Comprehensive Study Report

Development of the National Standards for Battery Energy Storage System (BESS) - Vietnam

ETP - UNOPS

V2.0

15 July 2024

ISSQ

Headquarters
52/46 Lien Mac
Bac Tu Liem, Hanoi
0981851111
tcvnissq@gmail.com

Southern Office
Van Dat Building
12 CN8, Tan Binh industrial zone
Tan Phu District, Ho Chi Minh City

Pondera

Headquarters Nederland
Amsterdamseweg 13
6814 CM Arnhem
088 – pondera (088-7663372)
info@ponderaconsult.com
Mailbox 919
6800 AX Arnhem

Office Vietnam
6th Floor, Serepok Building
56 Nguyen Dinh Chieu Street, Da Kao Ward, District 1 Ho Chi Minh City
Vietnam

Title page

Document type
Comprehensive Study Report

Project name
Development of the National Standards for Battery Energy Storage System (BESS) – Vietnam

Version number
V2.0

Date
15 July 2024

Client
ETP - UNOPS

Authors
The Consortium ISSQ – Pondera

Project Team Lead
Vu Van Dien

Quality control
Le Ngoc Thuc

Reviewed by
ISSQ

Table of contents

Chapter 1. Executive Summary

1.1 Brief overview of the study

In Vietnam, the substantial growth in solar capacity during 2019-2020 has significantly impacted power system operations, creating challenges such as meeting variable renewable energy demand and constructing responsive transmission lines within tight timeframes and budgets. The oversupply has also posed a significant threat to the security of the national grid, resulting in wasteful curtailment of solar projects. Consequently, Vietnam presents a promising opportunity for the development of Battery Energy Storage Systems (BESS).

BESS can mitigate renewable curtailment, reduce power losses, and alleviate investment pressures on the transmission grid by storing excess energy during periods of low demand and releasing it during periods of high demand. Furthermore, the integration of BESS, with its storage capacity projected to expand in the near future, will enhance the ability to predict and manage high load demands, supporting the development of energy-intensive technologies. On a broader scale, this will address energy security concerns and assist in achieving national decarbonization targets.

However, the absence of national standards (TCVNs) tailored to Battery Energy Storage Systems (BESS) presents a critical challenge to their development in Vietnam. This technical assistance project is designed to establish a comprehensive set of national standards for BESS, adhering to the procedural guidelines mandated by the Ministry of Science and Technology (MOST). This initiative represents a collaborative effort between the ETP and the Directorate for Standards, Metrology, and Quality (STAMEQ), which operates under MOST. The primary objective of this project is to develop a detailed and robust set of standards for BESS, facilitating the seamless integration of renewable energy into Vietnam's national grid.

This research program examines the present status of BESS in Vietnam and co-constructs a comprehensive strategy for the advancement of Vietnam's Technical Standards (TCVNs), following governmental guidelines. The analysis report includes the following aspects: encompasses defining BESS, appraising regulatory frameworks, evaluating current industry standards, and pinpointing crucial technical criteria. Furthermore, the study broadens its horizon to undertake a comparative analysis of five nations: Australia, Germany, the Netherlands, South Korea, and China to extract valuable insights from BESS standardization practices. Overall, this study offers valuable insights and direction for shaping regulatory frameworks and technical standards to advance BESS in Vietnam.

This comprehensive study aims to address the need to establish national standards for Battery Energy Storage Systems (BESS) in Vietnam. By first analyzing the current state of BESS in Vietnam, including its technical regulations, industry standards, and technical requirements, and second by researching the standards of advanced countries in BESS, this comprehensive study seeks to lay the groundwork for the development and approval of a comprehensive set of Vietnamese National Standards (TCVN) for BESS. These include, amongst others, specifications and testing methods, planning and performance assessments, environmental issues, and safety considerations related to BESS.

The in-depth analysis report is structured into seven chapters, starting with an Introduction in Chapter 2 that outlines the research questions and emphasizes the importance of standards. Chapter 3 defines the Battery Energy Storage System (BESS) in Vietnam and examines the current status and application of technical regulations and standards for BESS projects. It also scrutinizes the hierarchical structure of technical standards in Vietnam, highlighting any disparities from international norms.

In Chapter 4, a thorough examination of global BESS standards is conducted, featuring case studies of BESS standards development in five countries. Efforts to promote BESS initiatives are expected to accelerate industry growth and facilitate the establishment of national standards, guided by a comprehensive understanding of the regulatory landscape governing BESS projects.

Chapter 5 addresses the need for specific BESS development standards suitable for Vietnam. By analyzing these requirements and identifying gaps compared to countries with extensive BESS experience, the research team proposes a draft list of TCVNs for BESS to address these disparities and support the implementation of BESS projects in Vietnam.

Chapter 6 outlines the methodologies and approaches for developing these TCVNs, including team organization and responsibilities. The proposed national standards will draw on international best practices and expertise from countries with advanced BESS development. A roadmap for the creation of these standards will be meticulously crafted and aligned with project deliverables for seamless implementation.

Finally, Chapter 7 presents the Consultant's conclusions and recommendations. It assesses how identified gaps impact the overall progress of BESS project development in compliance with regulations. Moreover, the standards proposed serve as invaluable guidance for stakeholders spanning designers, suppliers, purchasers, operators, and regulators across the developmental, implementation, and operational phases of BESS facilities.

1.2 Brief Overview of the Report's Objectives:

The objective of this project and the focus of this comprehensive report are to establish national standards for BESS. Through research, the research team discerned that these standards do not operate in isolation but are integral to the ecosystem governing BESS development. This ecosystem comprises various policies, laws, codes, standards, and regulations, collectively shaping the trajectory of BESS development in each country. Initiatives to foster BESS will expedite industry growth and stimulate the formulation of national standards. Technical challenges usually emerge once projects are rolled out, and the need for standards to define best practices and achieve consensus comes along to ensure smoother implementation for subsequent projects. Understanding the broader regulatory framework that governs BESS projects, especially the policies that give rise to the accelerated installations of BESS in leading BESS markets, to design national standards in harmony with these regulatory requirements is, therefore, essential.

The national TCVN standards for Battery Energy Storage Systems (BESS) will be developed by a technical team referencing international standards, and the knowledge and experience of countries with advanced expertise in BESS development. These standards are designed to follow technical regulations and are tailored to Vietnam's unique geographical, climatic, technical, and technological characteristics, ensuring they safeguard national interests without any adverse impact.

The comprehensive study report addresses the critical need for establishing national standards for Battery Energy Storage Systems (BESS) in Vietnam by identifying the current gaps in standards related to BESS. This includes an assessment of how these gaps affect the overall progress of developing BESS projects by regulations. The identified technical gaps stem from extensive research and analysis of the current state of policies, regulations, and standards for BESS in Vietnam, alongside research and study on international policies, regulations, and standards from leading countries in BESS. Identifying and assessing these gaps will help shape the standards needed to support the sustainable and effective development of BESS projects in Vietnam.

Chapter 2. Introduction

2.1 Project Background

This study for the United Nations Office for Project Services (UNOPS) supports the Government of Vietnam in developing Vietnamese National Standards (TCVN) for BESS. The Battery Energy Storage System (BESS) standards in Vietnam are essential and fundamental for the planning, investigations, testing, manufacturing, endorsement, licensing, construction, operation, and maintenance, as well as the decommissioning process of BESS projects in Vietnam. The development of Standards is paramount for government officials to facilitate the integration of BESS and safeguard a safe, efficient, and sustainable energy system.

The project is carried out by the Consortium, which consists of the Institute for Standard and Quality Development Studies (ISSQ; consortium lead), and Pondera Consult B.V. (PONDERA). Moreover, to implement the project, we have a team of highly experienced experts from PHENIKAA UNIVERSITY and TUV NORD VIETNAM to handle specific parts of the project. ISSQ will lead the project and act as the main point of contact for the client.

The entire project covers the following ten deliverables:

1. Inception Report
2. A comprehensive study report.
3. Draft of the National Standards (TVCN) for BESS according to the list agreed with STAMEQ.
4. Two hybrid-mode consultation workshops will gather feedback and contributions on the draft TCVNs. The workshop proceedings will be collected one week after each event.
5. Trips to international labs in countries with solid experience in the management of BESS and reports, including lessons learned and recommendations for TCVNs in Vietnam
6. Reports on testing principles, practicality of TCVNs, and categorization of mandatory and optional standards
7. The final draft of the TCVNs for BESS was submitted to the Appraisal Council based on the comments and feedback from different stakeholders and in close consultation with STAMEQ.
8. A complete dossier of TCVNs on BESS to submit to MOST for promulgation.
9. Organization of the Final stakeholder workshop and the final workshop report
10. The final Completion report

As seen from the above list, this comprehensive report fulfills deliverable 2. It follows the Inception report submitted to the client in April 2024. The report serves as background information for the client and direct beneficiaries of the project.

2.2 Objective

This comprehensive study aims to address the need to establish national standards for Battery Energy Storage Systems (BESS) in Vietnam. By first analyzing the current state of BESS in Vietnam, including its technical regulations, industry standards, and technical requirements, and second by researching the standards of advanced countries in BESS, this comprehensive study seeks to lay the groundwork for the development and approval of a comprehensive set of Vietnamese National Standards (TCVN) for BESS. These include, amongst others, specifications and testing methods, planning and performance assessments, environmental issues, and safety considerations related to BESS.

2.3 Research questions and methodology

To reach the objective of this comprehensive study, the following methodology is applied: (i) collect information about the current state of BESS in Vietnam, (ii) study the international standards on BESS, and (iii) conduct desk surveys of the current status of technical regulations and standards applied in BESS projects in Vietnam, and make a comparison with international standards, and (iv) make recommendations on BESS standards to be developed and implemented in Vietnam.

The following research questions are to be answered:

1. What is the current state of BESS in Vietnam?
    a) What is the definition of BESS in Vietnam?
    b) What is the hierarchy of technical regulation and standards in Vietnam?
    c) What is the current status of standards applied in BESS projects in Vietnam?
    d) What is the current status of BESS application in the renewable energy projects in Vietnam?
2. What are the current states of standards for BESS internationally?
    a) What are the five suitable reference countries for Vietnam (for example countries like the United States, Australia, Japan, China, South Korea, The UK, Germany, Spain, France, and The Netherlands)?
    b) What are relevant international and national standards related to BESS?
3. What standards are required in Vietnam for BESS to be developed successfully?
    a) What are the current gaps related to standards for BESS in Vietnam?
    b) What is the proposed list of standards for BESS in Vietnam that should be developed?
    c) What content needs to be included in the standards for BESS in Vietnam?
4. How can the proposed list of standards for BESS in Vietnam be developed?
    a) What is the Consortium's approach to developing the standards?
    b) What is a suitable roadmap for developing the standards?

2.4 The purpose of using standards.

A technical standard is a recognized criterion or prerequisite for a repeatable technical task. It is a formal document that sets uniform procedures, practices, processes, and engineering or technical criteria. Essentially, BESS technological standards offer a clear group of specifications for the item, system, service, performance, and other components. The main intentions of standards are (i) Establish a defined target level of safety for the system to guarantee that human health and safety are not jeopardized, as well as ensure that performance (e.g., energy production) as the structural integrity of the installations meet the target safety and reliability levels. (ii) Establish uniformity regarding terminology, product specifications, protocols, processes, and more across manufacturers, designers, utilities, government agencies, and other stakeholders. (iii) Formalize the technical parts of a project contract or procurement agreement, such as the precise material performance requirements and others.

National or worldwide consensus-based organizations such as IEC, ISO, IEEE or NFPA create technical standards for BESS. Additionally, businesses can create standards unique to their organization, as is practice for Oil and Gas companies, for example, to maintain the same approach, working methods, and safety standards regardless of the geographical location of their operations.

Standards may be mandatorily enforced through government legislation; however, more often, they are agreed upon and required by all stakeholders (e.g., banks, investors, contractors) rather than being a legal requirement. There are standards applicable throughout all phases of BESS projects, including planning, design, construction, commissioning and performance assessment, operation, and maintenance...

2.5 Reading guide

- Chapter 3 describes the existing technical documents, including technical regulations, standards, and project requirements on BESS in Vietnam.
- Information about international standards on BESS is collected from relevant data from trusted resources. The results of this part of the study are included in Chapter 4.
- The results, together with insights obtained through the technical expert teams' practical experience, led to identifying gaps and developing a recommended list of standards for BESS projects, which is documented in Chapter 5.
- The essential findings, combined with the deliverables of the previous research questions and the researchers' expert judgments, will lead to the roadmap in Chapter 6.
- Chapter 6 presents the proposed list of National standards and a Roadmap to develop them, while Chapter 7 gives the conclusions and recommendations of this comprehensive study.

Chapter 3. Current Technical Regulations and Standards of BESS in Vietnam

This chapter is guided by the main research question: ‘’What is the current state of BESS in Vietnam?’’ and is divided into four sub-questions:

a. What is the definition of BESS in Vietnam?
b. What is the hierarchy of technical regulation and standards in Vietnam?
c. What is the current status of standards applied in BESS projects in Vietnam?
d. What is the current status of BESS application in the renewable energy projects in Vietnam?

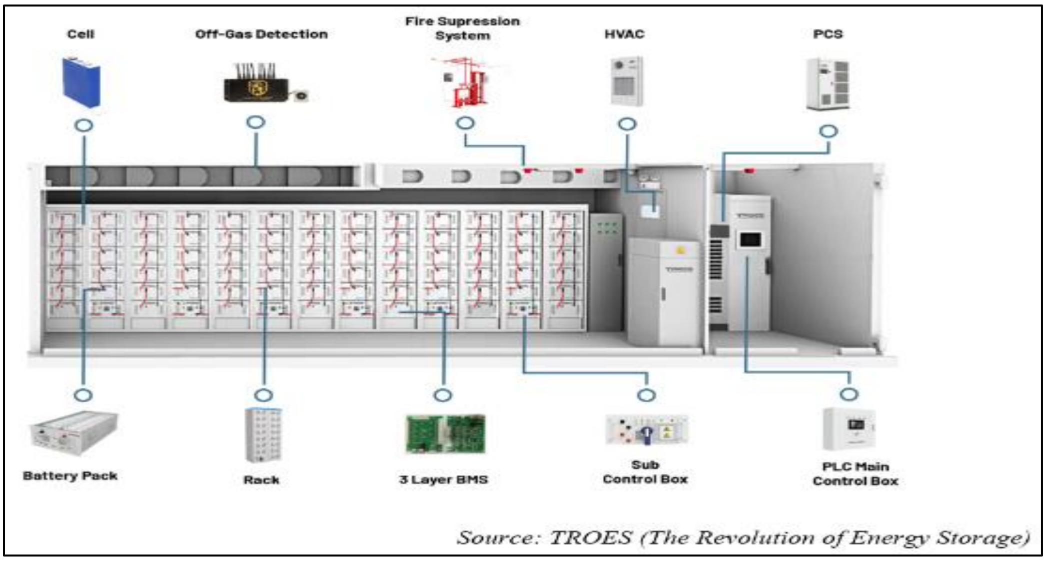
3.1 Definition of BESS

So far, there is no specific definition of BESS (Battery Energy Storage Systems) in the legislative documents of Vietnam. Currently in Vietnam, battery storage systems are primarily designed as energy storage solutions for backup electrical power and uninterruptible power supplies (UPS) in the power supply systems of users' premises, such as power plants, industrial facilities, civil buildings, and transportation.

The Battery Energy Storage System (BESS) can be understood as a grid-connected energy storage system that uses batteries to store and supply electrical power to an electrical power system. It allows grid operators to store energy generated by solar and wind resources when they are abundant and discharge that energy later when needed.

Depending on the specific design requirements, a BESS system consists of the following key components:

- Battery system
- Battery management system (BMS)
- Power conversion system (PCS)
- Energy management system (EMS)
- Site Management System (SMS)
- Balance of plant which includes transformer, point of connection (POC) switchgear, Heating, ventilation, and air conditioning (HVAC), Fire protection, and Container.



Source: TROES (The Revolution of Energy Storage)

Figure 1 Example of BESS system

Depending on the specific design there are several installation alternatives for integrating a BESS into the power system as illustrated in Figure 2, in which:

- Alternative (A): Connect to string Inverter.
- Alternative (B): Connect to Central Inverter.
- Alternative (C): connect to low voltage (LV) busbar.
- Alternative (D): connect to medium voltage (MV) busbar.

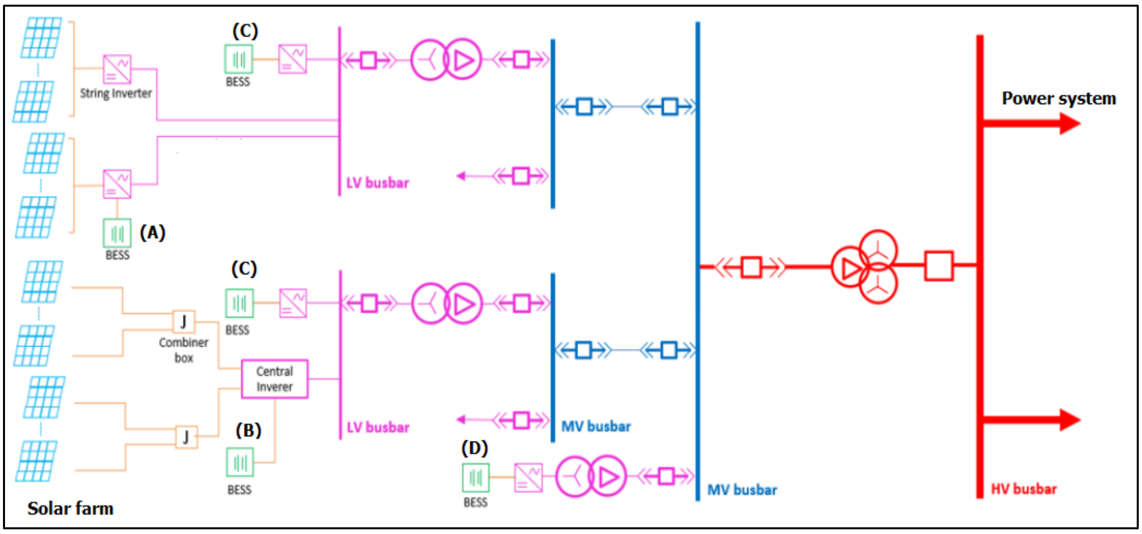


Figure 2 Example of grid-integrated BESS (Applying Battery Energy Storage System (BESS) for renewable energy project" of EVNPECC3 (Power Engineering Consulting Joint Stock Company 3), dated August 07, 2023.)

3.2 Technical Standards and Regulations in Vietnam

National Technical Standards and Regulations

The technical regulation framework in Viet Nam consists of technical regulations (QCVN), national standards (TCVN), industrial standards (TCN), and institution standards (TCCS). The definition of technical regulation and standards is stipulated in Law 68/2006/QH11 on standards and technical regulations, Article 3, as follows:

1. Standards are guidelines outlining technical specifications and management criteria used to classify and assess products, goods, services, processes, environments, and other elements within economic and social activities, aimed at enhancing their quality and efficiency.
   These standards are published by an organization in the form of documents for voluntary application.
2. Technical regulations are specifications that define the thresholds for technical characteristics and management requirements that products, goods, services, processes, environments, and other entities involved in economic and social activities must comply with. These technical regulations aim to ensure the safety, hygiene, and health of individuals, plants, and the environment; and safeguard national interests, security, consumer rights, and other fundamental requirements.
   These technical regulations are issued by competent state authorities in written form and are mandatory for implementation.

The current hierarchy of technical regulations and standards in Vietnam is described in the following order:

- Law on Technical Regulations and Standards
- National/Regional Technical Regulations (QCVN)
- National Standards (TCVN)
- Institutional Standards (TCCS)

The principles for the application of standards are stipulated in Law 68/2006/QH11 on standards and technical regulations, article 23 that (1) standards shall be applied on the principle of voluntariness. The application of part or the whole of a specific standard shall become mandatory when requested in a legislation document or technical regulation; (2) Industrial and institutional standards shall be applied within the scope of management of organizations that announce them.

The principles for and methods of application of technical regulations are stipulated in the forgoing Law (law 68/2006/QH11), article 38.

The project development process requires adherence to the legislation and technical regulation documents regarding appraisal and approval of projects; construction management, operation & maintenance, and demolition of the projects. Analysis of legislative documents, technical regulations, and standards regarding BESS will focus on these forgoing concerns.

Technical regulation relating to BESS

Current technical regulations relating to the development of BESS consist of the following:

- QCVN 01:2021/BXD, National technical regulation on construction planning.
- QCVN 02:2022/BXD, National Technical Regulation on Natural Physical and Climatic Data for Construction.
- QCVN 03:2022/BXD, National Technical Regulation on Classifications of Buildings and Structures for Design.
- QCVN 01: 2020/BCT, National technical regulation on Electric safety.
- QCVN QTĐ 05:2009/BCT, National technical regulation on electrical engineering, Part 5: National Technical Codes for Testing, Acceptance Test for Power Facility.
- QCVN QTĐ 06:2009/BCT, National technical regulation on electrical engineering, Part 6: National Technical Codes for Operating and Maintenance Power System Facilities.
- QCVN QTĐ 07: 2009/BCT, National technical regulation on electrical engineering, Part 7: National Technical Codes for Installation Power System Project.
- Circular No. 25/2016/TT-BCT and Circular 39/2022/TT-BCT, Regulation on electric power transmission system
- Circular No. 39/2015/TT-BCT and Circular 39/2022/TT-BCT, Regulation on electric power distribution system

Technical regulation QCVN 01:2021/BXD

The technical regulation QCVN 01:2021/BXD is issued by the Ministry of Construction under Circular No. 01/2021/TT-BXD dated May 19, 2021, by the Minister of Construction. This technical regulation specifies the limited levels of technical characteristics and mandatory management requirements that must be complied with in planning activities for district areas, inter-district areas, urban planning, and rural planning. It includes the processes of drafting, appraisal, approval, adjustment of planning, and organizing the implementation of planning. This regulation serves as a basis for the development of national standards and local laws in the field of urban-rural planning. The BESS stations are regulated as substations under Article 2.14, which specifies the requirements for power supply.

Technical regulation QCVN 02:2022/BXD

The technical regulation QCVN 02:2022/BXD is issued by the Ministry of Construction under Circular No. 02/2022/TT-BXD dated September 26, 2022, by the Minister of Construction. This technical regulation specifies the natural condition data applicable in the preparation, appraisal, and approval of construction activities. This includes construction planning, development of construction investment projects, construction design, construction execution, supervision of construction, and management of construction investment projects in Vietnam. The content of the standard has provided complete data for design purposes, including data on climate, weather, adverse natural phenomena, lightning density, wind, and earthquakes. The natural condition data specified in the regulations are helpful for the preliminary designs of the Pre-FS phase. In subsequent design phases, specific surveys such as topographical, geological, meteorological, and hydrological conditions should be conducted according to the objectives established for the particular project's design class.

Technical regulation QCVN 03:2022/BXD

The technical regulation QCVN 03:2022/BXD is issued by the Ministry of Construction under Circular No. 05/2022/TT-BXD dated November 30, 2022, by the Minister of Construction. This regulation stipulates classifications of buildings and construction structures based on the following:

a. Consequences caused by damaged or destroyed structure elements (hereinafter referred to as "consequence class");
b. Design lifetime of buildings and structures;
c. Fire-related technical classifications of buildings and structures include fire-resistance category, fire risk level of structure, and fire risk category by occupancy;
d. The consequence classes of constructions are divided into three classes: C1 (Low), C2 (Moderate), and C3 (High), as specified under Annex A of the regulation.

The design lifetimes are divided into four levels: 1,2,3 and 4, with a lifetime of 20, 25, 50, and 100 years, respectively. The BESS are categories to energy construction projects (industrial sector); the design lifetime of BESS shall be at least 50 years as per regulation in Table 01 of technical regulation QCVN 03:2022/BXD.

The fire resistance is divided into five categories: I, II, III, IV, and V, depending on the number of stories (or fire service height of construction), fire risk category by occupancy, fire compartment area, and fire hazard of technology process within the constructions. Fire risk levels of structural elements are divided into S0, S1, S2, and S3, depending on the fire risks of the elements. The fire risk category by occupancy (hazard occupancy) is classified into five fire risk categories by occupancy of F1, F2, F3, F4, and F5 depending on use characteristics and threat to human safety in case of fire, considering age, physicality, possibility of people sleeping, number of occupied people.

Currently, national technical regulations still need to be put in place to guide fire prevention and firefighting measures for BESS projects. This potential causes inconsistent design of fire protection among projects and between the appraised design documents and actual supplies provided by suppliers.

Technical regulation QCVN 01:2020/BCT

The technical regulation QCVN 01:2020/BCT is issued by the Ministry of Industry and Trade under Circular No. 39/2020/TT-BCT dated November 30, 2020, by the Minister of Industry and Trade. This regulation stipulates the safety measures to be ensured during the execution of construction, operation, business, testing, inspection, and repair of power lines, electrical equipment, and other tasks as prescribed by law.

Technical regulation QCVN QTĐ-5:2009/BCT

The technical regulation QCVN QTĐ-5:2009/BCT is issued by the Ministry of Industry and Trade under Circular No. 40/2009/TT-BCT dated December 31, 2009, by the Minister of Industry and Trade. This technical regulation specifies the requirements for inspection activities during installation, completion testing, and periodic testing for electrical apparatus of power grids, hydropower, and thermal power plants. The regulation specifies requirements in Article 39 for inspecting batteries, including measuring voltage and checking for balanced charging. This Article is limited to the battery systems of the auxiliary power supply systems of substations and power plants.

Technical regulation QCVN QTĐ-6:2009/BCT

The technical regulation QCVN QTĐ-6:2009/BCT, issued by the Ministry of Industry and Trade under Circular No. 40/2009/TT-BCT dated December 31, 2009, by the Minister of Industry and Trade, outlines the technical requirements essential for the operation and maintenance of hydraulic structures and auxiliary mechanical equipment in hydropower plants, thermal process equipment in thermal power plants, and electrical apparatus within power grids. These standards are formulated to ensure the safety, environmental protection, and reliability of the associated facilities and equipment. The regulation specifies requirements in Part VI, chapter 6 for battery systems, including operation voltage, inspection, ventilation, control voltage, and symbols and numbering. This chapter is limited to the battery systems of the auxiliary power supply systems of substations and power plants.

Technical regulation QCVN QTĐ-7:2009/BCT

The technical regulation QCVN QTĐ-7:2009/BCT is issued by the Ministry of Industry and Trade under Circular No. 40/2009/TT-BCT dated December 31, 2009, by the Minister of Industry and Trade. This regulation provides requirements for technical tasks such as constructing and repairing electrical apparatus in the power grid. This regulation is applied to creating and installing electrical facilities with voltages up to 500 kV. The regulation specifies requirements in Chapter 3, item 6 for station battery systems, including requirements for busbar systems, and installation of battery banks. This chapter is limited to the battery systems of the auxiliary power supply systems of substations and power plants.

Circular No. 25/2016/TT-BCT and The Circular 39/2022/TT-BCT

The Circular 25/2016/TT-BCT, issued by the Ministry of Industry and Trade (MOIT) on November 30, 2016, regulates the electric power transmission system. Circular 39/2022/TT-BCT, issued by MOIT on December 30, 2022, amends and supplements some provisions of Circular No. 25/2016/TT-BCT and Circular No. 39/2015/TT-BCT. These circulars stipulate requirements for the electric power transmission system, load forecasting, transmission grid development plans, technical requirements, procedures for connecting to the power transmission grid, security assessments of the power system, and the operation of transmission line systems.

Article 42 relates to the development of BESS. This article specifies the technical requirements for wind and solar power plants, including operational capabilities of the wind and solar power plants concerning frequency, voltage, and load control in both steady and transient states. The requirements are consistent with recognized international standards. Circular 25/2016/TT-BCT explicitly outlines the requirements for the interconnection of inverter-based resources to the transmission level of the electric power system.

Circular No. 39/2015/TT-BCT and The Circular 39/2022/TT-BCT

The circular 39/2015/TT-BCT, issued by the MOIT on November 18, 2015, regulates the electric power distribution system. Circular 39/2022/TT-BCT, issued by MOIT on December 30, 2022, amends and supplements some provisions of Circular No. 25/2016/TT-BCT and Circular No. 39/2015/TT-BCT. These circulars stipulate requirements for the electric power distribution system, load forecasting, distribution grid development plans, technical requirements, and procedures for connecting to the power distribution grid, and the operation of electric power distribution systems.
Articles 40 and 41 relate to the development of BESS. Article 40 specifies the technical requirements for wind and solar power plants connecting to the electrical power distribution system at medium voltage levels and above. Article 41 addresses solar power systems connecting to low-voltage power distribution systems. These articles specify the operational capabilities of the wind and solar power plants concerning

frequency, voltage, and load control in both steady and transient states. The requirements are consistent with recognized international standards. Circular 39/2015/TT-BCT explicitly outlines the requirements for the interconnection of inverter-based resources to the distribution level of the electric power system.

Construction management, operation & maintenance, and demolition of the projects

Referring to Circular 06/2021/TT-BXD, classification of constructions and guidelines for application in the management of construction investment, appendix I, battery supply/charging stations are designated as class III projects with all scales. In line with Decree 15/2021, on elaborating certain regulations on the management of construction projects, Article 3, Appendix X, categorizes BESS as projects significantly impacting safety and community interests. So, the feasibility study and technical design reports for BESS projects must undergo appraisal by a construction authority as mandated by Articles 13 and 14, Articles 36 and 37 of Decree 15/2021 respectively.

Articles 14 and 33 of Decree 15/2021 mandate that design documents submitted for appraisal by the construction authority, depending on the project phase, must delineate the list of standards, technical regulations applied, technical specifications, and maintenance procedures for the construction. Currently, comprehensive national standards for the design, operation, and dismantling of BESS projects are not yet to be fully developed.

Furthermore, Decree 06/2021/NĐ-CP, which elaborates on implementing several quality management regulations, Article 5 outlines the testing, inspection, and acceptance criteria necessary for project quality control. However, the technical standards and procedures for testing, monitoring, and surveying BESS remain insufficient.

In instances where national standards are absent, which is currently the case for BESS, project developers are required to apply the international standards. Consequently, developers must navigate the process of obtaining approval for these applied international standards in compliance with regulatory requirements stipulated in Decree 15, Article 8, clause 2 in case of applying foreign standards as follows:

- In the construction design reports or technical specifications (if any), there must be an assessment of compatibility, consistency, and compliance with national technical regulations;
- Priority should be given to the use of recognized and widely applied foreign standards.

Applying foreign standards poses considerable challenges for authorities in the design document appraisal process due to the potential of:

- Differences with natural conditions and technical regulation of Viet Nam
- Variations in technical design criteria among different developers and projects.

Therefore, there is a strong need for a comprehensive set of standards for BESS that applies to the entire nation to streamline the design document appraisal process.

3.3 National Standards on BESS

Currently, Vietnam's national standard system has existing TCVNs related to Batteries, which are entirely equivalent in content to the corresponding IEC and ISO standards, namely:

Table 1 National standards on Battery issued in Vietnam

No	National TCVNs	Equivalent standards	Description
1	TCVN 12668-1:2020	IEC 60086-1:2015	Primary batteries - Part 1: General provisions

No	National TCVNs	Equivalent standards	Description
2	TCVN 12668-2:2020	IEC 60086-2:2015	Primary batteries - Part 2: Technical regulations on physics and electricity
3	TCVN 12668-3:2020	IEC 60086-3:2016	Primary batteries - Part 3: Batteries for wristwatches
4	TCVN 12668-4:2020	IEC 60086-4:2019	Primary Batteries - Part 4: Safety of lithium batteries
5	TCVN 12668-5:2020	IEC 60086-5:2016	Primary batteries - Part 5: Safety of batteries using liquid electrolyte
6	TCVN 12508:2018	ISO 23828:2013	Fuel cell road vehicles - Energy consumption measurement – Vehicles fuelled with Compressed hydrogen vehicles
7	TCVN 12240:2018	IEC 62281:2016	Safety of primary and secondary lithium batteries and batteries during transportation
8	TCVN 11919-2:2017	IEC 62133-2:2017	Secondary cells and batteries containing alkanes or other non-acid electrolytes – Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications – Part 2: Lithium system
9	TCVN 12241-1:2018	IEC 62660-1:2018	Secondary lithium-ion cells for the propulsion of electric road vehicles - Part 1: Performance testing
10	TCVN 12241-2:2018	IEC 62660-2:2018	Secondary lithium-ion cells for the propulsion of electric road vehicles – Part 2: Reliability and abuse testing
11	TCVN 12241-3:2018	IEC 62660-3:2016	Secondary lithium-ion cells for the propulsion of electric road vehicles - Part 3: Safety requirements
12	TCVN 9055: 2011	ISO/TR 11954: 2008	Fuel cell road vehicles – Maximum speed measurement
13	TCVN 7568-6:2013	ISO 7240-6:2011	Fire detection and alarm systems - Part 6: Carbon monoxide fire detectors using electrochemical cells
14	11 TCN 20-2006 - Part III	Not Applied	Regulation on Electrical Equipment - Part III Distribution Equipment and Substations.

The TCVN 12668 series, from parts 1 to 5, pertains to primary batteries, which are designed for single-use and disposal, unlike secondary cells (rechargeable batteries) that can be recharged and reused.

TCVN 12508, TCVN 12240, TCVN 11919, TCVN 12241 (parts 1 to 3), and TCVN 9055 are testing standards for battery energy storage and fuel cell systems in road vehicles.

TCVN 7568-6:2013 specifies the requirement for testing methods and specifications for Carbon monoxide fire detectors that use electrochemical cells of fire alarm systems.

The standards mentioned above do not pertain to Battery Energy Storage Systems (BESS) integrated into the power system; therefore, the consultant will not analyze the content of these standards further.

11TCN 20-2006 – part III is a section of the industrial standard concerning electrical equipment. This regulation was promulgated under Decision No. 19/2006/QĐ-BCN dated July 11, 2006, by the Ministry of Industry. This regulation is divided into four parts:

- Part I - General regulations,
- Part II - Electrical transmission systems,
- Part III - Distribution equipment and substations,

- Part IV - Protection and automation.

11TCN 20-2006 – Part III specifies the guidelines for batteries in Chapter III. The scope of application includes fixed acid batteries and alkaline batteries used in electrical power projects. The requirements for electrical equipment are specified in clauses III.3.3 to III.3.25, providing the necessary technical specifications for battery banks, chargers, bus bars, and accessory equipment. Clauses III.3.26 to III.3.39 outline the technical requirements for the construction of battery rooms. The requirements for the sanitary facilities of battery rooms are specified in clauses III.3.40 to III.3.45. The requirements for battery equipment in this industrial standard are limited to the direct current (DC) auxiliary power supply systems of electrical power projects.

It has been found that the TCVNs for BESS, which should include specifications and testing methods, planning and performance assessments, environmental issues, and safety considerations, remain insufficient. The requirements for the interconnection of BESS to the transmission and distribution levels of the electric power system are explicitly outlined in Circular 25/2016/TT-BCT and Circular 39/2015/TT-BCT respectively.

3.4 Current status of BESS application in the renewable energy projects in Vietnam [1]

Development of renewable energy in Vietnam

In an effort to fulfill Vietnam's commitments made at the COP 26 conference, the Government of Vietnam has set renewable energy development goals in the following documents:

- Strategy for Renewable Energy Development in Vietnam to 2030, with a Vision to 2050.
- Resolution No. 55-NQ/TW dated February 11, 2020, of the Politburo of Vietnam.

The Strategy for Renewable Energy Development in Vietnam for the period up to 2030, with consideration to 2050, was approved by the Prime Minister in Decision No. 2068/QĐ-TTg dated November 25, 2015. It specifies that the proportion of electricity generated from renewable energy sources in the total national power production must reach 38% by 2020, 32% by 2030, and 43% by 2050.

Resolution No. 55-NQ/TW dated February 11, 2020, by the Politburo stipulates that the proportion of renewable energy sources in the total primary energy supply should reach 15-20% by 2030 and 25-30% by 2045. Correspondingly, the share of electricity from renewable energy in the total national power generation is expected to be about 30% in 2030 and 40% in 2045.

To achieve the aforementioned renewable energy targets, the government has issued various mechanisms to encourage the development of renewable energy. Among these, several decisions and regulations have had a positive impact on the development of wind and solar power, as follows:

- Decision No. 37/2011/QĐ-TTg, dated June 29, 2011, on the mechanism to support the development of wind power projects in Vietnam.
- Decision No. 11/2017/QĐ-TTg, dated April 11, 2017, regarding the mechanism to encourage the development of solar power projects in Vietnam.
- Circular No. 16/2017/TT-BCT, dated September 12, 2017, which stipulates the development of projects and template power purchase agreements applicable to solar power projects.
- Decision No. 39/2018/QĐ-TTg, dated September 10, 2019, amending and supplementing several provisions of Decision No. 37/2011/QĐ-TTg dated June 29, 2011, by the Prime Minister on the mechanism to support the development of wind power projects in Vietnam.

[1] The contents in this section are extracted from General report of the National Power Development Plan for the period 2021~2030, with a vision to 2050, issued under Decision No. 500/QĐ-TTg, dated May 15, 2023, by the Prime Minister.

- Circular No. 02/2019/TT-BCT, dated January 15, 2019, which stipulates the implementation of wind power project development and template power purchase agreements for wind power projects.
- Decision No. 13/2020/QĐ-TTg, dated April 6, 2020, regarding the mechanism to encourage the development of solar power in Vietnam.

The aforementioned incentive mechanisms have significantly boosted the development of the renewable energy sector, particularly in the southern and south-central regions, where there is high technical potential for renewable energy. The National Power Development Plan for the period 2021-2030, with a vision to 2030, indicates:
- Regarding wind power, as of December 2020, the total installed capacity of about 600MW of wind power had been put into operation nationwide. Along with this, many projects are under construction, with a total wind power capacity of about 3000MW having signed power purchase agreements (PPAs) with Vietnam Electricity (EVN).
- Regarding solar power, by the end of 2020, grid-connected solar power capacity reached about 9,000 MW, with nearly 3,500 MW in Ninh Thuan and Binh Thuan provinces. The planned capacity of solar power projects has been increased to over 15,400 MW, with a total registered capacity for construction not yet added of nearly 97,000 MW. In addition to solar farm projects (installed on land and water surfaces), rooftop solar projects have also developed very rapidly. By the end of 2019, the installed capacity of rooftop solar power nationwide was only 340 MWp (approximately 272 MW), but by the end of 2020, the total installed capacity reached nearly 7,800 MW. Provinces in the Southeast region (including Ho Chi Minh City) continue to lead in rooftop solar installations in both the number of projects and total installed capacity.

The plan to implement the National Power Development Plan for the period 2021-2030, with a vision to 2050, issued under Decision No. 262/QĐ-TTg dated April 1, 2024, by the Prime Minister, sets the following targets for renewable energy capacity by the year 2030:
- The total capacity of Offshore Wind Power is 6,000 MW;
- The total capacity of onshore wind power (including land-based and nearshore) is 21,880 MW;
- The additional capacity for rooftop solar power (self-generation, self-consumption) is 2,600 MW.

Issues related to the integration of renewable energy sources into the power system.

The characteristic of power production from renewable energy sources is that it is intermittent and unstable. When integrating these types of power sources, the power system faces the following technical challenges:
- Electric quality is an important factor in the power system to ensure stability and high efficiency of the power grid, creating high reliability and low cost: The rectifiers and inverters in wind and solar power systems generate harmonics, which if not properly filtered or mitigated, can pose a risk of adversely affecting the electric power quality of the power system.
- Availability of power is one of the biggest concerns in integrating renewable energy sources with the power system: Solar energy does not generate power at night, and wind energy depends on wind speed.
- Accuracy of forecasting: In power systems, forecasting is a main topic of energy management systems for planning grid development to ensure stability and high reliability, because most renewable energy technologies depend on weather and environmental factors, making power generation forecasts very difficult to accurately predict. The accuracy typically achieved in load

forecasting for the electricity distribution system leads to high operational quality due to continuous power generation and ensures future load demands.

- Location of renewable energy sources: Most large-scale renewable energy power plants occupy a significant land area. The choice of site for constructing renewable energy power plants involves many factors that affect their integration into the power grid. When the location of the renewable power plant is far from the load center, it impacts the cost and operational efficiency of the project. The power generation capacity of renewable sources also highly depends on the weather and climate conditions at the site of the renewable energy source.

It is evident that with the characteristic of rapid, uncontrollable changes in power output, wind, and solar energy can cause significant fluctuations to the power system whenever there is a variation in wind or a cessation. If alternative power sources are not invested in to replace them at those times, or if the existing power sources are not adjusted to increase (or decrease) their power output in time to compensate while wind and solar are contributing, the power system will lose balance between supply and demand. Consequently, the voltage and frequency of the power system may drift outside the allowable limits, and technical protection systems will activate, potentially leading to severe consequences such as grid collapse and widespread power outages.

Further, Solar power plants face a challenge in that their generation time is limited to a specific timeframe (approximately from 7 AM to nearly 5 PM, with peak capacity between 11 AM and 2:30 PM, depending on geographical location). Meanwhile, the peak load hours in Vietnam occur between 9 and 11 AM, from 2 to 4 PM during summer, and from 5 to 7 PM in winter. This discrepancy leads to a significant amount of power generated during the peak times of solar plants becoming redundant and wasted.

To cope with the issues mentioned above, the application of Battery Energy Storage Systems (BESS) has been identified as one of the appropriate solutions to address economic and system stability challenges. This strategy is in line with the Prime Minister's directive to install 300 MW of BESS by 2030 and to increase storage power capacity to between 30,650 MW and 45,550 MW by 2050. Recognizing this trend, the installation of BESS will soon become widely adopted in renewable energy projects, particularly in solar power projects.

The application of Battery Energy Storage Systems (BESS) for renewable energy development in Vietnam is becoming an important trend to ensure the stability and efficiency of the electrical system. This technical solution not only helps improve the regulation of frequency and voltage in the power grid but also enhances the reliability and safety of the power supply as follows:

- System Stability: BESS can store excess energy during high production periods and release it back into the grid when demand increases or when the supply is interrupted, helping to stabilize the system and avoid energy waste.
- Peak Demand Response: BESS can quickly supply energy to the grid for short periods, meeting power demands during peak times without the need to start backup power plants, thus reducing costs and environmental impacts.
- Mitigating Renewable Energy Variability Risks: With the characteristic dependence on weather conditions, solar and wind energies are highly variable. BESS helps to smooth the power generation curve, reducing adverse effects on the system due to rapid changes in supply.
- Load Regulation Support: BESS provides an efficient solution for load regulation in the power system, especially in situations where traditional load adjustments are too slow or ineffective.

- Cost saving: Integrating BESS into the power system helps reduce investment costs for backup power stations and also reduces operational costs by minimizing the number of starts and stops of large power plants.

Despite the compelling advantages that Battery Energy Storage Systems (BESS) offer for renewable energy integration and grid stability, there are significant challenges in their widespread adoption, such as high initial investment costs, demanding technological and technical requirements, and recycling of waste batteries. However, these challenges are becoming less formidable due to the rapid advancement of technology.

Application of BESS for Renewable Energy Development in Vietnam

Currently, BESS projects in Vietnam are in the research and pilot proposal phase. The Government of Vietnam issued Decision No. 1009/QĐ-TTg on August 31, 2023, allowing Vietnam Electricity (EVN) to invest in a pilot Battery Energy Storage System (BESS) with a capacity of 50MW/50 MWh to study ancillary services and lay the groundwork for developing pricing policies as well as technical standards. Recently, on March 26, 2024, EVN had a meeting with the Asian Development Bank (ADB) about the draft proposal for a pilot project of a Battery Energy Storage System (BESS) to provide ancillary services in Vietnam. Research units and specialized power system consulting firms such as the Energy Institute of the Ministry of Industry and Trade, and EVN's power engineering consulting companies (EVNPECC1, EVNPECC2, EVNPECC3, EVNPECC4) have been tasked with participating in research on the design and application of BESS in renewable energy projects to address the current issues of power shortages, overloads of the power grid, and the risk of power system instability.

Recently in Vietnam, to meet the self-production and self-consumption requirements for rooftop solar power, many households, commercial premises, office buildings, and factories in the southern region have installed micro–Battery Energy Storage Systems (BESS) with capacities ranging from a few kWh to several dozen kWh. Notably, the Electricity Construction Consulting Joint Stock Company No. 2 (EVNPECC2) has installed a 750 kW BESS with a battery storage capacity of 2 MWh, which has been in operation since 2021 as a pilot project.

Figure 3 BESS pilot project in Vietnam

3.5 Current status of standards applied in BESS projects in Vietnam

Currently, there are no BESS projects officially in operation on the Vietnamese power system. The applicable standards are limited to the design of battery storage stations within the DC auxiliary power supply system and uninterruptible power supplies (UPS) of substation stations and power plants as follows:

- QCVN 01: 2020/BCT, National technical regulation on Electric safety.
- QCVN QTĐ 05:2009/BCT, National technical regulation on electrical engineering, Part 5: National Technical Codes for Testing, Acceptance Test for Power Facility.
- QCVN QTĐ 06:2009/BCT, National technical regulation on electrical engineering, Part 6: National Technical Codes for Operating and Maintenance Power System Facilities.
- QCVN QTĐ 07: 2009/BCT, National technical regulation on electrical engineering, Part 7: National Technical Codes for Installation Power System Project.
- 11 TCN 20-2006 Regulation on Electrical Equipment - Part III Distribution Equipment and Substations.
- IEC 60623 Secondary cells and batteries containing alkaline or other non-acid electrolytes.

Chapter 4. International policies, regulations, and standards on BESS

The objective of this project and the focus of this comprehensive report are to establish national standards for BESS. Through research, the research team discerned that these standards do not operate in isolation but are integral to the ecosystem governing BESS development. This ecosystem comprises various policies, laws, codes, standards, and regulations, collectively shaping the trajectory of BESS development in each country. Initiatives to foster BESS will expedite industry growth and stimulate the formulation of national standards. Technical challenges usually emerge once projects are rolled out, and the need for standards to define best practices and achieve consensus comes along to ensure smoother implementation for subsequent projects. Understanding the broader regulatory framework that governs BESS projects, especially the policies that give rise to the accelerated installations of BESS in leading BESS markets, to design national standards in harmony with these regulatory requirements is, therefore, essential.

Hence, this chapter is guided by the main research question: "What is the current state of standards on BESS internationally?" and the following sub-questions:

a. What are the five suitable reference countries for Vietnam?
b. What are the relevant international and national standards related to BESS?

4.1 Five Suitable Reference Countries for Vietnam

4.1.1 Selection of reference countries

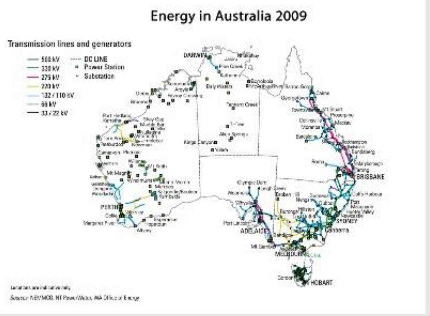
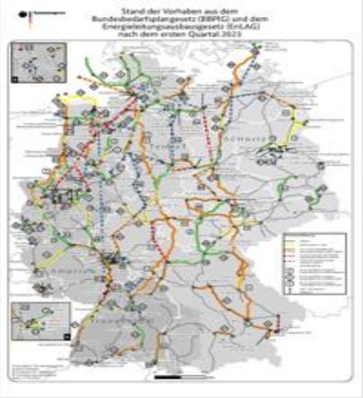
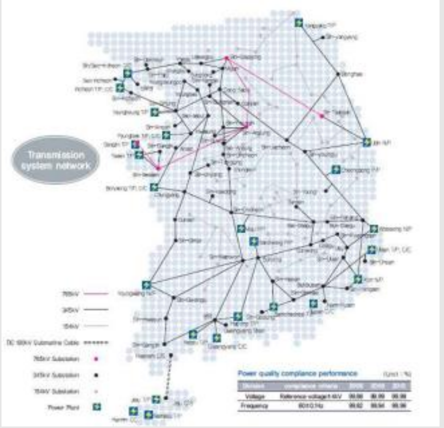
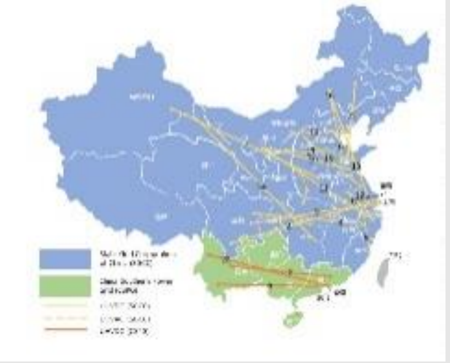
The reference countries have been selected based on specific criteria, including their experience in installing BESS at a grid-scale, having a clearly defined plan for integrating BESS into the grid, and the development of their own national standards or translation of international standards to their local context.

Considering these criteria, the chosen reference countries are the Netherlands, Germany, Australia, China, and South Korea.

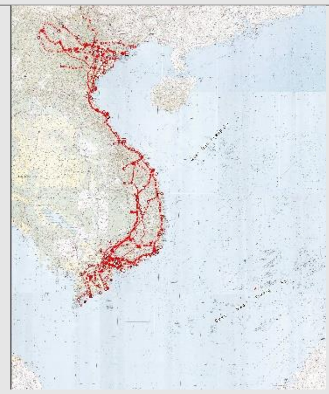
Table 2 Selection criteria for 5 representative countries

Countries / Criteria	Vietnam	Australia	Germany	The Netherlands	South Korea	China
Power system design	Vietnam's electricity system consists of two parallel 1,500-km 500-kV transmission lines linking the north and south, with the center acting as a transmission link. The system is divided into three regions: the North (from Ha Tinh northwards), the Central (from Quang Binh to Khanh Hoa, including the four Central Highlands provinces), and the South (from Ninh Thuan southwards). Coal-fired power plants are concentrated in the North and South. The North primarily uses domestic coal with a capacity of approximately 12,670 MW, while the South mainly uses imported coal, totaling around 8,680 MW. Combined cycle gas turbine plants, using gas and oil, are located in the South, with a capacity of about 7,420 MW. Hydropower plants, including small hydropower plants, are distributed across all three regions: the North has about 11,640 MW, the Central region about 5,450 MW, and the South about 3,910 MW (IE, 2021). Renewable energy, particularly	Fossil fuels contributed 68% of total electricity generation in 2022, including coal (47%), gas (19%) and oil (2%)[2]. In Australia, electricity generation varies by state. Western Australia produced 43,923 GWh mainly from natural gas (85%) and coal (15%). The Northern Territory generated 4,919 GWh, primarily from natural gas (94%) with some renewables (6%). Queensland's 69,454 GWh mainly came from coal (81%) and renewables (19%). South Australia generated 13,927 GWh, largely from renewables (65%) and coal (35%). New South Wales produced 70,440 GWh, with coal (73%) and renewables (27%). Victoria's 53,097 GWh was split between coal (67%) and renewables (33%). Tasmania generated 11,693 GWh, predominantly from hydroelectric power (99%)[3] Australia's grid network consists of three main interconnected electricity systems: the National Electricity Market (NEM), the Southwest Interconnected System (SWIS), and the Northern Territory system. Due to its large size and the location of its population, Australia lacks a single grid that covers all states, but has a transmission grid that extends along the east coast from Queensland via New South Wales and Victoria to South Australia and also connects via submarine DC cable with Tasmania. The network includes major AC	In 2021, renewable energies comprised 42.8% of Germany's electricity generation, down from 48.0% in 2020. Wind power led with 22.6%, followed by solar at 9.3%, and other renewables at 10.9%[4]. In Germany, most conventional power plants are located near urban areas where energy is consumed, except for lignite-fired plants in central Germany, which are near coal mines and require electricity transport to consumption centers. Renewable energy sources are spread throughout the country, with wind energy concentrated in the north and photovoltaic energy in the south (Martinho, 2023). The extra-high voltage grid (220 kV or 380 kV) serves as the main transmission network, connecting large power plants and offshore wind farms and linking to the European interconnected grid. The high voltage grid (60 kV or 110 kV) acts as a distribution network for industrial consumers, linking fossil fuel plants, wind farms, and hydroelectric stations. The medium voltage grid (1 kV to 60 kV) distributes power from renewable sources like solar, wind, biogas, and hydroelectric to industrial and large	In 2022, the Netherlands' top energy sources were natural gas (40%), wind (18%), solar (15%), coal (14%), and biomass (7%)[7]. Natural gas and oil production centers around offshore areas in the North Sea and coastal regions. Renewable energy sources like wind and solar power are strategically located along the North Sea coast and in regions with high wind activity in the north and northwest. Hydrogen production facilities are spread across the country, supporting industrial and automotive sectors as vital energy sources[8] The grid core is a high-voltage transmission grid managed by TenneT, typically operating at voltages ranging from 110 kV to 380 kV. This above-ground system includes visible pylons and transmission lines. It serves as the backbone for transporting electricity from large-scale power plants, including renewable sources like offshore wind farms in the North Sea, to regional distribution networks. The regional distribution networks, managed by Distribution Network Operators (DNOs), deliver electricity at medium voltages (10 kV to 50 kV) and low voltages (230 V and 400 V) to residential, commercial, and industrial consumers. Households and other relatively small users are connected to the distribution grid, while large-scale	In 2022, South Korea's electricity production breakdown was as follows: nuclear (29.6%), coal (32.5%), LNG (27.5%), non-renewable energy excluding coal and LNG (8.9%), and hydrogen & ammonia (1.4%)[9]. The largest natural gas field in South Korea, Donghae-1, is situated offshore on the eastern coast. Oil production centers on offshore sites in the west and northwest, with Ulsan housing the largest refinery. Coal resources are concentrated in places like Jang Seong, supporting facilities such as the Gwangyang coal gasification plant. Renewable energy, including wind farms in the south and solar installed nationwide. Hydrogen production hubs are located in industrial and automotive areas. Bioenergy facilities across urban areas, including Seoul, process biomass and waste[10](Lee et al., 2015). Electricity production in South Korea is predominantly concentrated in the southern provinces, while consumption is heavily focused in metropolitan areas like Seoul. This geographic disparity necessitates efficient long-distance transmission of electricity, which is managed primarily by the Korea Electric Power Corporation (KEPCO). The transmission system includes major networks operating at 765kV and 345kV, local systems at 154 kV and 22.9 kV. Additionally, Jeju Island's power system is connected to the mainland via two High	In 2022, non-fossil fuels accounted for 49% of the total installed electricity generation capacity in China. This predominantly came from hydroelectric sources (16%), solar energy (15%), and wind power (14%)[12]. Coal mining predominates in northern and central regions like Inner Mongolia and Shanxi. Major oil production occurs in Daqing and offshore fields in Jiangsu, with refining centered at Zhenhai in Zhejiang. Natural gas extraction is prominent in eastern areas like Inner Mongolia's Sulige Gas Field, supplemented by reserves in western regions such as Xinjiang and Sichuan. Hydropower is a significant renewable source, particularly along the Yangtze and Yellow Rivers in provinces like Yunnan and Sichuan. Nuclear power plants are located in coastal provinces such as Guangdong and Zhejiang. China's renewable energy leadership is evident in extensive solar installations in Inner Mongolia and Xinjiang, and wind farms in Gansu and Inner Mongolia[13] China has developed a comprehensive network of provincial and regional power grids, including six inter-provincial grids and three independent provincial grids. These grids are interconnected through AC and DC transmission lines to efficiently distribute electricity across the country. Due to uneven distribution of resources, China has implemented strategies like the north, center, and south corridors to transfer power

[2] Electricity generation | energy.gov.au
[3] Australian Energy Statistics, Table O Electricity generation by fuel type 2020-21 and 2021 | energy.gov.au
[4] Bundesnetzagentur - Aktuelle Strommarktdaten
[7] Netherlands - Energy (trade.gov)
[8] Energy industry in the Netherlands (aenert.com)
[9] wnisr2023-table12-south_korea_elec_mix.pdf (worldnuclearreport.org)
[10] Energy industry in South Korea (aenert.com)
[12] China generates increased amounts of electricity from non-fossil fuel sources (www.gov.cn)
[13] Energy industry in the People's Republic of China (aenert.com)

Countries / Criteria	Vietnam	Australia	Germany	The Netherlands	South Korea	China
	wind and solar, is predominantly produced in the south and south-central regions, while the north remains energy deficient. The backbone of Vietnam's electrical grid is the 500 kV network, integrating northern, central, and southern regions with over 7,500 km of 500 kV lines and nearly 40,000 km of 110 and 220 kV lines. Electricity is distributed through medium-voltage (35 kV, 22 kV, 10 kV) and low-voltage (0.4 kV) lines, serving residential, commercial, and industrial customers. Additionally, Vietnam's grid connects with neighboring countries for electricity import and export, importing about 1.5 TWh annually from China through two 220 kV lines with an 800 MW peak, enhancing supply from Laos using abundant hydropower resources, and exporting about 1 TWh/year to Cambodia through a 220 kV transmission line Vietnam Electricity (EVN) is the main operator responsible for managing the electricity grid in Vietnam	interconnectors such as the Queensland to New South Wales Interconnector (QNI) and Victoria to New South Wales Interconnector (VNI), typically operating at voltages around 330 kV. The Victoria to South Australia Interconnector, known as the Heywood Interconnector, operates at voltages around 275 kV. In addition to AC interconnectors, Australia utilizes DC interconnectors like Basslink, connecting Tasmania to Victoria at approximately 400 kV, Murraylink at about 150 kV, and Directlink at around 300 kV. The NEM, the largest wholesale electricity market, encompasses eastern and southern states: Queensland, New South Wales, Victoria, South Australia, and Tasmania, connected via the Basslink submarine DC cable. The SWIS serves the southwestern part of Western Australia, including Perth, while the Northern Territory system covers areas such as Darwin and other major towns. 	commercial enterprises. The low-voltage grid (220 V or 400 V) delivers electricity from solar panels to residential and small commercial establishments, ensuring reliable supply and grid stability. The electricity grid in Germany is divided into four voltage levels and has a total length of 1,837,495 kilometres (as of 2019) with the largest share of the network length is accounted for by the low-voltage level[5]. Germany's transmission grid spans approximately 37,000 kilometers and is managed by four transmission system operators (TSOs): TenneT, 50Hertz, Amprion, and TransnetBW[6] 	industrial consumers may connect directly to the transmission grid. The responsibility for these fine-meshed distribution networks falls to regional DNOs such as Delta Netwerkbedrijf, Stedin, Enexis, and Liander. Additionally, the Dutch transmission grid connects directly to those of Germany and Belgium and extends to Norway (via NorNed) and Great Britain (via BritNed) through direct current cables. 	Voltage Direct Current (HVDC) submarine cables, with a third cable currently under construction to further support the island's power needs (Lee et al., 2015). Electricity in South Korea is produced by six major power generation companies, independent power producers, and community energy systems. This electricity is traded through the Korea Power Exchange (KPX) and then purchased by KEPCO for distribution[11]. 	from resource-rich western regions to major load centers in the east. The infrastructure included AC/DC transmission systems with 500 kV, 330 kV, and 220 kV AC lines, along with 500 kV DC lines. (Zhou et al., 2010) The State Grid Corporation of China (SGCC) and China Southern Power Grid (CSG) are the primary operators responsible for managing China's national and regional electricity transmission networks. SGCC oversees the largest power transmission and distribution network globally, covering most of China. CSG operates in southern China, managing electricity transmission and distribution in provinces like Guangdong and Guangxi 

[5] Stromnetz - Aufbau, Struktur und Länge des deutschen Stromnetzes (stromauskunft.de)
[6] Set-up and challenges of Germany's power grid | Clean Energy Wire
[11] - Overview of Korea's Electric Power Industry | KEPCO -

Countries / Criteria	Vietnam	Australia	Germany	The Netherlands	South Korea	China
						
Target	300MW by 2030	32 GW by 2030	630 MW to serve as part of the primary control reserve	9GW of BESS to be connected to the TenneT	36 GW 2030	100GW by 2030 (all energy storage form)
Track record	-	19 BESS projects in 2022 totaled 1380MW output and 2004MWh energy capacity	59 big BESS projects in Germany, totaling 400 MW in power and approximately 550 MWh in capacity by 2022	The largest operational system in this country was brought online in 2022 by GIGA Buffalo with a capacity of 25 MW and 48 MWh	2,729 BESS with a capacity of about 10 GWh, most of which are LiB. The total capacity of energy storage systems connected to the Korean power system has reached 1.6 GW/4.8 GWh by 2022	43.44 GW of energy storage capacity, of which battery storage account for 86.5% by 2022
Installed capacity	-	2.657 GWh with approximately 756 MWh was non-residential by 2021	Around 1.5 GWh[14] by 2022	-	4.8 GWh by 2022	37.57 GW by 2021
The presence of national standards for BESS	No	Yes	Yes	Yes	Yes	Yes
The general trend of adopting international standards or creating new standards	Possibility of adopting international standard such as IEC and IEEE into national standards	Establish their standard with a narrow scope and combination it with international standard from IEC	Adopting standards from EN and IEC 62933	Adopting standards from EN and IEC 62933	Establish their standards, adopting standards from IEC 62933	Establish their standard, Adopting international standards

[14] https://ionanalytics.com/insights/infralogic/news-analysis-the-german-battery-storage-opportunity/

Understanding that countries define BESS differently is crucial for stakeholders in the energy sector. In Vietnam, as stated in Section 3.1, BESS is defined as a grid-connected energy storage system that uses batteries to store and supply electrical power to an electrical power system. Meanwhile, in developed markets, BESS applications span residential, industrial, and utility scales. Clarifying these definitions helps identify the role of BESS in each country's energy storage strategy and supply monitoring. Additionally, this understanding can improve the definition of BESS in Vietnam, aligning it more closely with international standards and practices. Table 3 shows the definition of BESS in five reference countries.

Table 3 Definition of BESS countries

Country	Definition of BESS
Australia	Battery energy storage system
Germany	Large-scale battery storage (Batteriegroßspeicher) or utility-scale batteries (BMWK, 2023)
The Netherlands	Battery Storage (Batterijopslag)
South Korea	Lithium-ion Battery Energy Storage System (LiB ESS)
China	Battery energy storage system

4.1.2 Australia

Australia is witnessing rapid growth in the battery energy storage system (BESS) market, both in residential and grid-scale applications. By the end of 2023, there were twenty-seven large-scale battery projects under construction, collectively amounting to approximately 5 GW / 11 GWh of storage capacity. This marks a substantial increase compared to the figures from 2022, which saw nineteen batteries under construction with a total capacity of about 1.4 GW / 2 GWh[15].

Australian Energy Market Operator (AEMO)'s 2022 Integrated System Plan forecasts the retirement of 8 gigawatts of coal-fired generation capacity by 2030. Consequently, since 2022, Australia's record-high share of renewable energy in its total electricity generation, reaching 32%, highlights the significant contributions of solar (14%), wind (11%), and hydropower (6%). As these renewable sources transition into primary energy resources, maintaining system resilience becomes increasingly complex due to their intermittent nature. Also, Frequency Control Ancillary Services (FCAS) has traditionally been provided by mostly coal and gas electricity generators; however, AEMO's overseas experience showed that renewable energy providers can also supply FCAS to help keep the grid secure and stable. Hence, the primary use of BESS in Australia is to support the integration of renewable energy into the electricity grid to ensure network stability, reduce congestion in Victoria's electricity grid, and manage price volatility and reliability risks during high-demand periods.

BESS project development is emerging as a major category within the renewable energy sector. Currently, several grid-scale BESS facilities are under construction, reflecting a promising outlook for BESS deployment in Australia. The largest utility-scale battery storage project commissioned in 2023 was the 150 MW / 300 MWh Riverina Energy Storage System. This project, located in NSW and developed by Edify, began operation in October 2023 after completion in May. It utilizes advanced Tesla Megapack systems to provide critical stabilizing services to the transmission grid, with its output sufficient to supply

[15] Clean-Energy-Australia-2024.pdf (cleanenergycouncil.org.au)

electricity to 240,000 homes for two hours during peak times[16].The primary battery type utilized in grid-scale BESS is Lithium-ion (Li-ion) chemistries (Australian Energy Council Limited, 2023). Australia targets the deployment of 32 GW of renewable energy storage by 2030[17].

Recognizing the pivotal role of battery energy storage systems (BESS), the government has integrated BESS into its policy objectives. The Next Generation Renewables program, launched to facilitate this transition, aimed to install 36 MW of battery storage across 5000 homes and businesses between 2016 and 2020. Additionally, the Renewable Energy Industry Development Strategy (REIDS) focuses on fostering growth in the clean economy sector. This initiative supports the development of solar, wind, and ESS industries through the establishment of renewable energy test facilities and a collaborative business research precinct involving both government and industry partners. Furthermore, efforts to promote and expand energy storage in Australia have been bolstered by the Clean Energy Council, which has proposed thirteen market reforms. These reforms target leveling the playing field, removing regulatory barriers to behind-the-meter BESS, recognizing the value of storage, and ensuring consumer protection through established standards (Sani et al., 2020).

The establishment of national standards of BESS is executed by a joint Australian / New Zealand (AS/NZS) development committee via developing unique standards for the country. The Australian/New Zealand Standard 5139 on Electrical installations – Safety of battery systems for use with power conversion equipment (AS/NZS 5139), published in 2019, provides comprehensive requirements and information related to the safe installation of battery systems connected to power conversion equipment (PCE). Endorsed by electrical safety regulators across Australian States and Territories, as well as in New Zealand through representatives on the Electrical Regulatory Authorities Council (ERAC), AS/NZS 5139 outlines installation, commissioning, and documentation requirements for three primary categories of battery systems:

- Pre-assembled integrated battery energy storage systems.
- Pre-assembled battery equipment.
- Battery systems and Battery Energy Storage Systems (BESSs) that do not conform to the Best Practice Guide: Battery Storage Equipment – Electrical Safety Requirements.

While AS/NZS 5139 has a narrower scope compared to other codes, it offers detailed requirements and information on crucial topics such as system integration, design, and installation. For instance, it provides specific requirements, specifications, and diagrams for the layout and configuration of battery system rooms (refer to § 6.2.6.2). The technical guidance provided in AS/NZS 5139 at this level of detail can be particularly beneficial for stakeholders involved in the design and installation of BESS.

During the execution of BESS projects, this national standard is expected to align with other relevant national standards such as AS/NZS 3000, AS/NZS 4509.1, AS/NZS 4777.1, and AS/NZS 4777.2[18]. Additionally, international standards such as IEC 62933, IEC 62109, IEC 62619, IEC 62477, and UL1973[3] may also be utilized to ensure comprehensive compliance and safety measures.

[16] Clean-Energy-Australia-2024.pdf (cleanenergycouncil.org.au)
[17] Clean-Energy-Australia-2024.pdf (cleanenergycouncil.org.au)
[18] NETCC-Tech-Guide-Battery-Energy-Storage-Systems-V1-Readable.pdf (newenergytech.org.au)

4.1.4 Germany

As a global leader in renewable energy, Germany is heavily reliant on the expansion of energy storage systems, particularly battery storage systems. However, the largest share of the reported battery storage systems is accounted for by home storage systems. In 2022, utility-scale installations reached a record 434 MW capacity, totaling 467 MWh of deployed energy storage[19]. Meanwhile, private households saw significant growth in energy storage installations, with around 650 000 battery home storage systems installed by the end of the year, averaging 8.8 kWh in capacity[20]. Most of these systems are integrated with residential PV plants to boost self-consumption and reduce costs. On a large scale, in 2020, there were 59 grid-scaled BESS projects in Germany, totaling 400 MW in power and approximately 550 MWh in capacity (Figgener et al., 2020). It is expected that more BESS projects will be installed up until 2024.

Despite already leading in renewable energy, which accounts for approximately 36% of all electricity consumption, Germany aims to significantly increase its green electricity production by 2030. The Energy Storage Strategy[21] published by the Ministry of Economic Affairs and Climate Action (BMWK) in 2023 targets around 600 terawatt hours (TWh) of green electricity by 2030, a substantial jump from the 254 TWh generated in 2022, with the rapidly growing shares of electricity generation from wind energy (targets: 115 GW onshore wind and 30 GW offshore wind in 2030) and PV (target: 215 GW in 2030). The envisioned future electricity mix will be primarily driven by onshore wind, photovoltaics (PV), offshore wind, imports of renewable electricity, and power plants leveraging green hydrogen.

The integration of various renewable energy production sources into the grid necessitates increasing flexibility in the energy system, which leads to a growing demand for energy storage systems. These systems play a dual role: facilitating the temporal shift of generation or consumption and ensuring grid stability by rapidly responding to short-term power fluctuations. BESS emerges as a pivotal solution, capable of storing electricity for short durations and providing crucial support to grid operations, particularly in the frequency containment reserve (FCR) market. Additionally, BMWK highlighted the potential applications of BESS as the integration of power generation from large PV systems and wind farms into the grid, limited grid boosters to support grid operation management, and optimization of energy management at large industrial sites.

Major energy companies like RWE and VERBUND are leading the charge, with ambitious plans to construct large-scale battery storage systems. RWE aims to build 3 GW of battery storage capacity by 2030, while VERBUND is targeting 1 GW of large battery storage systems by the same timeframe. Additionally, LEAG's development of a significant storage facility in Lausitz, with a prospective capacity of around 750 MW[22]

According to scenario calculations by the Fraunhofer Institute for Solar Energy Systems ISE, Germany will require about 100 GWh of electrical storage capacity by 2030 and about 180 GWh by 2045[23]. The main part of the capacity is to be deployed in northern Germany close to the sea, where electricity from off-shore wind parks will be fed into the grid (Babrowski et al., 2016). Germany has pre-qualified battery

[19] Germany's grid-scale BESS installs up 910% but still under half a gigawatt in 2022 - Energy-Storage.News
[20] Germany - Energy storage systems make strong gains (pveurope.eu)
[21] Stromspeicher-Strategie (bakermckenzie.com)
[22] RWE starts construction of large-scale battery storage project at two locations in North Rhine-Westphalia
[23] Fraunhofer ISE Kurzstudie: Batteriegroßspeicher an ehemaligen Kraftwerksstandorten sinnvoll - Fraunhofer ISE

energy storage systems (BESS) with a collective capacity of 630 MW to serve as part of the primary control reserve, which is currently needed at a level of 570 MW. Lithium-ion technologies dominate the BESS market.

Under the German Renewable Energy Sources Act (EEG), ESS that return stored energy to the grid are exempt from grid tariffs and levies. Amendments in 2017 expanded these exemptions, supporting ESS by covering energy losses and self-supply scenarios. However, provisions like §51(1) of the EEG, which subsidizes renewable energy during periods of negative prices, pose challenges to ESS development. Adjusting these laws to incentivize ESS alongside renewable energy will be crucial for a balanced energy transition (Sani et al., 2020).

The technical standards governing energy storage systems are established primarily by Deutsches Institut für Normung (DIN) and Verband der Elektrotechnik, Elektronik und Informationstechnik e.V (VDE) in collaboration with Bundesverband Energiespeicher (BVES) and Zentralverband Elektrotechnik- und Elektronikindustrie (ZVEI), harmonizing international standards from IEC and EN into national standards and establishing their standards. These standards cater to various battery types, including Lithium-Ion, Nickel-Cadmium, Nickel-Metal Hydride, and Lead-Acid batteries. Other standards address general requirements, testing procedures, and grid connection protocols. Some key general standards include:

- DIN EN IEC 62933-1 (VDE 0520-933-1:2019-08): Defines terminology related to Electrical Energy Storage (EES) Systems.
- DIN EN IEC 62933-2-1 (VDE 0520-933-2-1:2019-02): Specifies unit parameters and testing methods for EES systems.
- DIN IEC/TS 62933-2-2; VDE V 0520-933-2-2:2022-07 Electric Energy Storage Systems - Part 2-2: Unit parameters and testing methods - Applications and Performance testing
- DIN IEC TS 62933-3-1 (VDE V 0520-933-3-1:2020-09): Addresses planning and performance evaluation of EES systems.
- DIN IEC/TS 62933-4-1 (VDE V 0520-933-4-1:2019-10): Electrical energy storage (EES) systems - Part 4-1: Guidance on environmental issues - General specification
- DIN IEC/TS 62933-5-1 (VDE V 0520-933-5-1:2020-04): Electrical energy storage (EES) systems - Part 5-1: Safety considerations for grid-integrated EES systems - General specification
- DIN EN 50549-2 (VDE 0124-549-2:2020-10): Defines requirements for connecting generation units to the medium voltage distribution network.
- DIN EN 61427-1:2014-02 (VDE 510-40): Covers general requirements and test methods for renewable energy storage batteries.
- DIN EN 61427-2:2016-09 (VDE 0510-41): Specifies requirements and test methods for rechargeable batteries in grid-connected renewable energy storage applications, focusing on durability and performance validation.

4.1.3 The Netherlands

Dutch TSO TenneT has devised a strategy to navigate the expected developments in the Dutch electricity market from 2025 to 2030. According to the National Program Regional Energy Strategy, 35 TWh of large-scale onshore generation (>15kW) must be achieved for renewable electricity by 2030. By 2050, the majority of renewable electricity will come from wind, both onshore and offshore, with a generating capacity between 48 and 92 GW, providing 25-60% of the renewable electricity supply. Solar power, with its highest generating capacity (100-183 GW), will contribute 10-20% due to fewer hours of sunlight[24]. The energy transition will significantly alter the momentum in the energy system, with substantial fluctuations in energy supply due to the increasing role of weather-dependent sources like wind and solar power. TenneT aims to ensure system stability amidst the growing grid volatility and the increased presence of renewable energy sources.

In the Dutch market, BESS is anticipated to have a multifaceted role in supporting grid operations and ensuring system stability. While there's low demand for Frequency Containment Reserve (FCR), the need for Frequency Restoration Reserve (FRR) is expected to rise, requiring new providers. Given the diminishing availability of conventional power plants for FCR and automatic Frequency Restoration Reserve (aFRR), large-scale storage solutions are pivotal for TenneT to uphold grid stability. BESS can also offer reliable black start functionality during grid collapses, but current Netcode specifications must be updated to accommodate Distributed Energy Resources (DERs) such as wind, solar, and BESS. Additionally, there's a high demand for both upward and downward dispatch, surpassing grid reinforcements. BESS serves as a congestion management solution and may offer flexibility through bilateral contracts with network operators and ongoing efforts aim to integrate BESS without exacerbating congestion. Also, it can absorb and generate reactive power, addressing voltage-level challenges amid the growth of renewable energy generation. Moreover, BESS can provide Synthetic Inertia, swiftly reacting to frequency changes, crucial as inertia from fossil fuel generators declines.

The largest operational system in this country was brought online in 2023 by Sem per Power with a capacity of 30 MW/68 MWh, followed in quick succession by the largest under-construction projects being launched by Rolls-Royce and Alfen in 2022 and 2023 respectively[25]

TenneT anticipates requiring approximately 10GW of flexible storage by 2030 to maintain an acceptable level of Loss of Load Expectation (LOLE) under the current government policy, which mandates the cessation of coal burning by power plants by 2030. Additionally, it is expected that some new large-scale solar farms will be equipped with battery storage (colocation batteries), increasing the expected installed capacity of BESS from 1.3 GW in 2028 to 2.0 GW in 2030 to 2.7 GW in 2033[26]. However, demand-side response (DSR) initiatives are progressing slower than required due to the industry's reliance on baseload modeling. Consequently, TenneT foresees the need for approximately 9GW of BESS to be connected to the TenneT grid to ensure system stability. Large BESS (>70MW) is identified as crucial for providing system stability amidst these evolving market dynamics.

In the Netherlands, BESS, crucial for integrating renewables and enhancing grid stability, faces challenges such as limited business interest and slow adoption due to existing net-metering policies that may discourage investment. While efforts are made to develop legislative support and provide financial incentives like tax exemptions for renewable energy investments, comprehensive laws supporting ESS and new grid solutions are still evolving. Policy experiments launched in 2015 aim to stimulate innovation

[24] Transition of the Dutch energy system: scenario's 2030-2050 - II3050 Management Summary (netbeheernederland.nl)
[25] Netherlands: Battery storage developer Lion Storage interview (energy-storage.news)
[26] Monitor Leveringszekerheid 2024 (tennet-drupal.s3.eu-central-1.amazonaws.com)

in electricity storage and renewables but require further refinement to address regulatory uncertainties and market barriers (Sani et al., 2020).

The national standards for BESS are developed by the Nederlands Normalisatie-instituut (NEN) through a harmonization process involving international standards from IEC and EN and developing its standards. These standards cover various aspects of BESS, including safety requirements, testing methods, unit parameters, planning, and performance assessment. Some key standards in this domain include:

- NEN 4288:2020 Operation of battery energy storage systems - Additional requirements to NEN 3140
- NEN-EN-IEC 62933-5-2:2020 Electrical energy storage (EES) systems - Part 5-2: Safety requirements for grid-integrated EES systems - Electrochemical-based systems
- NEN-EN-IEC 62933-2-1:2018 Electrical energy storage (EES) systems - Part 2-1: Unit parameters and testing methods - General specification
- NEN-EN-IEC 62933-1:2018 Electrical Energy Storage (EES) systems - Part 1: Vocabulary
- NVN-IEC/TS 62933-2-2:2022 Electrical energy storage (EES) systems - Part 2-2: Unit parameters and testing methods - Application and performance testing
- NVN-IEC/TS 62933-3-3:2022 Electrical energy storage (EES) systems - Part 3-3: Planning and performance assessment of electrical energy storage systems - Additional requirements for energy intensive and backup power applications
- NVN-IEC/TS 62933-3-2:2023 Electrical energy storage (EES) systems - Part 3-2: Planning and performance assessment of electrical energy storage systems - Additional requirements for power intensive and renewable energy sources integration related applications
- NEN-EN-IEC 62933-2-1:2018/C1:2019 Electrical energy storage (EES) systems - Part 2-1: Unit parameters and testing methods - General specification
- NEN-EN-IEC 62932-1:2020 Flow battery energy systems for stationary applications - Part 1: Terminology and general aspects
- NEN-EN-IEC 61427-2:2015 Secondary cells and batteries for renewable energy storage - General requirements and methods of test - Part 2: On-grid applications

Additionally, the Guideline for PGS 37-1 Energy Storage Systems (Richtlijn voor PGS 37-1 Energieopslagsystemen)[27] was developed by a team of experts from industry and government in 2023. This guideline specifically focuses on the safety of lithium-containing energy carriers and their proper application in Energy Storage Systems (ESS). PGS 37-1 ensures uniform safety measures, which are essential given the rapid rise of ESS in both industrial and residential environments. The forthcoming PGS 37-2 will complement this guideline by addressing the storage of lithium-containing energy carriers and is expected to be published later.

4.1.6 South Korea

Korea has emerged as a global leader in the development and distribution of Lithium-ion Battery Energy Storage Systems (LiB ESS). As of September 2022, Korea Electric Power Corporation (KEPCO) alone has installed a total of 2,729 BESS with a capacity of about 10 GWh, most of which are LiB. KEPCO's public BESS project, which has passed the preliminary feasibility study, plans to use a total of 970 MW of ESS,

[27] Richtlijn voor PGS 37-1 Energieopslagsystemen gepubliceerd (nen.nl)

predominantly LiB[28]. Upon 2021, there were 13 sites where frequency regulation (FR) BESSs are installed in South Korea. The total generation capacity is 376 MW, which is the same as the PCS capacity of a BESS, and batteries with a capacity of 103 MWh with a 4 C-rate or higher have been installed through an operation simulation of each FR BESS. The response rate of each FR BESS according to the transient phenomenon at 60 Hz is configured to reach 130 ms (Kim et al., 2021). As of 2021, the scale of frequency regulation ESS installed domestically is 376MW[29].

In 2022, more than half of South Korea's electric power generation came from fossil fuel sources like coal and liquid natural gas, with around 9.4 percent from renewable sources. The Korean government has been promoting the transition to safe and clean energy through the energy transition roadmap, aiming to expand renewable energy (RE) generation to 30–35% by 2040 (Aryani et al., 2022).

Meanwhile, the Korean power grid currently relies heavily on large-scale generation complexes located in the east and west coastal regions due to economic and site availability considerations. These complexes are essential for meeting the load demand in the Seoul metropolitan area, which accounts for over 50% of the total demand. However, necessary transmission enhancements have been delayed by public opposition and environmental concerns, causing stability issues when large-capacity outgoing transmission lines from these complexes are affected. Given the current situation of the grid, connecting RE to the grid is expected to cause instability. To maintain stability in the Korean power system amid the expansion of RE generation facilities, increased uncertainty in facility upgrades, and concentrated load demands, BESS emerges as a critical solution.

In the Korean market, ESS is used for the purposes of (1) controlling variable output and stabilizing the power system in connection with new and renewable energy, (2) adjusting the frequency change caused by the mismatch between the power generated and the load power, (3) storing surplus power or cheap electricity generated at night and supplying it in the event of a power shortage, and (4) quickly supplying stable power when power generation is temporarily suspended.

In 2022, KEPCO has been promoting a project to build ESS with a total capacity of 970 MW across six substations. The Sinnanwon substation, with a capacity of 336 MW, is expected to be the largest, along with the Bubuk substation, since the launch of KEPCO's public ESS project[30].

KEPCO has planned to install 1.8 GW of new BESS by 2034 and 9GW of ESS is expected to be installed by 2040[31]. BESS deployment is also incentivized through a higher Renewable Energy Certificate (REC) weight of 5.0 for PV and wind-connected ESS systems.

The "Energy Storage Technology Development and Industrialization Strategies in 2020 (K-ESS)" in South Korea is a comprehensive initiative designed to advance energy storage technologies, crucial for integrating renewable energy and enhancing grid stability. The strategies have evolved in line with South Korea's 10th Basic Plan for Long-Term Electricity Supply and Demand. A key component of these

[28] 전기화학적 배터리 기반 중장주기 에너지 저장기술 개발 동향 및 미래 전망 - 전기저널 (keaj.kr)
[29] 에너지 저장기술 현황 및 미래 전망 - 전기저널 (keaj.kr)
[30] 현대일렉트릭, 창사 최대 규모 ESS 프로젝트 수주 - 조선비즈 (chosun.com)
[31] 에너지 저장기술 현황 및 미래 전망 - 전기저널 (keaj.kr)

strategies is the Electricity Charge Discount Program (ECDP), introduced in 2015, to promote the installation of Energy Storage Systems (ESS). The ECDP offers discounted electricity rates under specific conditions: ESS owners benefit from reduced rates when charging their systems during low-demand periods (light load) and further discounts apply when discharging during peak demand periods, thus helping to lower the grid's peak load. To increase the program's effectiveness, a policy introduced in 2017 temporarily increases the discount rate based on the ratio of battery storage capacity to the contracted power of the electricity customer. This policy aims to incentivize larger storage capacities, further supporting the grid and facilitating the use of renewable energy (Sani et al., 2020).

The national standards for Battery Energy Storage Systems (BESS) in Korea, developed by the Korean Standards and Certification (KSCI)[32], align with international standards from the International Electrotechnical Commission (IEC). These standards cover comprehensive aspects of BESS technology, including safety protocols, testing methodologies, unit specifications, planning frameworks, and performance evaluation criteria. Key standards include:

- KS C 7901 Lithium-ion Battery Energy Storage System (BESS) - Guidelines for Establishment and Operation of Safety-Related PMS
- KS C IEC62933-1 Electrical Energy Storage (EES) Systems — Part 1: Terminology
- KS C 8548 Battery Energy Storage Terminology — Lithium Secondary Battery System
- KS C IEC62932-1 Stationary Flow Cell Energy Systems — Part 1: Glossary and General
- KS C IECTS62933-3-1 Electrical Energy Storage Systems (EES) Part 3-1: Planning and Performance Evaluation of Electrical Energy Storage Systems — General Requirements
- KS C IEC63056 Secondary battery cells and cells containing alkali or other non-acidic electrolytes — Safety requirements for lithium secondary battery cells and cells for use in electrical energy storage systems Electrical Energy Storage (EES) Systems — Part 2-1: Unit Parameters and Test Methods — General Specifications
- KS C IEC/TS62933-5-1 Electrical Energy Storage (EES) Systems — Part 5-1: Safety Considerations for Grid-Tied EES Systems — General Specifications
- KS C IEC62933-5-2 Electrical Energy Storage (EES) Systems — Part 5-2: Safety Requirements for Grid-Tied EES Systems — Electrochemical-Based Systems
- KS C IEC62933-2-1 Electrical Energy Storage (EES) Systems — Part 2-1: Unit Parameters and Test Methods — General Specifications
- KS C IECTR61850-90-9 Communication Networks and Systems for Power Utility Automation — Part 90-9: Use of IEC 61850 for Electrical Energy Storage (EES) Systems

In addition to these standards, the Korea Smart Grid Association (KSA) has established SPS-SGSF-025-4-1972, which outlines general performance requirements for power conversion systems (PCS) used in electric energy storage systems. This standard specifies safety, performance, and grid connection requirements for PCS. The development of BESS safety standards has involved several stakeholders, including the government and major battery producers like Samsung SDI and LG Chem. These companies have implemented their own ESS safety measures, such as special fire extinguishing systems, in response to fire incidents.

[32] e-나라표준인증 (standard.go.kr)

Korean BESS also adheres to various international standards, such as IEEE 1547 for interconnection systems and electromagnetic compatibility standards like EMC CISPR 11:2011 and IEC 61000 and current safety standards in Korea include IEC 62477-1, IEC 62477-2, and IEC 62103 (LS Group, n.d.).

4.1.7 China

China's energy storage industry has experienced significant development since the release of the 13th Five-Year Plan in 2016 (National Development and Reform Commission, 2016; China Energy Storage Alliance, 2021). As of 2021, China has installed a total of 43.44 GW of energy storage capacity, of which battery storage accounts for 86.5% (CHEN Zhu et al., 2022).

China's rapid expansion in renewable energy is evident with a 66% increase in new wind energy capacity in 2023 compared to the previous year, and its new solar PV capacity matching the global total for 2022. Projections suggest that China will contribute to 60% of the world's new renewable electricity generation by 2028 [33].China faces considerable challenges in managing renewable energy (RE) curtailment due to geographic disparities between RE generation in the West and demand centers along the East Coast. The energy landscape's profound adjustment has triggered significant changes in the power system's development mode. Distributed energy sources are increasingly integrated into the distribution network, transitioning terminal loads from rigid to flexible. Moreover, the focus of power system construction is shifting gradually from the main grid to the distribution network. Energy storage, pivotal with its dual role in power supply and load management, plays a crucial role in ensuring the stable operation of this evolving power system (CHEN Zhu et al., 2022). As of 2023, pumped storage remains the most mature and economical energy storage technology in China, suitable for large-scale development and construction. The national plan encourages the development of new energy storage technologies such as lithium-ion batteries[34]

The large-scale development of energy storage technologies will address China's flexibility challenge in the power grid, enabling the high penetration of renewable sources.

On June 30, 2024, the first phase of the Datang Hubei 100 MW/200 MWh sodium-ion energy storage power station science and technology innovation demonstration project, which is provided by Zhongke Haina, was completed and put into operation, with a production scale of 50 MW/100 MWh[35]. It is expected that the new installed capacity of lithium battery energy storage will total 858 GWh, with 270 GWh expected to be added domestically in 2025[36].

The Renewable Energy Law of China, initially enacted in 2005 and amended in 2009, provides a regulatory framework for the development and deployment of Energy Storage Systems (ESS) across the country. Several key national documents complement this legal foundation. The Catalogue for the Guidance of Renewable Energy Industry Development (2005) emphasizes expanding the scale and commercialization of ESS batteries. The National Medium- and Long-Term Development Plan for Science and Technology (2006–2020) supports technological advancements in ESS materials and technology. Various Five-Year Plans, such as the 12th, 13th, and 14th plans, highlight the integration of BESS into

[33] 国际能源署预测:未来5年全球可再生能源将迎来快速增长期---国家能源局 (nea.gov.cn)
[34] 国家电网积极推动储能产业发展 “超级充电宝”助建新型能源体系---国家能源局 (nea.gov.cn)
[35] 我国首个百兆瓦时级别，全球最大钠电池储能项目投运_能见度_澎湃新闻-The Paper
[36] 锂电储能行业深度报告：应用场景多点开花，万亿市场即将开启_腾讯新闻 (qq.com)

smart grids, microgrids, and renewable energy systems, promoting research, development, and demonstration projects especially large-scaled BESS[37] (Sani et al., 2020). From 2017-2020, more than 20 policies have been promulgated by five ministries and commissions, and more than 50 supporting policies have been issued by governments at all levels (周喜超, 2020). In April 2024, the National Energy Administration (NEA) issued a notice titled "Promotion of New Energy Storage Integration and Dispatch Utilization," aimed at standardizing the integration of new energy storage into the grid and promoting efficient dispatch utilization (Xin, 2024). The notice clarifies pre-connection technology requirements for new ESS, ensuring they meet strict performance, safety, and stable power system operation standards before grid connection (Lin, 2024).

In China, national standards can be either mandatory (GB) or voluntary (GB/T). GB/T standards, initially voluntary, may become mandatory if referenced in laws, regulations, or contractual agreements. The Standardization Administration of China (SAC) oversees the approval process for national standards, managing everything from proposal and drafting to public consultation and final review. Some key standards include:

- System Standards:
    - GB/T 36558-2023: General technical requirements for electrochemical energy storage systems of the power system
    - GB/T 36547-2018: Technical rule for electrochemical energy storage systems connected to the power grid
    - GB/T 42288-2022: Safety regulations for electrochemical energy storage stations, applicable to various types of batteries and stipulating safety measures, including automatic fire extinguishing systems.
- Cell Standards:
    - GB/T 36276-2018: Specifications technical requirements, test methods, and test rules for lithium-ion batteries for electrical energy storage.
    - GB/T 34120-2023: Technical requirements for the power conversion system of electrochemical energy storage systems.
- Safety and reliability
    - GB/T 42288-2022 specifies safety requirements for electrochemical energy storage stations, including the installation of automatic fire extinguishing systems linked with battery management systems and other safety devices. This ensures that BESS installations are safe and can prevent and manage emergencies effectively.
    - GB/T 36276-2023 includes stricter technical requirements and testing protocols, ensuring that lithium-ion batteries used in BESS perform reliably even in challenging conditions such as high temperatures and altitudes above 2000 meters.

[37] 国家发展改革委 国家能源局关于印发《"十四五"新型储能发展实施方案》的通知_国务院部门文件_中国政府网 (www.gov.cn)

Experience From Other Countries

Table 4 Experience from reference countries.

	Australia	Germany	Netherlands	South Korea	China
The focus of standardization efforts	Battery specification standard BESS grid connection standard	Battery specification standard BESS grid connection standard	Battery specification standard BESS grid connection standard	Safety standards A series of fire incidents was the reason the country ramped up safety regulations and standards for BESS	Grid connection standards The national grid is having a hard time keeping up with the increasing amount of renewables entering the system.
National standards	Joint Australian / New Zealand committee (AS/NZS)	Deutsches Institut für Normung (DIN)	Nederlands Normalisatie-instituut (NEN)	Korean Standard Certification (KS Certification)	Guojia Biaozhun (GB)
Legislation and certification requirements	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Regulatory measures	Prescriptive	Prescriptive	Prescriptive	Prescriptive	Prescriptive
Stakeholders	Committee of experts, standards users, and those impacted by standards that represent both New Zealand and Australian stakeholders	Experts from various stakeholders, including manufacturers, consumers, businesses, research institutes, public authorities, and testing bodies.	Standardization committees consist of representatives from all relevant parties.	Technical Committee members responsible for developing standards are selected from governments, the private sector, academic institutes, and industry associations based on a consensus principle.	Technical Committee members responsible for developing standards are selected from governments, the private sector, academic institutes, and industry associations based on a consensus principle.
Approving body	Joint Australian / New Zealand committee (AS/NZS)	Deutsches Institut für Normung (DIN)	Nederlands Normalisatie-instituut (NEN)	Korean Standards and Certification (KSCI)	The Standardization Administration of China (SAC)

4.3 International Standards

An international standards organization produces international standards, and examples are the International Electrotechnical Commission (IEC) and the International Organization for Standardization (ISO). A special group of standards organizations consists of classification societies and non-governmental organizations that establish and maintain technical standards for ships and offshore structures. In addition, various industry-based standards organizations exist, such as the Institute of Electrical and Electronics Engineers (IEEE). There are also regional standardization organizations such as the European Committee for Standardization (CEN) and European Committee for Electrotechnical Standardization (CENELEC), both recognized by the EU to provide European Standards (EN), and national standardization organizations such as a joint Australian / New Zealand committee (AS/NZS), Deutsches Institut für Normung (DIN) in Germany, Nederlands Normalisatie-instituut (NEN), Korean Standards and Certification (KSCI)and Standardization Administration of China (SAC). These organizations are responsible for developing, maintaining, and publishing the respective standards. Typically, the standards are developed and maintained by subject-related committees. In addition, local authorities can publish regulations, requirements, and/or standards such as Bundesamt für Seeschiffahrt und Hydrographie (BSH) in Germany and the Royal Netherlands Standardization Institute (NEN) in the Netherlands.

Table 5 presents an overview of the technical standards applied during the developmental phases of BESS projects across five representative countries and Europe. While Eurocodes (EN) are commonly adopted within European jurisdictions, the prevailing standards include those from the International Electrotechnical Commission (IEC) across all regions. Additionally, national standards are currently based on IEC and EN norms.

Table 5 Standardization bodies that produce standards specific for BESS

Type	**Organization**	**Involvement with the BESS industry**
International standard organizations	International Electrotechnical Commission (IEC)	IEC standards cover various aspects of BESS, including safety, performance, testing methods, and grid integration. These standards ensure the safety, reliability, and interoperability of BESS products and systems. IEC 62933 series provides guidelines for the design, operation, and performance evaluation of electrical energy storage systems. Additionally, standards like IEC 62477 and IEC 62103 focus on safety requirements for power electronic converter systems and equipment, addressing issues such as fire hazards and system management
Regional standard organizations	EU: European Committee for Standardization (CEN)	CEN, the European Committee for Standardization, is responsible for establishing standards for Battery Energy Storage Systems (BESS) in Europe. These standards cover various aspects of BESS, including design, installation, operation, and maintenance.
	EU: European Committee for Electrotechnical Standardization (CENELEC)	Like CEN, CENELEC is responsible for establishing standards for Battery Energy Storage Systems (BESS) in Europe. These standards cover various aspects of BESS, including design, installation, operation, and maintenance.

Type	Organization	Involvement with the BESS industry
National standardization organizations	Australia: joint Australian / New Zealand committee (AS/NZS)	The Australian/New Zealand Standard 5139 on Electrical installations – Safety of battery systems for use with power conversion equipment (AS/NZS 5139), published in 2019, provides comprehensive requirements and information related to the safe installation of battery systems connected to power conversion equipment (PCE)
	Germany: Deutsches Institut für Normung (DIN)	The technical standards for energy storage systems in Germany are primarily established by Deutsches Institut für Normung (DIN). Key standards include DIN EN IEC 62933-1 for terminology, DIN EN IEC 62933-2-1 for unit parameters and testing methods, DIN IEC/TS 62933-2-2 for applications and performance testing, DIN IEC TS 62933-3-1 for planning and performance evaluation, DIN IEC/TS 62933-4-1 for environmental guidance, and DIN IEC/TS 62933-5-1 for safety considerations.
	Netherlands : Nederlands Normalisatie-instituut (NEN)	The Netherlands develops its national standards for Battery Energy Storage Systems (BESS) through the Nederlands Normalisatie-instituut (NEN), in collaboration with international standards from IEC and EN, and its standards. These standards cover various aspects of BESS, including safety requirements, testing methods, unit parameters, planning, and performance assessment. Key standards include NEN 4288:2020, NEN-EN-IEC 62933-5-2:2020, NEN-EN-IEC 62933-2-1:2018, NEN-EN-IEC 62933-1:2018, NVN-IEC/TS 62933-2-2:2022, NVN-IEC/TS 62933-3-3:2022, NVN-IEC/TS 62933-3-2:2023, NEN-EN-IEC 62933-2-1:2018/C1:2019, NEN-EN-IEC 62932-1:2020, and NEN-EN-IEC 61427-2:2015.
	Korea: Korean Standards and Certification (KSCI)	Korea's Battery Energy Storage Systems (BESS) standards, developed by Korean Standards and Certification (KSCI), align with International Electrotechnical Commission (IEC) standards. These cover safety protocols (KS C 7901), terminology (KS C IEC62933-1, KS C 8548), unit specifications (KS C IEC62933-2-1, KS C IEC63056), performance evaluation (KS C IEC62933-3-1), environmental guidelines (KS C IEC62932-1), and safety considerations for grid-tied systems (KS C IEC/TS62933-5-1, KS C IEC62933-5-2). The Korea Smart Grid Association (KSA) also has standards for power conversion systems (SPS-SGSF-025-4-1972), addressing safety, performance, and grid connections. Major companies like Samsung SDI and LG Chem have added fire safety measures.
	China: Standardization Administration of China (SAC)	National standards for Battery Energy Storage Systems (BESS) are categorized as either mandatory (GB) or voluntary (GB/T). The approval and oversight of these standards are managed by the Standardization Administration of China (SAC). Key standards include GB/T 36558-2023 for general technical requirements, GB/T 36547-2018 for technical rules on grid-connected systems, GB/T 42288-2022 for safety regulations, GB/T 36276-2018 for specifications on lithium-ion batteries,

Type	Organization	Involvement with the BESS industry
		and GB/T 34120-2023 for technical requirements on power conversion systems within electrochemical energy storage systems
Classification societies/ bodies	Denmark: DNV	DNV-RP-0577 Standardized performance testing of battery cells to foster industry collaboration

Chapter 5. Required standards for BESS development in Vietnam

This Chapter answers the following question: 'What standards are required in Vietnam for BESS to be developed successfully?' and is guided by the following sub-questions:

a. What are the current gaps related to standards for BESS in Vietnam?
b. What is the proposed list of standards for BESS in Vietnam that should be developed?
c. What content needs to be included in the standards for BESS in Vietnam?

5.1 Current gaps related to standards for BESS in Vietnam

As observed in Section 3.3 the TCVNs for BESS remain insufficient. The gap lies in the absence of technical standards that are in place in countries with significant BESS experience. From the comprehensive analysis of current standards of BESS in Vietnam and internationally, the gaps observed are related to the following sections:

- Specifications and testing methods.
- Planning and Performance assessments.
- Environmental issues
- Safety considerations.

The development of national standards for BESS will support the development of BESS and Renewable energy in the following key areas:

- Safety and Reliability: The standard ensures that safety guidelines are met during the design, installation, and operation of BESS. This enhances public and regulatory acceptance by minimizing risks and accidents. High safety standards are essential for encouraging the widespread adoption of BESS technologies.
- Performance standards: The standard defines performance criteria for BESS, including efficiency, lifespan, and operation parameters. Manufacturers can use these benchmarks to design BESS that meet or exceed industry standards, leading to improved performance and reliability.
- Interoperability: The standard promotes interoperability between BESS and various renewable energy sources such as solar and wind. Seamless integration with the broader grid infrastructure enhances the efficiency and effectiveness of energy ecosystems.
- Testing and assessment: The standard outlines testing methods and performance assessment procedures for BESS. These provide confidence to users and investors regarding the quality and reliability of BESS products.
- Regulatory compliance: The availability of national standards for BESS helps designers, manufacturers, and investors meet regulatory requirements. Simplified approvals facilitate the deployment of BESS and renewable energy projects economically viable.
- Innovation and research: Clear goals and challenges set by the standard drive innovation in BESS technology. Researchers can focus on meeting these standards, accelerating advancements in renewable energy integration.
- Market growth: specific and appropriate specifications contribute to the growth of the BESS market and the broader renewable energy sector.

5.2 Proposed list of standards for BESS in Vietnam to be developed

The necessity of national standards TCVN is crucial for facilitating BESS development. These standards ensure that government authorities and investors do not encounter significant challenges or difficulties in the application procedures for permits, appraisals, approvals, agreements, and acceptance of project documents as stipulated by regulations. To achieve this objective, the proposed standards should address the identified gaps and issues outlined in Table 6.

Table 6 The gaps of TCVN for BESS.

No	Identified gaps	Addressed issue
1	Specifications and testing methods	1. Vocabulary 2. Unit parameters 3. Test and testing methods
2	Planning and Performance assessments	1. System environment 2. System sizing and selection 3. Functional system performance 4. Performance assessments 5. Design, Operation, and Maintenance
3	Environmental issues	1. Guidance on environmental issues 2. Standard on environmental issues 3. Greenhouse gas (GHG) emissions assessment
4	Safety considerations	1. Safety considerations 2. Safety requirements 4. Safety test methods and procedures 5. Fire protection

The rationale for selecting reference standards will adhere to the following priority hierarchy:

- IEC (International Electrotechnical Commission): This is the highest priority, ensuring conformity with existing Vietnamese standards specifically related to BESS.
- International Standards (e.g., ISO): These are adopted following the existing precedence of adapting ISO standards within Vietnam.
- IEEE (Institute of Electrical and Electronics Engineers) Standards: These are adopted following the existing precedence of adapting IEEE standards within Vietnam.
- International Regional Standards (e.g., Eurocode): These standards will be considered following IEC, ISO, and IEEE standards.
- National Standards (e.g., from the UK, Germany, China, and Australia): These will be used when more regionally specific or international standards do not suffice.
- Internationally Recognized Institutional or Association Standard Systems (e.g., NFPA): These standards are considered when other higher-priority frameworks are not applicable.

In compliance with Circular 11/2021/TT-BKHCN, which details the development and application of standards as specified in Article 4, ISSQ is required to submit a proposal to STAMEQ for the development of 15 TCVNs for Battery Energy Storage Systems (BESS), as outlined in the Terms of Reference (TOR)[38], Annex 2. To ensure alignment among all parties and to maintain the quality and schedule of the project, it is essential to analyze the required standards, which are listed in Table 7.

[38] See Appendix 1. Of this report for the overview of standards from TOR – Annex 2.

Table 7 The proposed list of TCVN for BESS as specified in Annex 2 of TOR.

No	Description	Rationale for Recommended Standards
I	**Specifications and testing methods**	
1	Battery energy storage systems (BESS) - Part 1: Vocabulary	The requirement in TOR – Annex 2 The reference standard should be IEC 62933-1:2024 This part defines terms applicable to battery energy storage systems (BESS) including terms necessary for the definition of unit parameters, test methods, planning, installation, safety, and environmental issues. This terminology document applies to grid-connected systems able to extract electrical energy from an electric power system, store it internally, and inject electrical power into an electric power system.
2	Battery energy storage systems (BESS) - Part 2-1: Unit parameters and testing methods - General specification	The requirement in TOR – Annex 2 The reference standard should be IEC 62933-2-1:2017 This part deals with BESS performance defining: - unit parameters, - testing methods.
3	Battery energy storage systems (BESS) - Part 2-2: Unit parameters and testing methods - Application and performance testing	The requirement in TOR – Annex 2 The reference standard should be IEC TS 62933-2-2:2022 This part defines testing methods and duty cycles to validate the BESS's technical specification for the manufacturers, designers, operators, utilities, and owners of the BESS systems which evaluate the performance of the BESS for various applications.
4	Battery energy storage systems (BESS) - Part 2-200: Unit parameters and testing methods - Case study of battery energy storage systems (BESS) located in EV charging station with PV	The requirement in TOR – Annex 2 The reference standard should be IEC TR 62933-2-200:2021 This part presents a case study of battery energy storage systems (BESS) located in electric vehicle (EV) charging stations with photovoltaic (PV) power generation (PV-BESS-EV charging stations). This document includes the following elements: - overview of general PV-BES-EV charging stations; - operational analysis of BESS in typical project cases; - summary and recommendation of the BES system's operation modes.
II	**Planning and Performance assessments**	
5	Battery energy storage systems (BESS) - Part 3-1: Planning and performance assessment of electrical energy storage systems - General specification	The requirement in TOR – Annex 2 The reference standard should be IEC TS 62933-3-1:2018 This part applies to BESS designed for grid-connected indoor or outdoor installation and operation. This document considers: - necessary functions and capabilities of BESS - test items and performance assessment methods for BESS

No	Description	Rationale for Recommended Standards
		- requirements for monitoring and acquisition of BESS operating parameters - exchange of system information and control capabilities required
6	Battery Energy Storage Systems (BESS) - Part 3-2: Planning and performance assessment of battery energy storage systems - Additional requirements for power intensive and renewable energy sources integration-related applications	The requirement in TOR – Annex 2 The reference standard should be IEC TS 62933-3-2:2023 This part provides the requirements for power-intensive and renewable energy sources integration-related applications of BESS, including grid integration, performance indicators, sizing and planning, operation and control, monitoring, and maintenance.
7	Battery Energy Storage Systems (BESS) - Part 3-3: Planning and performance assessment of battery energy storage systems - Additional requirements for energy-intensive and backup power applications	The requirement in TOR – Annex 2 The reference standard should be IEC TS 62933-3-3:2022 This part defines the requirements, guidelines, and references when BESS is designed, controlled, and operated for energy-intensive, islanded grid, and backup power supply applications.
III	**Environmental issues**	
8	Battery energy storage systems (BESS) - Part 4-1: Guidance on environmental issues - General specification	The requirement in TOR – Annex 2 The reference standard should be IEC TS 62933-4-1:2017 This part is a Technical Specification, describes environmental issues associated with battery energy storage systems (BESS), and presents guidelines to address the environmental impacts to and from BESS including the impacts to humans due to chronic exposure associated with the mentioned environmental impacts.
9	Battery Energy Storage Systems (BESS) - Part 4-2: Assessment of the environmental impact of battery failure in an electrochemical-based storage system.	The requirement in TOR – Annex 2 The reference standard should be IEC 62933-4-2 ED1 This part defines the requirements and structure for the evaluation and reporting of the impact on the environment, from a failure of the electrochemical core of the battery energy storage system (BESS), i.e. the cell, battery, or cell stack due to internal and exogenous causes. This failure may result in a negative impact on the environment in which the BESS exists. The IEC 62933-4-2 ED1 is currently in the development process and has not yet been published.
10	Battery energy storage systems (BESS) - Part 4-3: The protection requirements of BESS according to the environmental conditions and location types.	The requirement in TOR – Annex 2 The reference standard should be IEC 62933-4-3 ED1 This part focuses on the protection requirements of BESS according to the environmental conditions and location types. The IEC 62933-4-3 ED1 is currently in the review process and has not yet been published.

No	Description	Rationale for Recommended Standards
11	Battery energy storage systems (BESS) - Part 4-4: Environmental requirements for battery-based energy storage systems (BESS) with reused batteries	The requirement in TOR – Annex 2 The reference standard should be IEC 62933-4-4:2023 This part describes environmental issues when reused batteries are considered for a BESS. It provides detail and requirements for identifying and preventing environmental issues in each life cycle stage, i.e., from the design to the disassembly of such reused batteries in a BESS.
IV	**Safety considerations**	
12	Battery energy storage systems (BESS) - Part 5-1: Safety considerations for grid -integrated BESS systems - General specification	The requirement in TOR – Annex 2 The reference standard should be IEC TS 62933-5-1:2017 This part is a Technical Specification, that specifies the safety considerations (e.g. hazard identification, risk assessment, risk mitigation) applicable to BESS integrated with the electrical grid. This document provides criteria to fosterthe safe application and use of electric energy storage systems of any type or size intended for grid-integrated applications.
13	Battery energy storage systems (BESS) - Part 5-2: Safety requirements for grid-integrated BESS - Electrochemical-based systems	The requirement in TOR – Annex 2 The reference standard should be IEC 62933-5-2:2020 This part primarily describes safety aspects for people and, where appropriate, safety matters related to the surroundings and living beings for grid-connected energy storage systems where an electrochemical storage subsystem is used.
14	Electrical energy storage systems (BESS) - Part 5-3: Safety requirements for grid-integrated BESS – performing unplanned modifications of electrochemical-based system	The requirement in TOR – Annex 2 The reference standard should be IEC 62933-5-3:2023 This part applies to those instances when BESS undergoes unplanned modifications. Such modifications can involve one or more of the following: - Changes to accumulation subsystem (energy storage capacity; chemistries, design and manufacturer of the accumulation subsystem); - Changes of a subsystem component using non-OEM parts, - Changes to mode of operation - Changes in the installation site - Changes in an accumulation subsystem due to the installation of reused or repurposed batteries
15	Battery energy storage systems (BESS) - Part 5-4: Safety test methods and procedures for grid integrated BESS – Lithium-ion battery-based systems.	The requirement in TOR – Annex 2 The reference standard should be IEC 62933-5-4 ED1 This part provides test methods and procedures to address safety concerns for grid-integrated BESS – Lithium-ion battery-based systems The IEC 62933-5-4 ED1 is currently in the development process and has not yet been published.

From the above analysis, concerning the proposed list of TCVN for BESS in Annex 2 of the TOR, it is found that there are three proposed standards with their intended reference IEC standards are currently under review or development and have not yet been published as follows:

- Battery Energy Storage Systems (BESS) - Part 4-2- Assessment of the environmental impact of battery failure in an electrochemical-based storage system. The reference standard is IEC 62933-4-2 ED1, which has been at the AFDIS[39] stage since February 2024, with a forecasted publication date in December 2024.
- Battery energy storage systems (BESS) - Part 4-3: The protection requirements of BESS according to the environmental conditions and location types. The reference standard is IEC 62933-4-3 ED1, which has been at the CDM[40] stage since June 2024, with a forecasted publication date in August 2025.
- Battery energy storage systems (BESS) - Part 5-4 – Safety test methods and procedures for grid integrated EES systems – Lithium-ion battery-based systems. The reference standard is IEC 62933-5-4 ED1, which has been at the CDM stage since November 2023, with a forecasted publication date in September 2025.

On June 25, 2024, ISSQ sent letter number 16814/ISSQ-DA to STAMEQ requesting feedback on replacing the standards for energy storage systems currently under research and development. In response, STAMEQ replied to ISSQ in letter number 570/TCCL-TC2 dated July 10, 2024, allowing ISSQ to use these IEC draft documents as reference standards to research and develop draft TCVN standards for Vietnam.

To address STAMEQ's recommendations and ensure consistency within the standardization framework concerning reference standards, consultants will continue developing these standards by referencing the respective IEC standards that are currently under development. Throughout the standard development process, consultants will incorporate updates from the latest versions of these reference standards.

5.3 Contents to be covered in the proposed TCVNs

The objectives of the national TCVN standards for Battery Energy Storage System (BESS) are to serve as:

- Reference documents for developers, investors, and authorities in the processes of applying for permits, agreements, appraisals, approvals, and acceptance of BESS.
- Guidelines for designers, suppliers, purchasers, operators, and regulators in the development, implementation, and operation of BESS.

The proposed standards for BESS in this stage are the standards in the list that will be submitted to STAMEQ for approval. The contents to be covered in the TCVNs for BESS regarding the reference respective standards would be:

Table 8 The contents covered in the TCVN for BESS

No	Description	The contents to be addressed	Note
I	**Specifications and testing methods**		
1	Battery energy storage systems (BESS) - Part 1: Vocabulary	This part defines terms applicable to battery energy storage systems (BESS) including terms necessary for the definition of unit parameters, test methods, planning, installation, safety, and environmental issues. The document covers the following main items: 1. Scope	TOR – Annex 2

39AFDIS: Approved for Final Draft International Standard

40 CDM: Committee Draft to be Discussed at Meeting.

No	Description	The contents to be addressed	Note
		2. Normative references 3. Terms and definitions for BESS classification 4. Terms and definitions for BESS specification 5. Terms and definitions for BESS planning and installation 6. Terms and definitions for BESS operation 7. Terms and definitions for BESS safety and environmental issues 8. Annexes	
2	Battery energy storage systems (BESS) - Part 2-1: Unit parameters and testing methods - General specification	This part deals with BESS performance defining: - unit parameters, - testing methods. The document covers the following main items: 1. Scope 2. Normative references 3. Terms, definitions, abbreviated terms and symbols 4. Classification of BESS 5. Unit parameters 6. Testing methods and procedures 7. Annexes	TOR – Annex 2
3	Battery energy storage systems (BESS) - Part 2-2: Unit parameters and testing methods - Application and performance testing	This part defines testing methods and duty cycles to validate the BESS. The document covers the following main items: 1. Scope 2. Normative references 3. Terms, definitions, and abbreviated terms 4. Application of BESS 5. Parameter testing methods for application 6. Duty cycle for specific applications 7. Annexes	TOR – Annex 2
4	Battery energy storage systems (BESS) - Part 2-200: Unit parameters and testing methods - Case study of electrical energy storage (EES) systems located in EV charging station with PV	This part presents a case study of battery energy storage systems (BESS) located in electric vehicle (EV) charging stations with photovoltaic (PV) power generation (PV-BESS-EV charging stations). The content covers the following main items: 1. Scope 2. Normative references 3. Terms, definitions, abbreviated terms 4. Overview of BESS located in EV charging stations with PV power generation. 5. Project of commercial PV-BESS-EV charging station based on common DC bus 6. Project of commercial PV-BESS-EV charging station based on common AC bus 7. Project of business PV-BESS-EV charging station based on common DC bus	TOR – Annex 2

No	Description	The contents to be addressed	Note
		8. Project of business of commercial PV-BESS-EV charging station based on common AC bus 9. Recommendation for operation modes of BESS located in EV charging station with PV panels 10. Annexes	
II	**Planning and Performance assessments**		
5	Battery energy storage systems (BESS) - Part 3-1: Planning and performance assessment of electrical energy storage systems - General specification	This part applies to BESS designed for grid-connected indoor or outdoor installation and operation. The content covers the following main items: 1. Scope 2. Normative references 3. Terms, definitions and symbols 4. General structure of BESS 5. Planning of BESS 6. BESS performance assessment 7. Annexes	TOR – Annex 2
6	Battery Energy Storage Systems (BESS) - Part 3-2: Planning and performance assessment of battery energy storage systems - Additional requirements for power intensive and renewable energy sources integration-related applications	This part provides the requirements for power-intensive and renewable energy sources integration-related applications of BESS, including grid integration, performance indicators, sizing and planning, operation and control, monitoring, and maintenance. The content covers the following main items: 1. Scope 2. Normative references 3. Terms, definitions, abbreviated terms and symbols 4. General planning and performance assessment considerations for BESS 5. Frequency regulation/control 6. Grid voltage support (Q(U)), volt/var support 7. Voltage sag mitigation (P(U)) 8. Renewable energy sources integration-related applications 9. Power oscillation damping (POD) 10. Annexes	TOR – Annex 2
7	Battery Energy Storage Systems (BESS) - Part 3-3: Planning and performance assessment of battery energy storage systems -	This part defines the requirements, guidelines, and references when BESS is designed, controlled, and operated for energy-intensive, islanded grid, and backup power supply	TOR – Annex 2

No	Description	The contents to be addressed	Note
	Additional requirements for energy-intensive and backup power applications	applications. The document covers the following main items: 1. Scope 2. Normative references 3. Terms, definitions, abbreviated terms and symbols 4. General planning and performance assessment considerations for BESS 5. Peak shaving and load leveling 6. Islanded grid application 7. Backup power supply and emergency support 8. Annexes	
III	**Environmental issues**		
8	Battery energy storage systems (BESS) - Part 4-1: Guidance on environmental issues - General specification	This part is a Technical Specification, describes environmental issues associated with battery energy storage systems (BESS), and presents guidelines to address the environmental impacts to and from BESS including the impacts to humans due to chronic exposure associated with the mentioned environmental impacts. The document covers the following main items: 1. Scope 2. Normative references 3. Terms and definitions 4. General 5. Identifying environmental issues in BESS 6. Environmental guidelines of BESS 7. Annexes	TOR – Annex 2
9	Battery Energy Storage Systems (BESS) - Part 4-2: Assessment of the environmental impact of battery failure in an electrochemical-based storage system.	This part defines the requirements and structure for the evaluation and reporting of the impact on the environment, from a failure of the electrochemical core of the battery energy storage system (BESS). The document covers the following main items: 1. Scope 2. Normative references 3. Terms, definitions, abbreviated terms and symbols 4. General 5. Failure of the electrochemical accumulation system in a BESS resulting in environmental issues 6. Guidlines for assessing the environmental impact of a failure of the battery of the BESS. 7. Annexes	TOR – Annex 2

No	Description	The contents to be addressed	Note
10	Battery energy storage systems (BESS) - Part 4-3: The protection requirements of BESS according to the environmental conditions and location types.	This part focuses on the protection requirements of BESS according to the environmental conditions and location types. The document covers the following main items: 1. Scope 2. Normative references 3. Terms and definitions 4. General 5. Environmental factors to BESS 6. The risk analysis of each environmental factor and the relevant measures. 7. Annexes	TOR – Annex 2
11	Battery energy storage systems (BESS) - Part 4-4: Environmental requirements for battery-based energy storage systems (BESS) with reused batteries	This part describes environmental issues when reused batteries are considered for a BESS. It provides details and requirements for identifying and preventing environmental issues in each life cycle stage. The content covers the following main items: 1. Scope 2. Normative references 3. Terms, definitions, abbreviation terms 4. General 5. Identifying environmental issues of BESS 6. Environmental guidelines of BESS 7. Annex	TOR – Annex 2
IV	**Safety considerations**		
12	Battery energy storage systems (BESS) - Part 5-1: Safety considerations for grid - integrated BESS systems - General specification	This part is a Technical Specification, that specifies safety considerations (e.g. hazard identification, risk assessment, risk mitigation) applicable to EES systems integrated with the electrical grid. The content covers the following main items: 1. Scope 2. Normative references 3. Terms and definitions 4. Basic guidelines for the safety aspect of BESS 5. Hazard considerations for BESS 6. BESS risk assessment 7. Requirements necessary to reduce risks 8. System testing 9. Guidelines and manuals 10. Annexes	TOR – Annex 2
13	Battery energy storage systems (BESS) - Part 5-2: Safety requirements for grid-integrated BESS -	This part primarily describes safety aspects for people and, where appropriate, safety matters related to the surroundings and living beings for grid-connected energy storage systems where an	TOR – Annex 2

No	Description	The contents to be addressed	Note
	Electrochemical-based systems	electrochemical storage subsystem is used. The content covers the following main items: 1. Scope 2. Normative references 3. Terms and definitions 4. Basic guidelines for the safety of BESS 5. Hazard considerations 6. BESS risk assessment 7. Requirements necessary to reduce risks 8. System validation and testing 9. Guidelines and manuals 10. Annexes	
14	Electrical energy storage systems (BESS) - Part 5-3: Safety requirements for grid-integrated BESS – performing unplanned modifications of electrochemical-based system	This part applies to those instances when BESS undergoes unplanned modifications. The content covers the following main items: 1. Scope 2. Normative references 3. Terms and definitions 4. General requirements for performing unplanned modifications 5. Changes to an accumulation subsystem 6. Changes of a subsystem component using non-OEM parts 7. Changes to the mode of operation 8. Changes in the installation site 9. Changes in an accumulation subsystem due to the installation of reused or repurposed batteries 10. Annexes	TOR – Annex 2
15	Battery energy storage systems (BESS) - Part 5-4: Safety test methods and procedures for grid integrated BESS – Lithium-ion battery-based systems.	This part provides test methods and procedures to address safety concerns for grid-integrated BESS – Lithium-ion battery-based systems. The content covers the following main items: 1. Scope 2. Normative references 3. Terms and definitions 4. Test methods and procedures for BESS	TOR – Annex 2

Chapter 6: Development of the list of National Standards

This Chapter answers the following question: 'How to develop the proposed list of Standards for BESS in Vietnam?' And is guided by the sub-questions:

a) What is the Consortium's approach to developing the standards?
b) What is a suitable roadmap for developing the standards?

6.1 Approach to develop the standards

This section elaborates upon the approach that the consortium takes towards the development of the standards. First, it explains how technical teams are formed that will be consulted throughout all deliverables of the project.

6.1.1 Technical teams

The national TCVN standards for Battery Energy Storage Systems (BESS) will be developed by a technical team referencing international standards, and the knowledge and experience of countries with advanced expertise in BESS development. These standards are designed to follow technical regulations and are tailored to Vietnam's unique geographical, climatic, technical, and technological characteristics, ensuring they safeguard national interests without any adverse impact.

Regarding project deliverables as specified in the Terms of Reference (TOR) and the consortium's proposal, a technical team has been established with the following roles:

- Deliverable 3: Compiling the draft of national standards for BESS according to the list agreed with STAMEQ
- Deliverable 4: Providing technical assistance to Consortium members during the two hybrid-mode consultation events, gathering and analyzing feedback from stakeholders participating in the events, and preparing consultation event reports.
- Deliverable 5: Absorbing knowledge and experience from countries with strong expertise in BESS during participation in international trips. Preparing the reports regarding lessons learned and recommendations for TCVNs on BESS in Viet Nam.
- Deliverable 6: Participating in the international laboratory test and preparing the report on testing principles, practical application of TCVNs, and categorization of mandatory and optional standards.
- Deliverable 7: Refining the final draft of the TCVNs for BESS based on comments and feedback from various stakeholders, in close consultation with STAMEQ.
- Deliverable 8: Providing technical clarification, as needed, during the appraisal of STAMEQ's progress and the promulgation procedure of MOST. Revising and resubmitting draft standards for appraisal and promulgation by MOST, if necessary.
- Deliverable 9: Providing technical assistance to Consortium members during the final stakeholder event, disseminating project results, gathering and analyzing feedback from stakeholders participating in the workshops, and preparing the final workshop report.

6.1.2 Team members' organizations chart

Regarding Annex 2, which outlines the proposed list of TCVNs for BESS, and Chapter 5, which presents the recommended list of national standards detailed in this report, the standards are categorized into four groups:

- Group I: Specification and Testing Methods
- Group II: Planning and Performance Assessments
- Group III: Guidance on Environmental Issues
- Group IV: Safety considerations for grid-integrated BESS

Therefore, the technical team should be organized into three teams, with Groups III and IV emerging into a single (team III) due to their similar background knowledge requirements. Each team should consist of members with relevant knowledge and experience in the corresponding area. The organization chart for the technical team members is as follows:

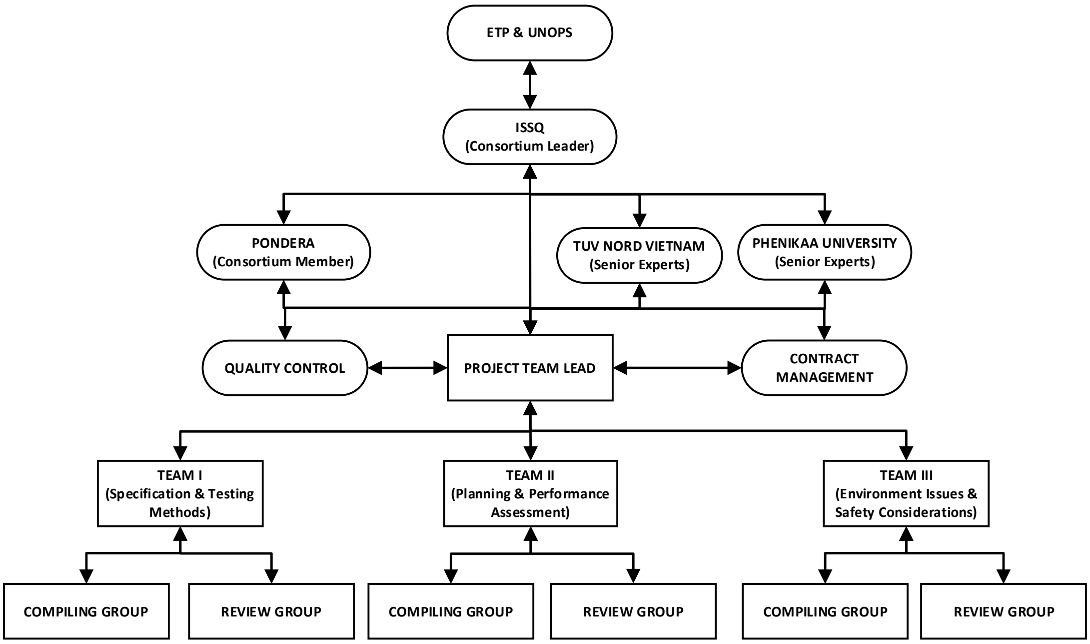


Figure 4 Organization chart of the technical team

6.1.3 Members of Technical Teams

The project team lead

The project team lead is kept consistent with the technical proposal, form D, section 1, item 3.3. Management structure and project management controls. There are two persons in the project team lead as follows:

- Project team lead: Mr. Vu Van Dien, from ISSQ, who possesses insight knowledge and regulatory expertise, and has extensive experience in the development of national standards.
- Deputy project team lead: Mr. Ngo Kien Cuong, from PONDERA, possesses extensive technical knowledge and has a long-standing track record in the development, implementation, commissioning, and maintenance of power projects.

Technical team members

The technical team members have been selected from the key individuals identified in Section 4.3, "Key Consultants," of the first deliverable (the Inception Report), as well as in Section 3, "Key Personnel Proposed," of the technical proposal, Form D. These key consultants are allocated to three distinct teams based on their relevant background knowledge and expertise, ensuring a match between their skills and the team's focus areas. The responsibility allocation for compiling and review based on the core expertise of each consortium partner. The details of the technical teams are as follows:

Whereas:

- Comp. = Compiling
- Rev. = Reviewing
- R = Responsible allocated

Table 9 The details of the technical teams

No	Name	Company	**Team I** (Specification & Testing Methods)		**Team II** (Planning & Performance Assessment)		**Team III** (Environment Issues & Safety Considerations)	
			Comp.	Rev.	Comp.	Rev.	Comp.	Rev.
1	Vu Van Dien	ISSQ	R		R		R	
2	Ngo Kien Cuong	Pondera		R		R		R
3	Jeroen de Veth	Pondera		R		R		R
4	Willem Bonnes	Pondera		R		R		R
5	Dennis Geutjes	Pondera		R		R		R
6	Pho Duc Son	ISSQ			R		R	
7	Bui Thanh Hung	ISSQ	R		R			
8	Le Tien Thanh	ISSQ			R		R	
9	Ha Duy Hieu	ISSQ	R		R			

6.1.4 Responsibilities of Technical Teams

The project team lead

The responsibilities of a project team lead encompass a broad range of tasks and duties aimed at ensuring the project's successful deliverables. The duties of the project team lead are as follows:

- Determining international standards and technical regulations to serve as reference documents when compiling draft national standards.
- Leading the teams compiling draft national standards, refining the final draft of national standards, and preparing the reports of the project.
- Participating in progress meetings, hybrid-mode consultation events, and international labs.
- Planning and scheduling activities to align with contract milestones for each deliverable.
- Monitoring and controlling the progress of deliverables to ensure they are on track.
- Building and maintaining a cohesive team, assigning tasks based on the skills and experiences of team members.
- Acting as the primary point of contact both within the project team and between the team and stakeholders.
- Identifying potential risks that could affect the timeline and quality of deliverables and developing strategies to mitigate these risks for smooth project execution as outlined in item 8 of the delivered Inception Report.
- Addressing and resolving any issues or conflicts that arise throughout the project.

- Engaging with stakeholders as outlined in item 5 of the delivered inception report to understand their needs and expectations, keeping them informed about the progress of the project, and addressing their concerns.
- Ensuring the draft national standard complies with all relevant laws and regulations.

Technical team member – Compiling groups

The responsibilities of the technical team members (compiling groups) are as follows:
- Supporting the team lead in identifying and selecting international standards and technical regulations that will serve as benchmark references for drafting national standards, ensuring alignment with global best practices.
- Engaging in drafting and refining national standards. Take responsibility for preparing reports as assigned.
- Weekly submit the draft standards to the review groups and provide feedback.
- Actively participating in progress meetings, engaging in hybrid-mode consultation events, and attending international laboratories as required, contributing to the project's success through collaborative effort and knowledge exchange.
- Utilizing specialized expertise to efficiently execute project tasks and creatively solve challenges, driving forward project objectives with skill and innovation.
- Working closely with team members across different disciplines to collaboratively meet project goals, fostering a supportive and productive team environment.
- Ensuring that the draft national standard adheres to all applicable legal and regulatory requirements while also meeting scheduled activities and milestone deadlines, maintaining high standards of quality and timeliness.

Technical team member – Review groups

The responsibilities of the technical team members (Review Groups) are to review and provide feedback on draft standards to ensure adherence to the following criteria:
- The presentation and content of the submission must comply with the national standard regulations TCVN 1-2:2008.
- The draft standards must conform to referenced international standards.
- The standards must comply with relevant technical regulations.
- The standards should be suitable for Vietnam's geographical, climatic, technical, and technological characteristics.
- The use of "Vietnamese technical terminology" in the standard should be appropriate and in line with current regulatory documents.
- The standards must ensure that there are no regulations that could potentially harm national interests or limit the competitive capability of the domestic supply chain.
- Recommend state-of-the-art practices and knowledge transfer techniques from leading Battery Energy Storage System (BESS) countries with advanced expertise, if any.

6.2 Roadmap to develop the standards

To develop the proposed national standards, the roadmap will be created by project deliverables and Circular No. 11/2021/TT-BKHCN, which details the development and application of standards. This process will be outlined in the following flowcharts:

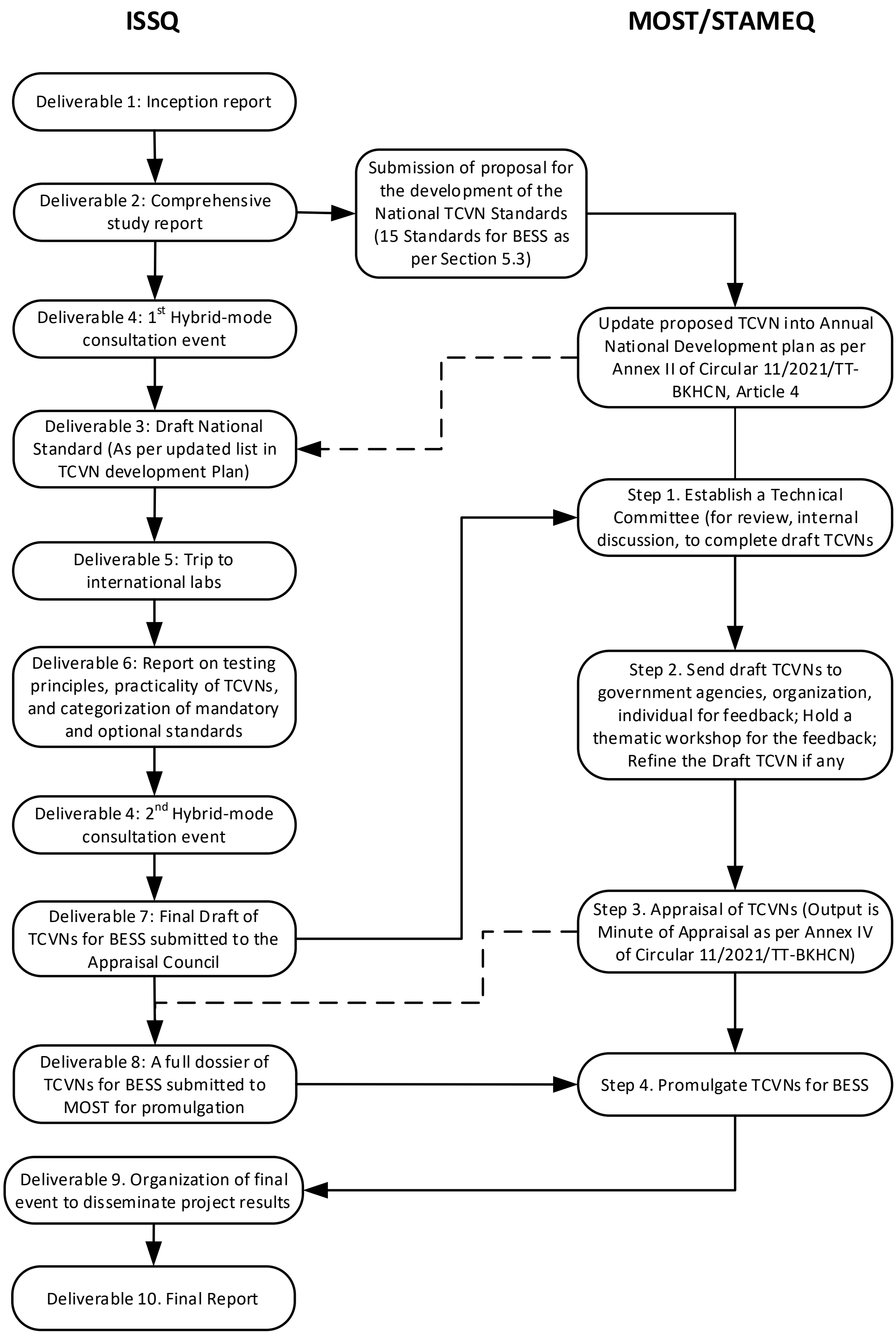


Figure 5 Process for developing the proposed national standards

The referenced standards draw from a variety of sources, including the IEC 62933 series, as well as standards from the IEC, ISO, IEEE, EN, and others. The priority hierarchy is described in Section 5.2. These standards incorporate modern technology that affects critical components, impacting the safety, stability, and operational availability of BESS. Subsequently, the selected reference standards are adapted to fit the TCVN framework. Based on the standard of short-listed references, the technical team will eventually provide a detailed schedule for the project, an updated organizational chart, and a division of tasks among technical teams. The preliminary reference standards for developing national TCVNs standards are as in Table 10.

Table 10 The preliminary reference standards

No	Proposed National TCVNs		Preliminary reference standards	
	Notation	Description	Notation	Description
I	**Specifications and testing methods**			
1	TCVN xxxxx-1:20xx	Battery energy storage systems (BESS) - Part 1: Vocabulary	IEC 62993-1:2024	Electrical energy storage (EES) systems - Part 1: Vocabulary
2	TCVN xxxxx-2-1:20xx	Battery energy storage systems (BESS) - Part 2-1: Unit parameters and testing methods - General specification	IEC 62993-2-1:2017	Electrical energy storage (EES) systems - Part 2-1: Unit parameters and testing methods - General specification
3	TCVN xxxxx-2-2:20xx	Battery energy storage systems (BESS) - Part 2-2: Unit parameters and testing methods - Application and performance testing	IEC TS 62993-2-2:2022	Electrical energy storage (EES) systems - Part 2-2: Unit parameters and testing methods - Application and performance testing
4	TCVN xxxxx-2-200:20xx	Battery energy storage systems (BESS) - Part 2-200: Unit parameters and testing methods - Case study of electrical energy storage (EES) systems located in EV charging station with PV	IEC TR 62993-2-200:2021	Electrical energy storage (EES) systems - Part 2-200: Unit parameters and testing methods - Case study of electrical energy storage (EES) systems located in EV charging station with PV
II	**Planning and Performance assessments**			
5	TCVN xxxxx-3-1:20xx	Battery energy storage systems (BESS) - Part 3-1: Planning and performance assessment of electrical energy storage systems - General specification	IEC TS 62993-3-1:2018	Electrical energy storage (EES) systems - Part 3-1: Planning and performance assessment of electrical energy storage systems - General specification
6	TCVN xxxxx-3-2:20xx	Battery Energy Storage Systems (BESS) - Part 3-2: Planning and performance assessment of battery energy storage systems - Additional requirements for power intensive and renewable energy sources integration-related applications	IEC TS 62993-3-2:2023	Electrical energy storage (EES) systems - Part 3-2: Planning and performance assessment of electrical energy storage systems - Additional requirements for power intensive and renewable energy sources integration-related applications

No	Proposed National TCVNs		Preliminary reference standards	
	Notation	Description	Notation	Description
7	TCVN xxxxx-3-3:20xx	Battery Energy Storage Systems (BESS) - Part 3-3: Planning and performance assessment of battery energy storage systems - Additional requirements for energy-intensive and backup power applications	IEC TS 62993-3-3:2022	Electrical energy storage (EES) systems - Part 3-3: Planning and performance assessment of electrical energy storage systems - Additional requirements for energy-intensive and backup power applications
III	**Environmental issues**			
8	TCVN xxxxx-4-1:20xx	Battery energy storage systems (BESS) - Part 4-1: Guidance on environmental issues - General specification	IEC TS 62993-4-1:2017	Electrical energy storage (EES) systems - Part 4-1: Guidance on environmental issues - General specification
9	TCVN xxxxx-4-2:20xx	Battery Energy Storage Systems (BESS) - Part 4-2: Assessment of the environmental impact of battery failure in an electrochemical-based storage system.	IEC 62933-4-2 ED1	Electric Energy Storage (EES) Systems - Part 4-2- Assessment of the environmental impact of battery failure in an electrochemical-based storage system
10	TCVN xxxxx-4-3:20xx	Battery energy storage systems (BESS) - Part 4-3: The protection requirements of BESS according to the environmental conditions and location types.	IEC 62933-4-3 ED1	Electrical energy storage (EES) systems - Part 4-3: The protection requirements of BESS according to the environmental conditions and location types
11	TCVN xxxxx-4-4:20xx	Battery energy storage systems (BESS) - Part 4-4: Standard on environmental issues battery-based energy storage systems (BESS) with reused batteries – requirements	IEC 62993-4-4:2023	Electrical energy storage (EES) systems - Part 4-4: Standard on environmental issues battery-based energy storage systems (BESS) with reused batteries – requirements
IV	**Safety considerations**			
12	TCVN xxxxx-5-1:20xx	Battery energy storage systems (BESS) - Part 5-1: Safety considerations for grid - integrated BESS systems - General specification	IEC TS 62993-5-1:2017	Electrical energy storage (EES) systems - Part 5-1: Safety considerations for grid - integrated EES systems - General specification
13	TCVN xxxxx-5-2:20xx	Battery energy storage systems (BESS) - Part 5-2: Safety requirements for grid-integrated BESS - Electrochemical-based systems	IEC 62993-5-2:2020	Electrical energy storage (EES) systems - Part 5-2: Safety requirements for grid-integrated EES system - Electrochemical-based systems

No	Proposed National TCVNs		Preliminary reference standards	
	Notation	Description	Notation	Description
14	TCVN xxxxx-5-3:20xx	Electrical energy storage systems (BESS) - Part 5-3: Safety requirements for grid-integrated BESS – performing unplanned modifications of electrochemical-based system	IEC 62993-5-3:2023	Electrical energy storage (EES) systems - Part 5-3: Safety requirements for grid-integrated EES system – performing unplanned modifications of electrochemical-based system
15	TCVN xxxxx-5-4:20xx	Battery energy storage systems (BESS) - Part 5-4: Safety test methods and procedures for grid integrated BESS – Lithium-ion battery-based systems.	IEC 62933-5-4 ED1	Electrical energy storage (ESS) systems - Part 5-4 – Safety test methods and procedures for grid integrated EES systems – Lithium-ion battery-based systems

Chapter 7. Conclusions and recommendation

The comprehensive study report addresses the critical need for establishing national standards for Battery Energy Storage Systems (BESS) in Vietnam by identifying the current gaps in standards related to BESS. This includes an assessment of how these gaps affect the overall progress of developing BESS projects by regulations. The identified technical gaps stem from extensive research and analysis of the current state of policies, regulations, and standards for BESS in Vietnam, alongside research and study on international policies, regulations, and standards from leading countries in BESS.

The data for this analysis were gathered through a desk study from trusted sources[41]. Additionally, information from relevant programs/projects on BESS National Standards, including the Vietnam Technology Catalogue for Power Generation and Storage - 2021 (Danish Energy Agency) and surveys conducted in five benchmark countries has enriched our findings.

Section 3.2 demonstrates that national standards (TCVN) are needed for facilitating BESS development, ensuring that Government Competent Authorities and investors face no significant challenges or difficulties in the application procedures of permit, appraisal, approval, agreement, and acceptance of project documents as per the stipulation of regulations. In instances where national standards are absent, which is currently the case for BESS, project developers are required to apply the international standards. Consequently, developers must navigate the process of obtaining approval for these applied international standards in compliance with regulatory requirements. Applying foreign standards poses considerable challenges for authorities in the design document appraisal process due to the potential of:

- Differences with natural conditions and technical regulation of Viet Nam
- Variations in technical design criteria among different developers and projects.

Findings in section 3.3 that the TCVNs for BESS, which include specifications and testing methods, planning and performance assessments, environmental issues, and safety considerations, remain insufficient. The requirements for the interconnection of BESS to the transmission and distribution levels of the electric power system are explicitly outlined in Circular 25/2016/TT-BCT and Circular 39/2015/TT-BCT respectively.

As observed in section 5.1, the gaps of TCVN for BESS lie in the absence of technical standards regarding:

- Specifications and testing methods
- Planning and Performance assessments
- Guidance on Environmental issues
- Safety considerations

The national standards for Battery Energy Storage Systems (BESS) will support the advancement of BESS and renewable energy by focusing on key areas such as safety and reliability, performance standards, interoperability, testing and assessment, regulatory compliance, innovation and research, and market growth.

Section 5.2, there are three proposed standards with their intended reference IEC standards are currently under review or development and have not yet been published as follows:

[41] These sources include www.ThuVienPhapLuat.vn for Vietnamese regulations and technical standards, iec.ch, iso.org, standards.ieee.org, en-standard.eu, and https://standards.iteh.ai/catalog/standards for international standards

- Battery Energy Storage Systems (BESS) - Part 4-2- Assessment of the environmental impact of battery failure in an electrochemical-based storage system.
- Battery energy storage systems (BESS) - Part 4-3: The protection requirements of BESS according to the environmental conditions and location types.
- Battery energy storage systems (BESS) - Part 5-4 – Safety test methods and procedures for grid integrated EES systems – Lithium-ion battery-based systems.

To address STAMEQ's recommendations in the letter 570/TCCL-TC2 and ensure consistency within the standardization framework concerning reference standards, consultants will continue developing these standards by referencing the respective IEC standards that are currently under development. Throughout the standard development process, consultants will incorporate updates from the latest versions of these reference standards.

Following the defined gaps, the report outlines a set of recommended standards for Battery Energy Storage Systems (BESS) in Vietnam in section 5.3. These standards are designed to act as reference materials for developers, investors, and authorities engaged in the various stages of permitting, agreement, appraisal, approval, and acceptance of BESS projects. Additionally, the standards offer guidance for designers, suppliers, purchasers, operators, and regulators throughout the development, implementation, and operational phases of BESS facilities.

Appendix 1. List of TCVNs for BESS as specified in the TOR – Annex 2

No	TCVN	Description
1	Electrical energy storage (EES) systems - Part 1: Vocabulary	This part defines terms applicable to electrical energy storage (EES) systems including terms necessary for the definition of unit parameters, test methods, planning, installation, safety, and environmental issues.
2	Electrical energy storage (EES) systems - Part 2-1: Unit parameters and testing methods - General specification	This part deals with EES system performance defining: - unit parameters, - testing methods.
3	Electrical energy storage (EES) systems - Part 2-2: Unit parameters and testing methods - Application and performance testing	This part defines testing methods and duty cycles to validate the EES system's technical specification.
4	Electrical energy storage (EES) systems - Part 2-200: Unit parameters and testing methods - Case study of electrical energy storage (EES) systems located in EV charging station with PV	This part presents a case study of electrical energy storage (EES) systems located in electric vehicle (EV) charging stations with photovoltaic (PV) power generation (PV-EES-EV charging stations). This document includes the following elements: - overview of general PV-EES-EV charging stations; - operational analysis of EES systems in typical project cases; summary and recommendation of EES systems' operation modes.
5	Electrical energy storage (EES) systems - Part 3-1: Planning and performance assessment of electrical energy storage systems - General specification	This document considers - necessary functions and capabilities of EES systems - test items and performance assessment methods for EES systems - requirements for monitoring and acquisition of EES system operating parameters exchange of system information and control capabilities required
6	Electrical Energy Storage (EES) Systems - Part 3-2: Planning and performance assessment of electrical energy storage systems - Additional requirements for power intensive and renewable energy sources integration related applications	This part provides the requirements for power-intensive and renewable energy sources integration-related applications of EES systems, including grid integration, performance indicators, sizing and planning, operation and control, monitoring, and maintenance.
7	Electrical Energy Storage (EES) Systems - Part 3-3: Planning and performance assessment of electrical energy storage systems - Additional requirements for energy-intensive and backup power applications	This part defines the requirements, considerations, and use cases for the application of EES systems for energy-intensive applications, islanded operations, and backup power supply.
8	Electrical energy storage (EES) systems - Part 4-1: Guidance on environmental issues - General specification	This part is a Technical Specification, describes environmental issues associated with electrical energy storage systems (EES systems), and presents guidelines to address the environmental impacts to and from EES systems including the impacts to humans due to chronic exposure associated with the mentioned environmental impacts.
9	Electric Energy Storage Systems - Part 4-2- Assessment of the environmental	This part defines the requirements and structure for the evaluation and reporting of the impact on the environment, from a failure of the electrochemical core of the battery energy storage system

No	TCVN	Description
	impact of battery failure in an electrochemical-based storage system	(BESS), i.e. the cell, battery, or cell stack due to internal and exogenous causes. This failure may result in a negative impact on the environment in which the BESS exists.
10	Electrical energy storage (EES) systems - Part 4-3: The protection requirements of BESS according to the environmental conditions and location types	This part focuses on the protection requirements of BESS according to the environmental conditions and location types.
11	Electrical energy storage (EES) systems- Part 4-4: Standard on environmental issues battery-based energy storage systems (BESS) with reused batteries – requirements	This part provides environmental requirements for BESS using reused batteries in various installations and aspects of life cycles.
12	Electrical energy storage (EES) systems - Part 5-1: Safety considerations for grid-integrated EES systems - General specification	This part includes a Technical Specification, specifies safety considerations (e.g. hazard identification, risk assessment, risk mitigation) applicable to EES systems integrated with the electrical grid. This document provides criteria to foster the safe application and use of electric energy storage systems of any type or size intended for grid-integrated applications
13	Electrical energy storage (EES) systems - Part 5-2: Safety requirements for grid-integrated EES systems - Electrochemical-based systems	This part primarily describes safety aspects for people and, where appropriate, safety matters related to the surroundings and living beings for grid-connected energy storage systems where an electrochemical storage subsystem is used.
14	Electrical energy storage (EES) systems Part 5-3: Safety requirements for electrochemical-based EES systems considering initially non-anticipated modifications - partial replacement, changing application, relocation, and loading reused battery	This part includes the requirements to achieve safe modifications of the BESS. Such undergoing unplanned modifications can involve one or more of the following: - Energy storage capacity adjustments - Changes in the chemistry, design, or manufacturer of batteries - Subsystem component substitutions - Changes in the mode of operation - Changes in the installation site Installation of reused or repurposed batteries
15	Electrical energy storage (ESS) systems - Part 5-4 – Safety test methods and procedures for grid integrated EES systems – Lithium-ion battery-based systems	This part provides test methods and procedures to address safety concerns for grid-integrated EES systems – Lithium-ion battery-based systems

References

ARYANI, D. R., SONG, H. & CHO, Y.-S. 2022. Operation strategy of battery energy storage systems for stability improvement of the Korean power system. *Journal of Energy Storage,* 56**,** 106091.

BABROWSKI, S., JOCHEM, P. & FICHTNER, W. 2016. Electricity storage systems in the future German energy sector: An optimization of the German electricity generation system until 2040 considering grid restrictions. *Computers & Operations Research,* 66**,** 228-240.

CHEN ZHU, YINZHE, X., NA, L., XIN, Y., TIANCHENG, S. & HAO, C. 2022. Research on Application of Stored Energy in Different Scenarios Under the New Power System.

KIM, H.-S., HONG, J. & CHOI, I.-S. 2021. Implementation of Distributed Autonomous Control Based Battery Energy Storage System for Frequency Regulation. *Energies,* 14.

LEE, S., KIM, W. & KIM, B. H. 2015. Performance Comparison of Optimal Power Flow Algorithms for LMP Calculations of the Full Scale Korean Power System. *Journal of Electrical Engineering and Technology,* 10**,** 109-117.

MARTINHO, V. J. P. D. 2023. Impacts of the Covid-19 context on the European Union energy markets: interrelationships with sustainability. *Environment, Development and Sustainability*.

SANI, S. B., CELVAKUMARAN, P., RAMACHANDARAMURTHY, V. K., WALKER, S., ALRAZI, B., YING, Y. J., DAHLAN, N. Y. & RAHMAN, M. H. A. 2020. Energy storage system policies: Way forward and opportunities for emerging economies. *Journal of Energy Storage,* 32**,** 101902.

ZHOU, X., YI, J., SONG, R., YANG, X., LI, Y. & TANG, H. 2010. An overview of power transmission systems in China. *Energy,* 35**,** 4302-4312.

周喜超 2020. 电力储能技术发展现状及走向分析.