluid and has a volume at least equal to the largest tank of the MAFB. Refer to the local safety regulations for other or additional protective measures.

12.5. **Operational hazards and measures**

12.5.1. **General**

When the MAFB is designed to work with other equipment upstream and/ or downstream, such as control centre upstream, a signal interface or other means shall be provided to enable a coordinated operation, including start, stop, emergency shutdown and discharge.

Improper integration can cause unintentional operation which potentially leads to a hazardous situation.

Proper coordinated operation shall be confirmed by appropriate methods.

12.5.2. **Start**

The MAFB shall be started only when the starting condition is achieved through ensuring that:

- all safeguards are in place and are functional,
- the safety conditions have been fulfilled for restart after a stop,

- non-hazardous conditions are verified for intentional restarting actuation,
- suitable interlocks are provided for correct sequential starting.

12.5.3. **Remote monitoring and control systems**

An MAFB that can be operated remotely shall have a local, labelled switch or other means to disconnect the system from remote signals that may be used while a local operator performs inspection or maintenance.

The implementation of a remote monitoring system shall be considered in order to check if the system is operating safely. The data collected automatically from the MAFB inquiry can help to evaluate its state of health and the remaining life of its components. Diagnosis is performed by monitoring the change of capacity or changes in the measured parameters. These data can be transmitted through an information network in a timely manner.

12.5.4. **Protection**

The MAFB shall be equipped with appropriate protective devices to detect abnormal situations and initiate an emergency stop.

12.5.5. **Auxiliary power failure**

In case of an auxiliary power failure to the MABSU, the MAFB shall be designed in such a way to ensure safe shutdown of the system. This may include:

- necessary detection of loss of power in the MAFB,
- the trigger of an alarm informing on the situation at the designated terminal,
- initiation of a proper designated shutdown including separation from the POMC, and
- stopping of the pumps and closing of the designated valves

As an example, this can be facilitated through integrating a UPS for supporting the Control Unit operation and/or supplying power from a separate secure source.

12.6. Safety requirement for stacks

The tests of stacks described below shall be carried out in order to ensure safety.

Table 4 - List of verification tests for stacks for protective measurements

Test	Test category	Test object	Acceptance criteria
External Short circuit	Type test	Stack	The test is passed if there is no fire, explosion, or fluid leakage.
Heat shock strength	Type test	Stack	There shall be no visible fluid leakage.
Leakage	Routine test	Stack	There shall be no visible fluid leakage.

13. **Sampling and Quality assurance**

13.1. **Sampling**

Refer Clause 7 of IS 6303-1

13.2. **Quality plan**

The manufacturer shall prepare and implement a quality plan that defines procedures for the inspection of materials, components, cells and batteries and which covers the whole process of producing each type of cell or battery. Manufacturers should understand their product capabilities and should institute the necessary controls as they relate to product safety.

14. **Example chemistries of metal air flow batteries**

Table 5 - Example chemistries of metal air flow batteries

S. No.	Negative electrode	Energy storage fluid	Positive electrode
1	Aluminium (Al)	Alkaline aqueous	Air
2	Zinc (Zn)	Alkaline aqueous	Air
3	Iron (Fe)	Alkaline aqueous	Air
4	Li (Li)	Non aqueous	Air

15. **PROCEDURE FOR CONDUCTING A STANDARD CYCLE**

A standard cycle will start with a standard discharge followed by a standard electrical or mechanical charge, whichever applicable.

Standard Discharge:

Discharge rate:	The discharge procedure including termination criteria shall be defined by the manufacturer. Discharge with 1C current if Constant Current (CC) discharge is applicable. If Constant Voltage (CV) discharge is applicable, then it should be discharged at the standard discharge voltage.
Discharge limit (end voltage or end power or end current):	Specified by the manufacturer

Rest period after discharge:	Minimum 30 min

Standard Charge:

Standard Electrical charge:	The charge procedure including termination criteria shall be defined by the manufacturer. Charge with C/3 current if Constant Current (CC) charge is applicable. If Constant Voltage (CV) charge is applicable, then it should be charged at the standard charge voltage.
Standard Mechanical charge:	Specified by the manufacturer

Annexure-I

प्रधानमंत्री कार्यालय
PRIME MINISTER'S OFFICE

साउथ ब्लाक / South Block,
नई दिल्ली / New Delhi– 110 011

Please find enclosed, for necessary action, copy of Minutes of meeting chaired by Shri Tarun Kapoor, Advisor to PM on 24.06.2023 through VC on 'Need for developing Chemistry Agnostic Standards for Energy Storage Technologies'.

(Vyasan R.)
Director
Tele: 23012456

Dr. V.K Saraswat, Member, NITI Aayog
Secretary, M/o Electronics & Information Technology
Secretary, M/o Heavy Industries
Secretary, D/o Science & Technology
Executive Director (R&D), IOCL
Director General, Bureau of Indian Standards

PMO ID No. 5655540- IR

Dated: 4.07.2023

Encl: as above

Minutes of meeting through VC on, "Need for Developing Chemistry Agnostic Standards For Energy Storage Technologies," under Chairmanship of Shri Tarun Kapoor, Adviser to the Prime Minister on 24th June 2023 at 1 PM.

1. A meeting was held under the Chairmanship of Shri Tarun Kapoor, Adviser to the Prime Minister on the topic, "Need for Developing Chemistry Agnostic Standards For Energy Storage Technologies." A list of participants is enclosed in the **Annexe-I.**
2. The following points emerged during the meeting:
   a. NITI Aayog may explore the possibility of setting up of an Expert Committee under the Chairmanship of Member (Energy). The expert group shall have representatives from the Ministries of Heavy Industry, Science and Technology, Electronics and Information Technology, Power, MNRE, Petroleum and other

relevant organisations. This committee may provide guidance regarding specifications, standards and other technical issues connected with energy storage.

b. NITI may advise Department of Heavy Industry (DHI) on the appropriateness of the matrix based on scientific parameters such as the energy capacity and cycle life developed on Production Linked Incentives-II by DHI.

c. The structure of the new tranche of PLI being issued by DHI may leave the decision on the nature of chemistry used in the batteries to the those setting up plants.

3. The meeting ended with thanks to the Chair.

*****

List of Participants

From Ministry/Department

1. Dr. V.K Saraswat, Member, NITI Aayog
2. Shri Sudhendu Sinha, Adviser, NITI Aayog
3. Shri Rajnath Ram, Adviser, NITI Aayog
4. Shri M.K Upadhyaya, Deputy Adviser, NITI Aayog
5. Shri Alkesh Kumar Sharma, Secretary, M/o Electronic & Information Technology
6. Dr. Sandip Chatterjee, Senior Director, M/o Electronics & Information Technology
7. Shri Kamran Rizvi, Secretary, M/o Heavy Industries
8. Dr. S Chandrashekhar, Secretary, D/o Science & Technology
9. Shri Umesh Srivastava, Executive Director (R&D), IOCL
10. Shri Rajeev Sharma, Deputy Director General, Bureau of Indian Standard

From PMO:

11. Advisor (TK)
12. Dir (V)

Annexure-II

File No. I-22/2/31/2023-(P&E)
Government of India
NITI Aayog
(Energy Vertical)

NITI Bhawan, Sansad Marg,
New Delhi-110001
Dated: 13th July, 2023

Office Memorandum

Subject: Constitution of the Expert Committee for Developing Chemistry agnostic standards for energy storage technologies.

The undersigned is directed to refer to PMO ID No. 5655540-IR dated 04th July 2023 regarding the minutes of the meeting on "Need for developing Chemistry Agnostic Standards for Energy Storage Technologies". As per para 2(a) of the minutes, an Expert Committee for developing chemistry agnostic standards for energy storage technologies has been constituted under the Chairmanship of Dr. V. K Sarsawat, Member, NITI Aayog. The composition of the committee is as follows:

1.	Dr. V. K Sarsawat, Member, NITI Aayog	Chairman
2.	Secretary (HI), Ministry of Heavy Industry	Member
3.	Secretary, Ministry of Science & Technology	Member
4.	Secretary, Ministry Electronics and Information Technology	Member
5.	Secretary, Ministry of Power	Member
6.	Secretary, Ministry of New and Renewable Energy	Member
7.	Secretary, Ministry of Petroleum and Natural Gas	Member
8.	Director General, BIS	Member
9.	Member (Hydro), CEA	Member
10.	Adviser (Transport & E-Mobility), NITI Aayog	Member
11.	Adviser (Energy, Natural Resources & Environment), NITI Aayog	Member
12.	Dr. Rahul Walawalkar, India Energy Storage Alliance	Member
13.	Sh. Kushagra Srivastava, CEO, Chakr Innovations	Member
14.	Sh. Manoj Kumar Upadhyay, Dy Adviser (Energy), NITI Aayog	Member- Secretary

2. The committee may co-opt any expert as a member of the committee.

3. The terms and references of the committee are as follows:

   a. To provide guidance regarding specifications, standards, and other issues pertaining to chemistry-agnostic storage technologies.
   b. To advise the Ministry of Heavy Industry on the appropriateness of the matrix based on scientific parameters such as the energy capacity and cycle life for Production Linked Incentives-II.

This issues with the approval of the competent authority.

(Manoj Kumar Upadhyay)
Dy Adviser (Energy)
Telephone: 23096757

To,

1. **The Secretary (HI), Ministry of Heavy Industry, Udyog Bhawan, Rafi Marg, New Delhi- 110011, Email id: shioff@nic.in**
2. **The Secretary, Department of Science & Technology, Technology Bhavan, New Mehrauli Road, New Delhi-110 016. Email id: dstsec@nic.in**
3. **The Secretary, Ministry Electronics and Information Technology, Electronics Niketan, 6, CGO Complex, Lodhi Road, New Delhi-110003, Email id: secretary@meity.gov.in**
4. **The Secretary, Ministry of Power, Shram Shakti Bhawan, Rafi Marg, New Delhi-110001, Email id: secy-power@nic.in**
5. **The Secretary, Ministry of New and Renewable Energy, Atal Akshay Urja Bhawan, CGO Complex, Lodhi Road, New Delhi - 110 003, India, Email id: secy-mnre@nic.in**
6. **The Secretary, Ministry of Petroleum and Natural Gas, Shastri Bhawan, Dr. Rajendra Prasad Road, New Delhi – 110001, Email id: sec.png@nic.in**
7. **The Member (Hydro), CEA, Central Electricity Authority, Sewa Bhawan, R.K.Puram, Sector-1, New Delhi-110 066 Email id: member.he@cea.nic.in**
8. **The Director General, BIS, 9, Bahadur Shah Zafar Marg, New Delhi-110002, Email id: dg@bis.gov.in**
9. **Dr. Rahul Walawalkar, India Energy Storage Alliance, Email id: rwalawalkar@ces-ltd.com, ddash@ces-ltd.com**
10. **Sh. Kushagra Srivastava, CEO, Chakr Innovations, Email id kushagra.srivastava95@gmail.com, kushagra@chakr.in**

Copy to

1. **PS to VC, NITI Aayog**
2. **PS to Dr. V. K Sarsawat, Member, NITI Aayog**
3. **PSO to CEO, NITI Aayog**
4. **PS to Adviser (Transport & E-Mobility), NITI Aayog**
5. **PS to Adviser (Energy, Natural Resources & Environment), NITI Aayog**

File No. I-22/2/31/2023-(P&E)
Government of India
NITI Aayog
(Energy Vertical)

NITI Bhawan, Sansad Marg,
New Delhi-110001
Dated: 22nd Sept, 2023

Office Memorandum

Subject: Revised Minutes of the first meeting of the Expert Committee for Developing Chemistry Agnostic Standards for Energy Storage Technologies held on 22nd August 2023 at 10:00 AM in Room No. 122, NITI Aayog.

A list of participants is at Annexure-I.

The first meeting of the Expert Committee for Developing Chemistry Agnostic Standards for Energy Storage Technologies was held on 22nd August, 2023 at 10:00 AM in Room No. 122, NITI Aayog. The meeting was chaired by Dr. V. K Saraswat, Member (Energy), NITI Aayog.

2. All the members of the committee were briefed about the background of the constitution of the Expert Committee and informed about the Broad ToRs of the

a. To provide guidance regarding specifications, standards, and other issues pertaining to chemistry-agnostic storage technologies.

b. To advise the Ministry of Heavy Industry on the appropriateness of the matrix based on scientific parameters such as the energy capacity and cycle life for Production Linked Incentives-II.

3. Chairman of the Committee, Member (Energy), NITI Aayog emphasized that the matrix should be developed in such a way that it attracts new chemistry technology both for mobility and stationary storage applications and disincentivizes the lower efficiency technologies. The matrix should be technology agnostic and must attract higher-efficiency battery technologies for suitable applications.

4. Two presentations were made. The presentation by Energy Vertical of NITI Aayog was about setting the context and the discussion agenda while the presentation from MHI was related to the progress of the PLI scheme of Advanced Chemistry Cell Manufacturing and the various issues and challenges pertaining to it. MHI also highlighted that the PLI scheme for Niche Chemistry Cells is already in the advanced

stage of preparation which will be helpful for the development of chemistry-agnostic technologies.

5. NITI Aayog further highlighted that the Li-Ion technology will have a strong market share for the next 5 to 10 years and currently, 70% of India's demand for lithium-ion batteries is met through imports, mainly from China and Hong Kong. The Environmental challenges pertaining to Li-ion batteries were also highlighted. It was also informed that currently, the Lithium-ion-based battery technology is matured and its prices are declining because of its size and scale but the bid received is largely skewed towards EV applications rather than stationary applications. However, MHI clarified that the bids received contain both EV and stationary applications.

6. Providing the status on the PLI scheme of ACC, the Secretary, Ministry of Heavy Industry informed that under the PLI scheme for National Advance Chemistry Cell and Battery Energy Storage, out of 50GWh, 30 GWh tender has already been awarded to three bidders (20 GWh to OLA, 5GWh to Rajesh Exports and 5 GWh to Reliance). The process for tendering for the remaining 20 GWh has been started. The Stakeholders consultative meeting was organized on 24th July 2023 and a note for the Empowered Group of Secretaries has been prepared.

7. The Committee deliberated upon the ToR (b) i.e., appropriateness of the matrix based on scientific parameters such as the energy capacity and cycle life for Production Linked Incentives-II.

8. The Joint Secretary, MHI informed that under PLI Battery Energy Storage is technology agnostic and shall incentivize cell production that shall have applications in both EV, Stationary Storage and Consumer Electronics. ACC matrix was designed to promote the manufacturing of next-gen (futuristic) batteries in India. The matrix was designed to keep the scheme application agnostic (mobility, stationary storage, consumer electronics etc.) and technology agnostic. Technology qualification and subsidy amount calculation were the only objectives of the matrix.

9. While JS, MNRE, and Member (Hydro), CEA informed that the total demand for stationary storage would be 411 GWh by 2030 (considering 5-hour storage). Out of this requirement, 175 GWh will be from Pump Hydro and 236 GWh (47 GW) from Battery Energy Storage. MNRE also informed that the gestation period of the Pump Hydro is long and in case the desired capacity from Pump Hydro is not available, the Battery Energy Storage System will be required to support the system, therefore, Battery Energy Storage needs to plan accordingly.

10. JS, MNRE further informed that a meeting under the chairmanship of the **Hon'ble Minister of Power and New & Renewable Energy** was held on 11.08.2023 wherein it was decided that out of the remaining capacity of 20 GWh under the ACC PLI scheme, 10 GWh capacity could be utilized for stationary storage capacity. MHI may be requested for allocation of additional budget out of savings from different PLI Schemes to enhance capacity proposed for stationary storage capacity under the PLI Scheme on ACC. The MoM of the aforesaid meeting is also attached at **Annexure-II**.

11. While presenting a global perspective, the Joint Secretary, Ministry of Heavy Industry informed that till 2022, 46 GW/95 GWh new energy storage (excluding pumped hydro and molten salt-based thermal storage) was installed globally. Out of this installation share of the Li-ion was ~94% (~43 GW) while Li-ion LFP 67.02%, Li-ion NMC 10.38%, Li-ion Other 16.99%, Other 5.60% (Na-ion 1.10%, LAB 1.50%, Flow battery 0.60%, CAES 1.30%, Flywheel 1.00%). More than 95% of the Gigafactory investments are in Li-ion technology (predominantly LFP and NMC chemistries). In addition, considerable investments have also been committed in Na ion technology (100+ GWh by 2030). Globally, supply-side investments are focused on lithium ion and sodium ion technologies.

12. Joint Secretary, Ministry of Heavy Industry further informed that MHI did a technology mapping based on Energy density (Wh/kg), Cycle life (Nos.), Round Tripping Efficiency (%), and C-rate (C) matrix (**Annexure-III**) for EV application and Stationary application and it has been observed that almost all ACC battery energy storage technologies (**Annexure-IV**) are covered under PLI scheme incentive matrix. Further, based on the stakeholder's consultations held on 24th July 2023 it has been observed that 60% of investors/bidders were comfortable taking the market risk based on only EVs; 33% of investors proposed sales to both segments (EV & Stationary storage); only 7% investors were focusing primarily on Stationary storage. The majority of the stakeholders did not recommend changing the ACC matrix.

13. Based on the inputs from the Ministry of Heavy Industry, no updates are needed in the existing ACC matrix, as it effectively promotes the participation of both mobility and stationary storage cells. The majority of prevalent battery cell technologies either fall within or just outside the ACC region of the matrix. Technological innovation trends and targets announcements from battery and EV OEMs indicate towards an increased likelihood of a higher number of technologies falling within the ACC region over the next 2-3 years.

14. After a detailed discussion on the matrix i.e., Energy density (Wh/kg), Cycle life (Nos.), Round Tripping Efficiency (%) for the incentive under the ACC PLI scheme, it was decided that Energy density (Wh/kg), Cycle life (Nos.) matrix may be chosen for incentive matrix. The parameter "Round Tripping Efficiency (%)" was also discussed from the perspective of inclusion in the matrix. The Committee deliberated the technology mapping done by MHI and it was observed that min RTE observed 75%. therefore, any technology having a lower RTE may not find a place in the bid. Hence it was decided that RTE need not be part of the incentive matrix.

15. The CEO of the Indian Energy Storage Alliance (IESA) indicated that the matrix has been devised based on a lot of stakeholder consultations and it is a perfectly balanced one, therefore is no need to change the existing matrix.

16. It was suggested that the Ministry of Heavy Industry needs to examine the decision on "<u>Out of 20 GWh remaining capacity under ACC PLI scheme, 10 GWh capacity could</u>

be utilized for stationary storage applications" (as per the decision taken by the **Hon'ble Minister of Power and New & Renewable Energy** on 11.08.2023 during inter-ministerial meeting (mom at **Annexure-II))** for the Stationary Storage out of the proposed 20 GWh BESS tender under PLI scheme of ACC.

17. Based on the above discussions, the following decisions were taken:

   a. The current incentive matrix (based on Energy density (Wh/kg), Cycle life (Nos.)) under the PLI scheme for National Advance Chemistry Cell (ACC) and Battery Energy Storage is technology technology-agnostic program that covers many battery energy technologies, therefore, no need to change the current incentive matrix.
   b. MNRE and the Ministry of Power may also frame separate schemes for incentivizing Stationary Storage technologies for energy storage requirements as projected by CEA by 2030.
   c. Ministry of Heavy Industry needs to finalize the incentive matrix for 5 GWh niche chemistry cell as approved under the PLI Scheme for supporting niche chemistry technologies.
   d. Discussion regarding specifications, standards, and other issues pertaining to chemistry-agnostic storage technologies will be taken in the next meeting.

18. The meeting ended with the vote of the chair.

19. These issues with the approval of the competent authority.

Upadhyay

(Manoj Kumar Upadhyay)
Dy Adviser
Telephone: 23096757

1. **The Secretary (HI), Ministry of Heavy Industry, Udyog Bhawan, Rafi Marg, New Delhi- 110011, Email id: shioff@nic.in**
2. **The Secretary, Department of Science & Technology, Technology Bhavan, New Mehrauli Road, New Delhi-110 016. Email id: dstsec@nic.in**
3. **The Secretary, Ministry Electronics and Information Technology, Electronics Niketan, 6, CGO Complex, Lodhi Road, New Delhi-110003, Email id: secretary@meity.gov.in**
4. **The Secretary, Ministry of Power, Shram Shakti Bhawan, Rafi Marg, New Delhi-110001, Email id: secy-power@nic.in**
5. **The Secretary, Ministry of New and Renewable Energy, Atal Akshay Urja Bhawan, CGO Complex, Lodhi Road, New Delhi - 110 003, India, Email id: secy-mnre@nic.in**
6. **The Secretary, Ministry of Petroleum and Natural Gas, Shastri Bhawan, Dr. Rajendra Prasad Road, New Delhi – 110001, Email id: sec.png@nic.in**
7. **The Member (Hydro), CEA, Central Electricity Authority, Sewa Bhawan, R.K.Puram, Sector-1, New Delhi-110 066 Email id: member.he@cea.nic.in**
8. **The Director General, BIS, 9, Bahadur Shah Zafar Marg, New Delhi-110002, Email id: dg@bis.gov.in**
9. **Sh. Lalit Bohra,** Joint Secretary, **Ministry of New and Renewable Energy, Atal Akshay Urja Bhawan, CGO Complex, Lodhi Road, New Delhi - 110 003, India, Email id:** lalit.bohra@gov.in
10. **Dr. Rahul Walawalkar, India Energy Storage Alliance, Email id: rwalawalkar@ces-ltd.com, ddash@ces-ltd.com**
11. **Sh. Kushagra Srivastava, CEO, Chakr Innovations, Email id kushagra.srivastava95@gmail.com, kushagra@chakr.in**

Copy to

1. **PS to VC, NITI Aayog**
2. **PS to Dr. V. K Sarsawat, Member, NITI Aayog**
3. **PSO to CEO, NITI Aayog**
4. **PS to Adviser (Transport & E-Mobility), NITI Aayog**
5. **PS to Adviser (Energy), NITI Aayog**

Annexure-I

List of the Participants

S. No.	Organisation	Name	Designation	Contact Details
NITI Aayog				
1	NITI Aayog	Dr. V K Saraswat	Member (Energy)	In - Chair
2	NITI Aayog	Sh. Rajnath Ram	Adviser (Energy)	
3	NITI Aayog	Sh. Joseph Teja	Consultant, EV/Transport Vertical	
Ministries & Departments				
4	M/o Heavy Industries	Sh. Kamran Rizvi	Secretary	23063633 **shioff@nic.in**
5	CEA	Sh. M. A. K. P. Singh	Member (Hydro)	2673-2701 member.he@cea.nic.in
6	M/o Heavy Industries	Sh. Hanif Qureshi	Joint Secretary, Auto MHI	7011931313
7	M/o Heavy Industries	Shri Vijay Mittal	Joint Secretary, MHI	9818977797
8	MNRE	Sh Lalit Bohra	Joint Secretary	Lalit.bohra@gov.in
9	MNRE	Sh Jeevan Kumar Jethani	Scientist F	Jethani.jk@nic.in 9810314003
	BIS	Dr. Priti	Scientist-F. &	heetd@bis.gov.in

10		Bhatnagar	Head (Electro-technical)	eetd@bis.gov.in priti@bis.gov.in 23231192 9425603660
11	MoPNG	Sh. Alok Sharma	ED-CHT	9818601855 d.cht@cht.gov.in 0120-2593701/0120-2593717, 9818601855
12	M/o Science & Technology	Mr. Suresh Babu Mutanna	Scientist-E	9971046796
13	MoPNG	Sh. Kishore K. Bhimwal	Addl. Director	9958798282
14	CEA	Sh. Rajesh Kumar	Director	9873047868
15	BIS	Sh. Neeraj Kushwaha	Scientist-B/Assistant Director	9140468418
16	M/o Electronics and Information Technology	Dr. Sandeep Chatterjee	Scientist-G	9910991783
17	India Energy Storage Alliance	Dr Rahul Walawalkar	President	rwalawalkar@ces-ltd.com 9503031765
18	Chakr Innovations	Sh. Kushagra Srivastava	CEO	Kushagra.srivastava95@gmail.com 9871001912
19	Chakr Innovations	Sh. Mohit Singhvi	AVP	9871001912
20	MHI (Deloitte)	Sh. Akshay Parihor	Manage	7409078924

Annexure-II

Summary record of discussions held in the Meeting to discuss proposed Production Linked Incentive (PLI) scheme for Battery Energy Storage System (BESS)

A meeting under the chairmanship of **Hon'ble Minister of Power and New & Renewable Energy** was held on 11.08.2023 at Shram Shakti Bhawan, Ministry of Power, New Delhi. The officers from NITI Aayog, DPIIT, MoP, MoF, DHI and MNRE attended the meeting as per list placed at **Annexure**.

2. The Hon'ble Minister in his opening remarks mentioned the requirement of Energy storage for achieving grid integration of large renewable energy capacities. He highlighted the importance of local manufacturing of stationery energy storage capacities in the country and the need for a PLI to kickstart such manufacturing.

3. After detailed discussions, following action points emerged in the meeting:

a) The existing PLI scheme on "National Programme Advanced Chemistry Cell (ACC) Battery Storage" being implemented by Ministry of Heavy Industries (MHI) has 20 GWh unallocated capacity. Out of this 20 GWh capacity, 10 GWh capacity could be utilised for stationary storage capacity subject to provisions available under the Cabinet approval of the PLI.

b) Further, MHI may request for allocation of additional budget out of savings from different PLI Schemes to enhance capacity proposed for stationary storage capacity under PLI Scheme on ACC.

c) MNRE/MoP/CEA to quickly examine the provisions of Cabinet Note of the PLI Scheme on ACC and send requirement of stationary energy storage capacity to DHI, NITI Ayog and DPIIT.

The meeting ended with vote of thanks to the Chair

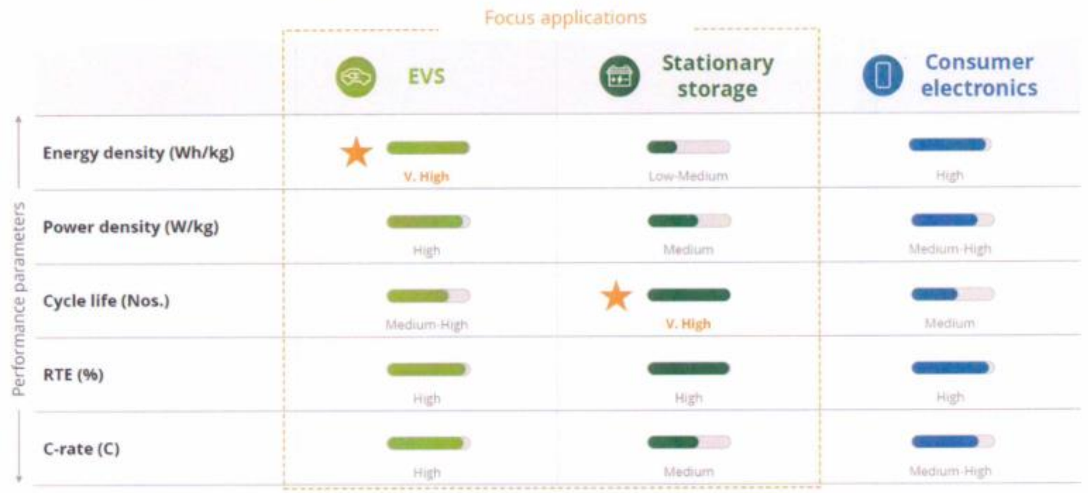
ANNEXURE

LIST OF PARTICIPANTS:

Sl. No.	Name	Designation & Department
1	Shri B.V.R. Subrahmanyam	CEO, NITI Aayog
2	Shri Rajesh Kumar Singh	Secretary, DPIIT
3	Shri Bhupinder S Bhalla	Secretary, MNRE
4	Shri Pankaj Agarwal	Secretary, MoP
5	Shri Lalit Bohra	Joint Secretary, MNRE
6	Shri Amit Negi	Joint Secretary, MoF
7	Shri Vijay Mittal	Joint Secretary, MHI
8	Shri J. K. Jethani	Senior Director, MNRE
9	Shri Rajesh Gupta	Director, NITI Aayog
10	Dr. Kuldeep Singh Rana	Scientist-E, MNRE

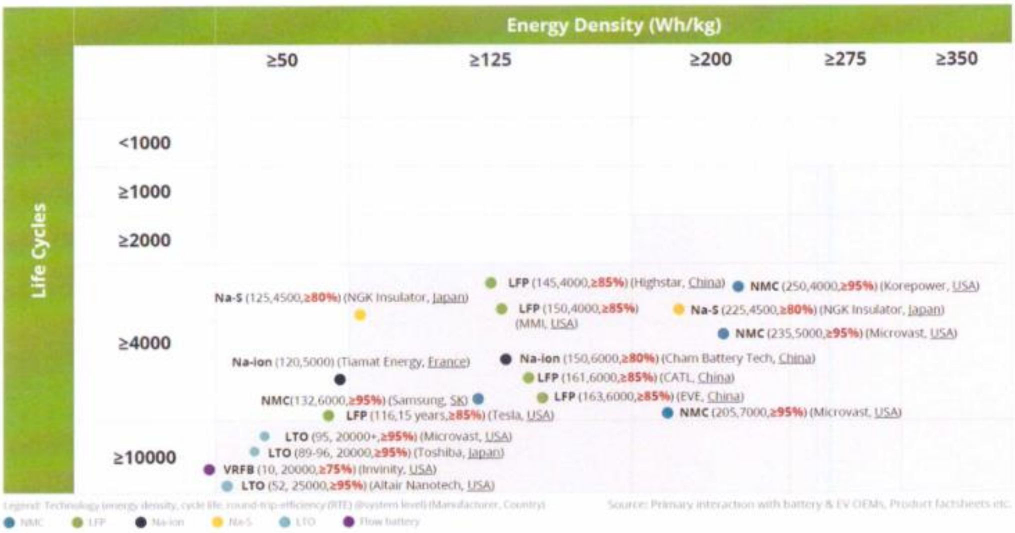
Annexure-III

Critical performance parameters for leading demand driver applications

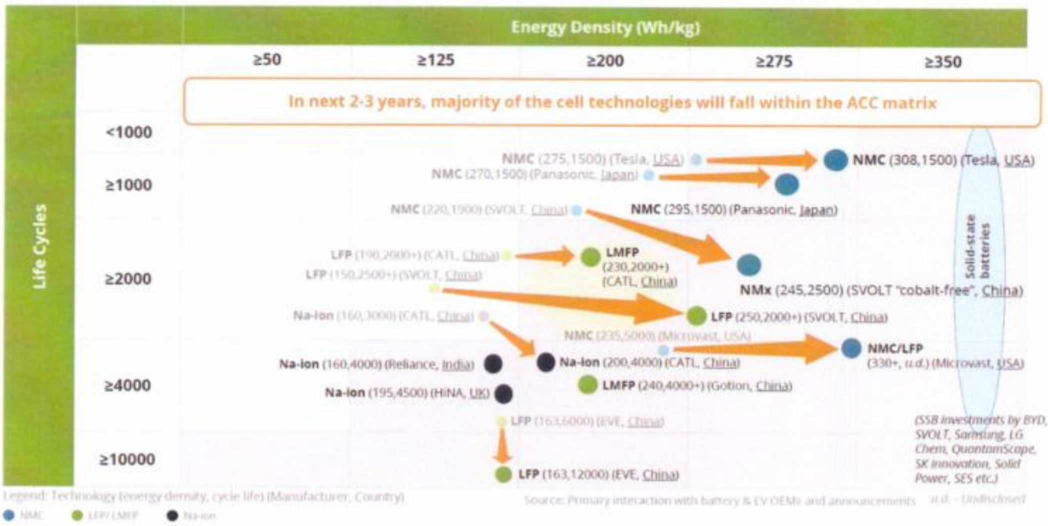


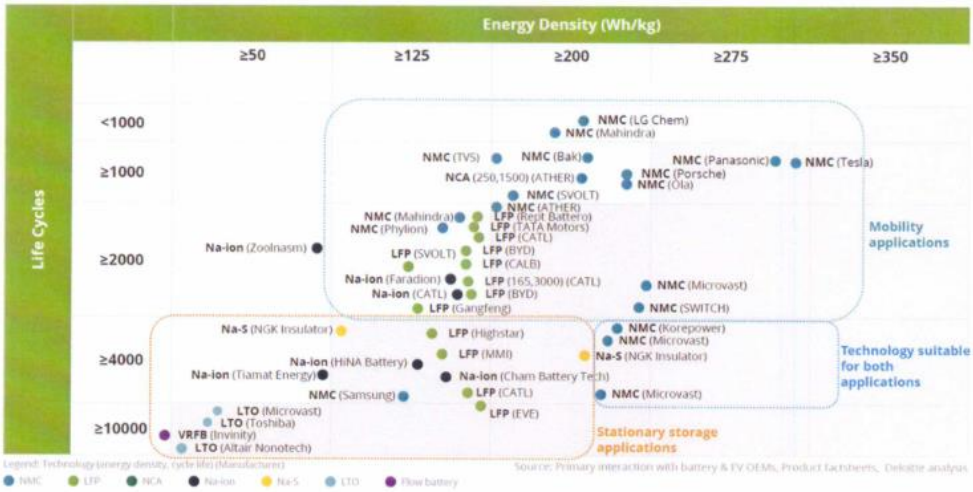
12

Current ACC matrix enable participation from stationary storage cells



ACC matrix: Technology outlook based on OEM announcements 2025-26





Energy Density (Wh/kg)
≥50
≥125
≥200
≥275
≥350
Life Cycles
<1000
≥1000
≥2000
≥4000
≥10000
NMC (LG Chem)
NMC (Mahindra)
NMC (TVS)
NMC (Bak)
NMC (Panasonic)
NMC (Tesla)
NCA (250,1500) (ATHER)
NMC (Porsche)
NMC (Ola)
NMC (SVOLT)
NMC (ATHER)
NMC (Mahindra)
LFP (Repit Battero)
NMC (Phylion)
LFP (TATA Motors)
LFP (CATL)
Na-ion (Zoolnasm)
LFP (SVOLT)
LFP (BYD)
LFP (CALB)
Na-ion (Faradion)
LFP (165,3000) (CATL)
NMC (Microvast)
Na-ion (CATL)
LFP (BYD)
LFP (Gangfeng)
NMC (SWITCH)
Mobility applications
Na-S (NGK Insulator)
LFP (Highstar)
NMC (Korepower)
NMC (Microvast)
LFP (MMI)
Na-S (NGK Insulator)
Na-ion (HiNA Battery)
Na-ion (Tiamat Energy)
Na-ion (Cham Battery Tech)
NMC (Samsung)
LFP (CATL)
NMC (Microvast)
Technology suitable for both applications
LTO (Microvast)
LFP (EVE)
LTO (Toshiba)
VRFB (Invinity)
LTO (Altair Nonotech)
Stationary storage applications
Legend: Technology (energy density, cycle life) (Manufacturer)
NMC
LFP
NCA
Na-ion
Na-S
LTO
Flow battery
Source: Primary interaction with battery & EV OEMs, Product factsheets, Deloitte analysis

Annexure-IV

File No- I-22/2/31/2023-(P&E)
Government of India
NITI Aayog
(Energy Vertical)

NITI Bhawan, Sansad Marg,
New Delhi-110001
Dated: 30th January, 2024

<u>Office Memorandum</u>

Subject: Minutes of the second meeting of the Expert Committee for Developing Chemistry agnostic standards for energy storage technologies held on 17th January, 2024 at 11 A.M in Room No. 122, NITI Aayog, New Delhi

A List of the participants is at Annexure-I

The second meeting of the Expert Committee for Developing Chemistry Agnostic Standards on Energy Storage Technologies was held on 17th January, 2024 at 11 A.M in NITI Aayog, New Delhi. The meeting was chaired by Dr V K Saraswat, Member (Energy), NITI Aayog.

2. Adviser (Energy), NITI Aayog apprised the Committee on the decision taken during the first meeting of the Committee held on 22nd August, 2023. It was informed that no change in the incentive matrix of the PLI scheme under National Advance Chemistry Cell and Battery Storage was suggested by the Committee during the meeting. It was also informed that the EGOS in its meetings held on 2.11.2023 & 3.11.2023, suggested that Ministry of Heavy Industries (MHI) need to earmark 10 GWh of storage for grid scale stationery applications from the un-allocated capacity of 20 GWh. It was informed that MHI will publish this bid shortly as the bid is being prepared by MNRE. Advisor (Transport & E-Mobility) also confirmed above these developments to the Chair of the meeting. Member Secretary of the Committee invited to make brief presentation on the ToR and progress on the activities followed a presentation by the World Bank on the subject "Battery Energy Storage System (BESS) Testing, Handling, Installation and Maintenance, Safety Standards and Best Practices in India".

3. Member (Dr. V. K. Saraswat), NITI Aayog & the Chair of the Committee indicated that the committee needs to prepare the report within a month. The report must include all technical parameter and ranges required for the standards. The parameter & ranges must cover all the existing energy storage technology including pump hydro, fly wheel etc. and all emerging new battery storage technology like Metal Air, Metal Sulphur and many more. He was of the view that the standards should work for technology which are in lab stages and likely to penetrating in next 10 years.

4. Member Secretary of the Committee highlighted that BIS has already published 17 Standards and other 7 Standards are under different stages of development. The standards are application specific of chemistry and technology oriented. He informed that even in US, China and European Union, the energy storage standards are based on the application, chemistry and technology oriented. It was informed that BIS has developed IS6303 which covers safety standards of the Primary Batteries (no-rechargeable) and IS 16894 Part-I is covers safety Standards of the Secondary Batteries (rechargeable). After analysis of the existing standards, it was found that Redox Flow battery have partial compatibility with AIS038, AIS048, AIS049, AIS156 as these standards cannot evaluate mechanical parameters. Likewise Metal Air Flow Battery have partial compatibility with IEC62392 as overcharge test mentioned in this standard is not applicable to them. Similar case is with the Metal Sulphur, and Hydrogen Fuel cell.

5. It was observed that there is no centralized testing information for new battery innovators which is increasing time for certification and testing. Limited knowledge exists about chemistry of batteries by Labs and also longer time taken for standards development and publication by BIS.

6. On the Niche chemistry agnostic cell development under PLI scheme of ACC manufacturing, it was suggested that MNRE, MHI and the relevant stakeholders need to evolve strategies. However, it was suggested to organize one- day workshop to take stock of supply-chain, status of development and status on Domestic Content requirement on the various chemistry cells. It was suggested that Energy Vertical and Transport Vertical of NITI Aayog jointly need to organize this workshop.

7. World Bank made a presentation about preparation of the guidebook on "Battery Energy Storage System (BESS) Testing, Handling, Installation and Maintenance, Safety Standards and Best Practices in India". It focused on the major fire incidences & safety issues pertaining to battery energy storage projects worldwide. The said handbook is based on the use-cases for battery energy storage project funding by the World Bank.

8. After detailed deliberations, the following decisions were taken:

I. A sub-group of expert comprises of (i) Electro-chemical Power Sources Division , CSIR-Central Electro Chemical Research Institute, Karaikudi (ii) Energy Storage Laboratory (ESL), IIT Roorkee (iii) Chakra Innovation (iv) India Energy Storage Alliance (IESA) (v) International Advanced Research Centre for Powder Metallurgy & New Materials (ARCI), Hyderabad, Telangana (vi) Greenko (vii)CEA (viii) MNRE (ix) BIS (x) TATA Green Batteries needs to be constituted for finalization of the Chemistry Agonist parameter and ranges to include all available energy storage technologies and upcoming technologies. India Energy Storage Alliacne (IESA) and Chakra Innovation will be adopted as knowledge partners for preparing the draft report. The experts should finalize the report by Feb, 2024.

II. In Parallel, BIS need to modify the existing application standards like AIS038, AIS040, AIS041, AIS048, AIS049, AIS156 etc. to support the available & upcoming battery energy storage. Further modifications and clarifications may be appended as annexures with existing standards as discussed in the above para 7.

III. BIS needs to create an online dashboard by collecting all the labs equipment data for facilitating testing of the existing & upcoming battery storage technologies. This would help in creating centralized facility for certification also. This would also help to create awareness about their labs and existing & facilities with Innovators & technology developer.

IV. World Bank should adopt India use-cases and include agnostic guidelines instead of one chemistry-based guidelines, otherwise, it become hurdle for project funding by Banks etc. for upcoming new technologies which may not fall on same range of technical parameters.

V. On the part of the capacity building short-term, medium term and long-term skill development courses may be developed by BIS and Sector Skills Council along with BIS Labs may implement the programme.

9. The meeting ended with the vote of thanks to chair.

Gpodhyay

(Manoj Kumar Upadhyay)
Dy Adviser
Telephone: 23096757

1. **The Secretary (HI), Ministry of Heavy Industry, Udyog Bhawan, Rafi Marg, New Delhi- 110011, Email id: shioff@nic.in**
2. **The Secretary, Department of Science & Technology, Technology Bhavan, New Mehrauli Road, New Delhi-110 016. Email id: dstsec@nic.in**
3. **The Secretary, Ministry Electronics and Information Technology, Electronics Niketan, 6, CGO Complex, Lodhi Road, New Delhi-110003, Email id: secretary@meity.gov.in**
4. **The Secretary, Ministry of Power, Shram Shakti Bhawan, Rafi Marg, New Delhi-110001, Email id: secy-power@nic.in**
5. **The Secretary, Ministry of New and Renewable Energy, Atal Akshay Urja Bhawan, CGO Complex, Lodhi Road, New Delhi - 110 003, India, Email id: secy-mnre@nic.in**
6. **The Secretary, Ministry of Petroleum and Natural Gas, Shastri Bhawan, Dr. Rajendra Prasad Road, New Delhi – 110001, Email id: sec.png@nic.in**

7. **The Member (Hydro), CEA, Central Electricity Authority, Sewa Bhawan, R.K.Puram, Sector-1, New Delhi-110 066 Email id: member.he@cea.nic.in**
8. **The Director General, BIS, 9, Bahadur Shah Zafar Marg, New Delhi-110002, Email id: dg@bis.gov.in**
9. **Sh. Dinesh Dayanand Jagdale, Joint Secretary, Ministry of New and Renewable Energy, Atal Akshay Urja Bhawan, CGO Complex, Lodhi Road, New Delhi - 110 003, India, Email id: d.jagdale@gov.in**
10. **Dr. Rahul Walawalkar, India Energy Storage Alliance, Email id: rwalawalkar@ces-ltd.com, ddash@ces-ltd.com**
11. **Sh. Kushagra Srivastava, CEO, Chakr Innovations, Email id kushagra.srivastava95@gmail.com, kushagra@chakr.in**
12. **Ms. Mani Khurana, Sr. World Bank Specialist, World Bank, Email id: mkhurana@worldbank.org**

Copy to

1. **PS to VC, NITI Aayog**
2. **PS to Dr. V. K Sarsawat, Member, NITI Aayog**
3. **PSO to CEO, NITI Aayog**
4. **PS to Adviser (Transport & E-Mobility), NITI Aayog**
5. **PS to Adviser (Energy), NITI Aayog**

Annexure-I

The list of the participants

1. Dr V K Saraswat, Member (Energy), NITI Aayog
2. Sh. Sudhendu Jyoti Sinha, Adviser (Transport & E-mobility), NITI Aayog
3. Sh. Rajanth Ram, Advisor (Energy), NITI Aayog
4. Sh. M. A. K. P. Singh, Member (Hydro), CEA,
5. Sh. Dinesh Dayanand Jagdale, Joint Secretary, MNRE
6. Shri Dhiraj Kumar Srivastava Chief Engineer (EC, ET & EV), Ministry of Power
7. Sh. Rajesh Kumar, Chief Engineer, CEA
8. Sh. Rajnesh Singh, Director, Ministry of Heavy Industry
9. Shri R.C. Agarwal, Director, MoPNG/Centre for High Technology
10. Mr. Suresh Babu Mutanna, Scientist-E, M/o Science & Technology
11. Dr. Sankadip Das, Scientist-E, M/o Electronics and Information Technology
12. Dr. Kuldeep Singh Rana, Scientist E, MNRE
13. Sh. Kishore K. Bhimwal, Addl. Director, MoPNG/Centre for High Technology
14. Sh. Neeraj Kushwaha Scientist-B/Assistant Director, BIS
15. Dr Rahul Walawalkar, President, India Energy Storage Alliance,
16. Sh. Kushagra Srivastava, CEO, Chakr Innovations
17. Sh. Mohit Singhvi, AVP, Chakr Innovations
18. Sh. Abjeet Dutta, AGM, Chakr Innovations
19. Sh. Abhilasha, Manager, Chakr Innovations
20. Ms. Mani Khurana, Sr. World Bank Specialist, World Bank
21. Sh. Pyush Dogra, Sr. Environmental Specialist, World Bank
22. Dr. Deepanjan Majumdar, O/o Member (Energy), NITI Aayog
23. Sh. Manoj Kumar Upadhyay, Dy Advisor, NITI Aayog – Member Secretary of the Committee

Annexure-V

File No. I-22/2/31/2023-(P&E)
Government of India
NITI Aayog
(Energy Vertical)

NITI Bhawan, Sansad Marg,
New Delhi-110001
Dated: 16th Feb, 2024

Office Memorandum

Subject: Constitution of the Sub-Group of Experts for Developing Chemistry agnostic standards for energy storage technologies.

The undersigned is directed to refer to NITI Aayog OM No- I-22/2/31/2023-(P&E) dated 30th Jan, 2024 regarding minutes of the second meeting of the Expert Committee for Developing Chemistry agnostic standards for energy storage technologies. As per para 8(I) of the minutes, a Sub-Group of Experts for developing chemistry agnostic standards for energy storage technologies has been constituted under the Chairmanship of Adviser (Energy), NITI Aayog. The composition of the committee is as follows:

1.	Sh. Rajnath Ram, Adviser (Energy), NITI Aayog	Convener
2.	Representative from Transport & E-Mobility, NITI Aayog	Member
3.	Representative from Solar & Energy Division, MNRE	Member
4.	Representative from Hydro & Pump Hydro Division, CEA	Member
5.	Representative from Electro-technical Division, BIS	Member
6.	Representative from Electro-chemical Power Sources Division, CSIR-Central Electro Chemical Research Institute, Karaikudi	Member
7.	Representative from Energy Storage Laboratory (ESL), IIT Roorkee	Member
8.	Representative from International Advanced Research Centre for Powder Metallurgy & New Materials (ARCI), Hyderabad, Telangana	Member
9.	Representative from Chakra Innovation (knowledge partner)	Member
10.	Representative from Greenko	Member
11.	Representative from TATA Green Batteries	Member

12	Representative from India Energy Storage Alliance (IESA) (knowledge partner)	Member

2. The committee may co-opt any expert as a member of the committee.

3. The terms and references of the committee are as follows:

- To finalize Chemistry Agonist parameter and ranges to include all available energy storage technologies (including Pump Hydro, Fly Wheel etc.) and upcoming technologies.

4. The Ministry/Department, Agencies, Industry and knowledge Partners are requested to send nomination of their experts at earliest.

This issues with the approval of the competent authority.

Upadhyay

(Manoj Kumar Upadhyay)
Dy Adviser (Energy)
Telephone: 23096757

To,

1. **Sh. Dinesh Dayanand Jagdale, Joint Secretary, Ministry of New and Renewable Energy, Atal Akshay Urja Bhawan, CGO Complex, Lodhi Road, New Delhi - 110 003, India, Email id: d.jagdale@gov.in**
2. **The Member (Hydro), CEA, Central Electricity Authority, Sewa Bhawan, R.K.Puram, Sector-1, New Delhi-110 066 Email id: member.he@cea.nic.in**
3. **Shri. A R Unnikrishnan, Scientist G & Head (EETD), BIS, Manak Bhawan, 9, Bahadur Shah Zafar Marg, New Delhi-110002, Email id: heetd@bis.gov.in**
4. **Dr. K Ramesha, CSIR-Central Electrochemical Research Institute Karaikudi – 630003, Tamil Nadu, Email id: director@cecri.res.in (Kind Attention to Dr. A. Sivashanmugam, Chief Scientist, Email id: sivashanmugam@cecri.res.in**
5. **Prof. Yogesh Kumar Sharma, Department of Physics and Centre for Sustainable Energy and Head of Energy Storage Laboratory, East Block, Level-1, Department of Physics, Indian Institute of Technology Roorkee, Roorkee, Uttarakhand – 247667, Email id : yogesh.sharma@ph.iitr.ac.in**

6. **Dr. Tata Narasinga Rao, Director International Advanced Research Centre for Powder Metallurgy & New Materials (ARCI), Hyderabad, Telangana, director@arci.res.in / tata@arci.res.in.**
7. **Sh. Mahesh Kolli, President & Joint MD, Greenko, Group, 1366, Road No.45, Jubilee Hils, Hyderbad-500033, Email id; mahesh@greenkogroup.com, shatanshu.a@greenkogroup.com.**
8. **Dr. G Ganesh Das, Chief- Collaboration & Innovation, TATA Power, 34 Sant Tukaram Road, Carnac Bunder, Mumbai- 4000009, Email id: ganesh.das@tatapower.com**
9. **Dr. Rahul Walawalkar, India Energy Storage Alliance, Email id: rwalawalkar@ces-ltd.com, ddash@ces-ltd.com**
10. **Sh. Kushagra Srivastava, CEO, Chakr Innovations, Email id kushagra.srivastava95@gmail.com, kushagra@chakr.in**

Copy to

1. **PS to VC, NITI Aayog**
2. **PS to Dr. V. K Sarsawat, Member, NITI Aayog**
3. **PSO to CEO, NITI Aayog**
4. **PA to Program Director (Green Transition, Energy, Climate & Environment), NITI Aayog**
5. **PS to Adviser (Transport & E-Mobility), NITI Aayog**
6. **PS to Adviser (Energy), NITI Aayog**

References of Table 15: Ranges of Chemistry Agnostic Standards

[4]https://batteryuniversity.com/article/bu-205-types-of-lithium-ion
[5]https://www.batterydesign.net/sodium-ion-battery/
[6]https://batteryuniversity.com/article/bu-214-summary-table-of-lead-based-batteries
[7]https://www.sandia.gov/ess-ssl/wp-content/uploads/2021/02/ESHB_Ch6_RedoxFlow_Small.pdf
[8]https://batteryuniversity.com/article/bu-216-summary-table-of-lithium-based-batteries
[9]https://docs.google.com/document/d/1Zdtl-2OoSzegWTGr3ku6_62xZeAgUBKHLJOzOs6wfLo/edit
[10]https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwjCzcrB7LaEAxWx4TgGHV5HBWcQFnoECCoQAQ&url=https://www.hydrogen.energy.gov/docs/hydrogenprogramlibraries/pdfs/progress04/ivi3_borup.pdf&usg=AOvVaw3PkX5jero3GIN8Icto8Tm2&opi=89978449
[11]https://electronics.stackexchange.com/questions/130580/what-is-a-safe-max-discharge-rate-for-a-12v-lead-acid-battery
[12]https://www.indiamart.com/proddetail/hly-cell-26650-3-6v-5000mah-5c-battery-25a-high-discharge-rate-battery-26891444797.html
[13] https://research.chalmers.se/publication/534781/file/534781_Fulltext.pdf
[14]https://www.sciencedirect.com/topics/earth-and-planetary-sciences/sodium-sulfur-batteries
[15]https://batteryuniversity.com/article/bu-201-how-does-the-lead-acid-battery-work
[16]https://www.sciencedirect.com/topics/engineering/sodium-sulfur-battery
[17]https://thundersaidenergy.com/2023/11/02/redox-flow-batteries-for-the-duration/
[18]https://en.wikipedia.org/wiki/Sodium-ion_battery
[19]https://batteryuniversity.com/article/bu-409-charging-lithium-ion
[20]Study on Advanced Grid-Scale Energy Storage Technologies -Dept. of Hydro and Renewable Energy IIT Roorkee Oct'23
[21]https://www.sciencedirect.com/science/article/pii/S2352484723012118
[22]https://www.indiamart.com/proddetail/hly-cell-26650-3-6v-5000mah-5c-battery-25a-high-discharge-rate-battery-26891444797.html
[23]https://www.energy.gov/eere/fuelcells/articles/fuel-cells-fact-sheet
[24]https://web.iitd.ac.in/~sbasu/L5.pdf
[25]https://www.ineltro.ch/media/downloads/SAAItem/45/45958/36e3e7f3-2049-4adb-a2a7-79c654d92915.pdf
[26]https://www.sciencedirect.com/science/article/abs/pii/S0306261915007473
[27]https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10300782/
[28]https://www.researchgate.net/publication/373643116_Operating_Lithium-Sulfur_Batteries_in_an_Ultrawide_Temperature_Range_from_-50_C_to_70_C
[29]https://en.wikipedia.org/wiki/Fuel_cell
[30]https://www.sciencedirect.com/science/article/abs/pii/S0306261917315878