Powering the future

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Research paper

Powering the future: Unlocking energy storage market performance through business model innovation in smart grids

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A R T I C L E I N F O

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A B S T R A C T

The shift toward smart grids encourages businesses to adapt their operations to ensure long-term sustainability by integrating energy storage systems (ESS). Innovation is crucial for entering new markets and providing a competitive advantage. Therefore, this research focuses on variables impacting business model innovation in the grid to improve the performance of the energy storage market (ESM). The study employs a quantitative survey-based approach to examine key determinants of ESM performance, using data collected from 184 energy-sector stakeholders to capture critical constructs identified in the literature. Structural Equation Modeling (SEM) and Confirmatory Factor Analysis (CFA) were used to validate the measurement model and analyze the interrelationships among latent variables. The results highlight that profitability ($\beta = 0.289$, $p < 0.05$) has the strongest influence on ESM performance, subsequently competitiveness ($\beta = 0.205$), technological development ($\beta = 0.201$), organization learning ($\beta = 0.183$), customer satisfaction ($\beta = 0.166$), environmental ($\beta = 0.148$), and social performance ($\beta = 0.146$). These findings reveal that electricity service providers can enhance ESM performance by innovating business models that integrate organizational learning, technology adoption, customer satisfaction, social and environmental outcomes. This research provides a framework for decision-makers to foster innovation in smart grid systems, enabling smarter and more strategic choices leading to improved operational efficiency and performance in ESM. It proposes a model-based framework for analyzing ESM performance in emerging economies context.

1. Introduction

The growth trend of India's energy sector over the last few years has resulted in several additional new projects. A global target has been set to cut carbon emissions and make this world more sustainable. Businesses must obtain competitive advantages and enhance their performance. Understanding the challenges and opportunities is becoming increasingly important with society's transition towards sustainability, as it can develop effective business models (França et al., 2017). The electric grid intends to motivate businesses to strengthen their operations to ensure long-term sustainability and efficiency. Energy storage will become increasingly essential for both industry and consumers as renewable power output grows and the demand for grid stability and dependability grows, resulting in increased market expansion and the formation of new businesses. Energy storage is a useful technology for India's economy since it can help the nation accomplish economic growth while attaining its social, political, and environmental goals. This makes grid-connected energy storage as transformative solutions for India's economy (Gupta and Shankar, 2024). When a firm offers energy storage to its consumers, it engages in business model innovation, which alters the value proposition and other aspects of the business model. Energy storage is the most crucial component for a more sustainable future in the electricity industry. For businesses interested in improving the efficiency of the grid system, understanding energy storage systems (ESS) is vital. Utilities will require alternative solutions to address these issues associated with the current power grid. The development of the energy storage industry towards relatively strategic and autonomous business is accelerated by the rapid rise of advanced energy storage technologies (Li et al., 2015).

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1.1. Research motivation

Integrating information technologies into energy generation and distribution can reduce environmental impacts while enhancing power grid quality, stability, dependability, and productivity. Electrical Energy Storage Systems (EESs) are becoming critical components for a resilient and functional grid through various applications such as load shifting, energy management, frequency control, grid stability, and voltage support (Zhang et al., 2017; Gupta and Shankar, 2022). EES systems will become a crucial technology for designing, constructing, and operating electric power networks because of the growing need for enhanced grid services. Any new endeavor to adopt cutting-edge smart grid technology would first include existing utilities. Consequently, it is critical to determine when energy providers, who supply most of the electricity utilized by consumers and industrial users, will adopt innovative energy storage systems in power generation. Although energy storage helps the grid on the supply side and demand side, it is still unknown in what manner business model innovation influences the energy storage industry's performance. With the steady growth of renewable energy and the necessity for increasing electrical grid stability and reliability, energy storage will become gradually crucial for both industry and consumers, resulting in increased market growth and the formation of new businesses. The concept of energy business transformation, from energy generation to electricity consumption, is nourished by new technology. If successfully commercialized, smart grids can potentially change the electrical business (Bhatti and Danilovic,2018). As the power sector moves towards a new era of efficient and reliable production, various innovations in the smart grid field are happening, giving rise to multiple new opportunities. Kishore (2021) explains how the smart grid's invention leads to a positive shift in the existing electrical grid or other applications. Fig. 1. shows that innovation in the grid leads to improvement in energy generation, power quality, energy efficiency, demand response, etc. Also, innovation in the electric sector improves the growth of the energy storage market. This study is situated within the context of smart grids, where digitalization, real-time energy management, and the integration of distributed energy resources create new opportunities for value creation. In such an environment, business model innovation emerges as a critical mechanism through which technological, organizational, and market enablers are translated into improved energy storage market performance.

1.2. Research context, research gaps, research objectives

Existing studies have mainly focused on technology improvement (Narayanamoorthy et al., 2023; Zhang et al., 2023), use of successful business models for battery storage deployments (Kumar and Shrimali, 2021), modern policies for energy market (Bulut and Özcan, 2024; Wang et al., 2024), selection of energy storage system (Amir et al., 2023; Narayanamoorthy et al., 2023; Rana et al., 2023). Franzò et al. (2023) seek to explain the business model innovation process facilitated by advanced digital technology in the energy industry. Zhang et al. (2023) provides an innovative investigation of digitalization in energy storage development. Narayanamoorthy et al. (2023) determined the MCDM model to examine the most appropriate sustainable energy storage system. Reza et al. (2023) review storage integrated grids' uncertainties and modeling approaches. Gupta and Shankar (2022) identify the crucial factor for adopting energy storage systems in the grid. Wang et al. (2024) determine factors that affect public participation in community-shared energy storage projects. Liu et al. (2024) primarily analyzed the energy storage industry's value-added efficiency and influencing factors. Li et al. (2023) analyzed the innovation efficiency of the new energy industry from the perspective of industrial space distribution and obtained the mismatch of R&D resources in most regions, leading to low efficiency. Bulut and Özcan (2024) explore how modern policies affect the energy markets and how the markets shape the policies. Zabihi and Parhamfar, (2025) argued that Smart grid integration of EVs and charging infrastructure, supported by renewable energy and storage systems. They also explore the strategic balance of BESSs in the role of price taker/price maker when it comes to market effect. While the existing body of literature has made significant strides in exploring various aspects of energy storage systems (ESSs) and their integration into energy grids, critical gaps remain needed for further investigation. Existing research lacks an integrated framework that simultaneously links technological, organizational, market, and sustainability factors to energy storage market performance through business model innovation. There is a lack of comprehensive empirical research addressing the energy storage market. There is a need for empirical studies that integrate multiple variables, such as technological advancements, regulatory

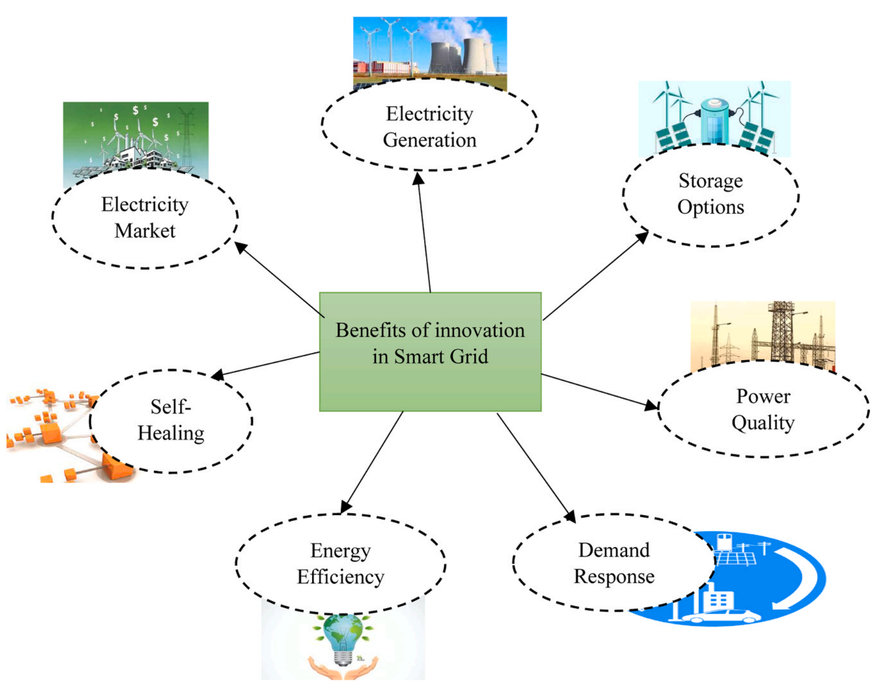

Fig. 1. Benefits of Innovation in Smart Grid.

frameworks, market demand, and economic incentives, to understand better their combined impact on the performance of the energy storage market. Hence, Future research could explore the interrelationship between business models and technology, regional resource allocation strategies, and participatory frameworks to enhance the ESS market. Thus, the research objective for the current study is as follows:

RO1: What factors influence business model innovation in high-end equipment manufacture in the energy storage sector for a sustainable future?

RO2: To conduct an empirical study of the potential factors influencing the performance of the energy storage market.

This study empirically examines the various elements that influence the performance of the energy storage market. The factors impacting business innovation in the energy storage market are evaluated through a review of scholarly research papers, conference proceedings, energy-related websites, and key technical information on storage systems. This research interviewed 184 experts actively exploring grid integration with energy storage systems. The interview material was used to synthesize their perceptions about growth factors in the ES market. This study introduces a novel SEM-based framework that positions business model innovation as a central link between technological, organizational, market, and sustainability drivers and energy storage market performance. It uniquely integrates these dimensions within a single model and provides empirical evidence from an emerging economic context.

1.3. Research contributions

1. This study addresses a key theoretical gap by developing an integrated framework that links technological, organizational, market, and sustainability factors with energy storage market performance through business model innovation, which has been largely overlooked in prior research.
2. Using Structural Equation Modeling (SEM), the study provides robust evidence on the interrelationships among these constructs in a smart grid context. The findings highlight the critical role of BMI in translating strategic and operational capabilities into improved market performance. This contributes to both theory and practice by offering a comprehensive and data-driven perspective in an emerging economy setting.
3. The study offers actionable insights for policymakers, investors, and industry leaders to design forward-looking, innovation-driven business models. These models drive economic growth and support national goals of energy security, reduced carbon footprint, and inclusive development.
4. By bridging theoretical perspectives with practical strategies, the research contributes to the broader societal goal of transitioning towards a cleaner, smarter, and more sustainable energy future.

The following section explains how the paper was organized: Section 2 examines the literature on business model innovation in the electric industry and the energy storage market scenario. The study model and hypothesis structure are explained in Section 3, which illustrates the factors influencing business model innovation in the energy storage market for a sustainable future. Section 4 shows how integrated CFA and SEM approaches were utilized to verify the research model's validity, reliability, and fitness from a questionnaire survey. Sections 5 and 6 contain result analyses and a description of the study model to demonstrate how these factors affect the performance of the energy storage market via business model innovation. Section 7 discusses how it will assist managers and academics, and Section 8 discusses conclusions and future scope.

2. Literature review

This section provides a theoretical background and reviews past studies on the energy storage sector, business model innovation within the energy industry, and the performance of the energy storage market. This comprehensive review aims to contextualize the current landscape and identify key trends and developments. Following this, Section 2.3 addresses the research gaps and outlines the contributions of the current study.

2.1. Theoretical background

India indicated its ambition to target a 33–35% reduction in emission intensity per unit of GDP by 2030, compared to the year 2005, and should also have a target of 40% cumulative non-fossil-fuel-based electric power generation capacity by the year 2030 (GOI, 2015). According to Upreti *et al.* (2018), in India, accessibility issues and troubles of energy insufficiency will lie specifically with the overall transmission setup and are assessed to increase in the following couple of years without appropriate attention. An enhanced automation system must be created to implement Smart Grid (SG) innovations for Indian power systems (Bala et al., 2012). The electrical sector is undergoing significant new developments in the third decade of the twenty-first century, which new business models must support. Energy generation, storage, and global warming are all major topics today, as well as popular research areas in economics and the environment (Olabi et al., 2020). Due to growing concerns about environmental degradation and resource depletion, research into alternate energy sources is receiving global attention. As a result, energy storage could be an essential part of a successful transition from fossil fuels to renewable energy sources (Topalovic et al., 2021). Das et al. (2020) investigate the Indian power sector's attempts to incorporate renewable energy to meet ambitious objectives. However, few studies have addressed the planning, regulations, markets, and contract models required for the Indian electrical industry to implement ESS (Jindal and Shrimali, 2022). Integrating energy storage systems helps balance supply and demand, thereby mitigating issues arising from the intermittent nature of renewable energy sources (Liu et al., 2023). Business modeling has caught the interest of practitioners, developers, and academicians in recent years as it focuses on developing organizational architecture, business activities, financial profits, and social and sustainability issues. To meet the ambitious goals, energy storage technology research, and development have drawn attention to different business models utilized for energy, transportation, electrical, telecommunications, and other industries (Chasin et al., 2020; Kubli and Puranik, 2023; Schwidtal et al., 2023; Sułek and Borowski, 2024).

2.2. Business model innovation (BMI) in the energy industry

According to the literature, looking at innovative performance in the service sector is critical, especially concerning new business models in the energy industry (Hee et al., 2018). To shed light on these ideas and their nomological network, several literature reviews on BMs and BMI have been conducted recently (Shomali and Pinkse, 2016; Chen et al., 2020; Karami and Madlener, 2021; Gupta and Shankar, 2023; Ancillai et al., 2023). Considering business model innovation in the energy domain, the literature has focused on the emergence of modernizations in solar power production, energy value chain, electric vehicle (EV) charging, and energy storage (Karakaya et al., (2016); Hamelink and Opdenakker, (2019)). BMI refers to reconfiguration with certain business model components or developing an entirely new method of providing and capturing value (Massa et al.,2017). Energy management has already seen progress in reducing carbon emissions, increasing energy efficiency, and attaining sustainability (Chen et al., 2020). Therefore, it has been determined that technology and innovation are the main forces behind the current development stage of the electrical industry. Technology innovation and business model innovation (BMI) often go hand in hand. Apart from their technological advantage, smart energy business models gain the benefits of several other factors that are collectively transforming the energy sector, such as decentralized renewable energy production (Midttun and Piccini, 2017; Shomali and Pinkse, 2016), market liberalization, and evolving customer demands (Avancini et al., 2019; Chasin et al., 2020). Also, green technologies are gaining acceptance in technology, business practices, social attitudes, and public policy (Moriarty and Honnery, 2016). Ilieva and Rajasekharan (2018) examines a range of techno-economic variables that affect the energy storage market and pinpoints crucial components that will support the creation of business models for the industry. Olajiga et al., (2024) examines the potential of energy storage technologies in optimizing grid performance, highlighting their effectiveness in improving grid reliability and resilience while reducing operational costs.

These are substantial efforts to learn how new technology can enable new players to compete with established enterprises. These projects show the value of business model research in energy management because they examine how changing business models can affect energy markets positively and negatively. Incremental or radical innovation consistent with business model fundamentals like novelty, complementarities, lock-in, and efficiency improves firm performance in the energy storage sector. Investing in R&D (research and development), management procedures establishing new manufacturing, and enhancing new products and services are all incentives for innovators rather than imitators.

2.3. Energy storage market

Energy storage is key to the global energy transition, enabling the integration of renewable sources and ensuring grid stability. The global energy storage systems market size is calculated at USD 288.97 billion in 2025 and is expanding by around USD 569.39 billion by 2034, with an impressive CAGR of 7.87% from 2025 to 2034. Although the Indian ESS industry is only at the beginning, there are numerous opportunities with a significant market upside. The energy storage market is an extremely diversified subject, ranging from small to large systems. The most frequent forms of energy storage are electrochemical, mechanical, thermal, and chemical energy storage. Table 1 presents a comparative analysis of major battery technologies used in smart grid applications. Due to their ability to store energy in various forms and provide according to end-user needs, energy storage systems have dominated both the renewable and conventional energy markets in recent years. With the huge acceptance of renewable energy, "energy storage" has become more common in recent years. Large-scale energy storage systems are getting more attention for their significant contributions to several aspects of electric networks. Previous studies have shown that a business plan's innovation is often seen as critical in a company's capacity to grow and operate profitably, particularly in emerging industries. Bhola et al. (2023) investigate the local viability and potential of community energy storage (CES) business models. Van der Linden (2006) states that energy storage has the potential to enhance the energy business for greater resource utilization, lower emissions, system efficiency, reliability, stability, and security. Because energy storage technology efficiently resolves the conflict between the power grid and electricity generation. As a result, as a large-scale user of renewable energy, the energy storage business has pressing practical needs (Koohi-Kamali et al., 2013). For a more sustainable future, energy storage appears to be unavoidable. Still, this sector has recently begun to move in the right direction, with small-scale and large-scale applications awaiting their first achievements. This success could be aided by an innovative business model (Hamelink and Opdenakker, 2019).

With ongoing technological advancements and deeper grid integration, the energy storage market is entering a transformative phase expected to accelerate through 2025 and beyond. One of the key trends is the emergence of long-duration energy storage technologies that bridge the gap between intermittent renewable generation and constant energy demand, ensuring greater grid stability. As global supply chains face disruptions, gaining control over the sourcing of raw materials and manufacturing equipment is becoming a strategic priority for ensuring the competitiveness and resilience of battery production. Moreover, supportive policy frameworks and the development of financial instruments such as green bonds and energy storage-as-a-service models are unlocking new avenues for market growth. Finally, integrating AI and advanced digital technologies reshapes business models, enabling smarter energy storage management, predictive maintenance, and real-time grid optimization. Collectively, these trends indicate a robust, technology-driven evolution of the energy storage sector, which is crucial for achieving a more sustainable and efficient energy future.

The energy storage market faces several key challenges. Backup power reliability is limited, especially when transferring electricity back to the grid during outages, potentially affecting grid stability. Additionally, the national grid faces limitations due to the distant power generation location from consumption centers, causing transmission inefficiencies. These challenges hinder the effective marketization and scalability of energy storage systems.

2.4. Relationship between electrical grid and energy storage

Although energy storage operators are independent entities, they typically do not own the generation or transmission infrastructure but operate in coordination with the grid operator (such as an ISO or RTO) to provide energy and ancillary services (Pollitt, 2012). These independent operators participate in electricity markets by buying electricity

Table 1
Comparison matrix of battery technologies in smart grid applications.

Battery technologies	Smart grid application	Key findings	Environmental impacts	References
Lithium-ion (Li-ion)	Grid storage, EV integration, frequency regulation	Widely deployed in grid-scale storage (≈78% of BESS); critical for renewable integration but requires safety and cost improvements	Moderate impact; mining and recycling issues	Choi et al., (2021)
Lead-Acid	Backup power, small-scale grid support	Limited economic viability in smart grids due to frequent replacement and lifecycle issues	High toxicity; recyclable but hazardous	Yang et al., (2024)
Sodium-ion Batteries	Grid-scale storage, renewable integration	Promising alternative with better economic feasibility for large-scale applications	Low impact; abundant, non-toxic materials	Yang et al., (2026)
Flow Batteries (Vanadium Redox)	Large-scale storage, renewable integration	Suitable for grid-scale storage with long cycle life and near-zero degradation, but high capital cost	Low–moderate; long life reduces waste	Phogat et al., (2025).
Nickel-Cadmium (Ni-Cd)	Industrial backup, remote grids	Used in niche applications due to environmental regulations and disposal concerns	High risk due to cadmium toxicity; strict disposal and environmental regulations required.	Taabodi et al., (2025)
Sodium-Sulfur (NaS)	Utility-scale storage, peak shaving	Effective for large-scale applications but operational risks and thermal constraints remain	Moderate; safety and temperature concerns	Sores et al., (2026)
Solid-State Batteries	Future smart grids, EVs	Emerging next-generation solution focusing on safety and performance enhancement	Lower environmental impact potential due to safer materials and reduced leakage risks; still under evaluation due to early-stage development.	Phogat et al., (2025).

when prices are low and selling it back when prices are high, effectively performing energy arbitrage. Additionally, they can contract directly with utilities or grid operators to provide services like peak shaving, spinning reserves, or even backup power during outages. This market-based participation allows independent storage operators to contribute to grid flexibility and resilience without being vertically integrated into the utility system. Their involvement promotes competition, innovation, and cost-effectiveness in the grid's evolution toward a cleaner, more decentralized structure.

The relationship between the electrical grid and energy storage systems (ESS) is fundamentally symbiotic, especially as power systems evolve to integrate higher shares of intermittent renewable energy sources like solar and wind. Energy storage plays a crucial role in maintaining grid stability by acting as both a load and a generator. During periods of excess generation—often when demand is low and renewable output is high—ESS absorbs surplus energy by charging, effectively reducing curtailment of renewable power. This charging and discharging cycle enable load shifting, peak shaving, and energy arbitrage, contributing to more efficient grid operation (Zhang et al.,2025). Moreover, energy storage enhances grid reliability by providing fast-response services such as frequency regulation, voltage support, and spinning reserves. These capabilities are critical for maintaining the real-time balance between supply and demand, which is essential for the stable operation of the grid. As the grid becomes more decentralized and complex, energy storage is a flexible asset that can smooth variability, buffer disturbances, and support the integration of distributed energy resources, making it a cornerstone of the modern, resilient power system.

2.5. Strategic antecedents of business model innovation: in the context of smart grid and energy storage integration"

The proposed research model integrates multiple drivers and outcomes to comprehensively examine business model innovation in the energy storage market, especially within the context of smart grid development. The inclusion of factors such as organizational learning ability (Comlek et al., 2012), technological development (Mori et al., 2016), market competitiveness (Karami and Madlener, 2021), and customer satisfaction (Jones et al., 2021) is essential because these elements represent internal capabilities and external pressures that directly influence a firm's capacity to innovate its business model. Organizational learning enables adaptation and strategic renewal; technological development provides the foundation for product and service innovation; market competitiveness encourages differentiation and value creation; and customer satisfaction drives demand and long-term viability. Additionally, smart grid innovation is included as a contextual factor because it significantly reshapes how energy is generated, distributed, and consumed—creating new opportunities and requirements for storage solutions. The model also considers key performance outcomes—profitability, environmental and social performance, and market performance—to capture the multi-dimensional value generated through business model innovation (Ma et al., 2025; Mori and Zhang, 2024). This holistic approach helps us understand what drives innovation and how it contributes to sustainable and competitive growth in the evolving energy landscape.

2.6. Role of mediating variable

Even though all the antecedents may directly influence energy storage market performance, in this study, business model innovation acts as a mediating variable, which plays a crucial role as a mediator between all the antecedents and market performance. Each antecedent (driver) —technological development, policy and regulation, market demand, competitive pressure, organizational capabilities, environmental concerns, and financial resources—can directly influence performance in the energy storage market; business model innovation (BMI) plays a crucial mediating role. Technological advancements may improve efficiency, but BMI determines how these innovations are commercialized and scaled.

For example, Technological advancements in the energy storage market can directly influence energy market performance, leading to better products, lower operational costs, enhanced customer satisfaction, and more competitive position in the market. However, business model innovation is crucial to technological advancements and market performance. While technological development can improve product performance, business model innovation determines how the technology is deployed, marketed, and monetized. For instance, technological advances have led to new business models like pay-per-use, leasing, or energy-as-a-service, which can expand the customer base and open new revenue streams. A new business model may also help mitigate risks associated with new technologies (e.g., customer adoption barriers and capital costs) and thus accelerate market adoption.

Similarly, Organizational learning ability equips firms to absorb, adapt, and apply new knowledge, but it is through business model innovation (BMI) that this learning is operationalized—by embedding insights into value creation. In increasingly competitive energy markets, BMI allows firms to strategically differentiate themselves through innovative offerings, customer engagement methods, and pricing strategies that go beyond traditional models. Competitive pressure drives firms to innovate their models for differentiation, and strong organizational capabilities support redesigning operations through BMI. Customer satisfaction, while essential, is significantly enhanced when business models are redesigned to provide greater personalization, accessibility, and convenience—fostering deeper loyalty and market traction. Profitability is also strengthened when BMI enables firms to create more efficient cost structures, explore new revenue streams, or shift from product-based to service-based models. Similarly, firms with a sustainability orientation or those aiming to improve social and environmental performance can use BMI to integrate these priorities into the core business strategy by adopting circular economy principles, impact-driven partnerships, or inclusive service delivery models. Ultimately, BMI acts as the strategic bridge that transforms internal capabilities and external pressures into coherent, market-aligned strategies—driving competitive advantage and sustained performance in the energy storage sector.

3. Research hypothesis and model

Exploratory and descriptive research was undertaken to examine the factors influencing the performance of energy storage markets in the Indian context. The exploratory method enabled the classification of characteristics consistent with the existing literature and the identification of specific attributes aligned with established categories. The factors influencing the energy industry's performance vary depending on the technology used and organizational and environmental considerations. The following sections go through each of these elements in greater detail. In addition, Fig. 2. shows the research model.

3.1. Role of organization learning ability in business model innovation in smart grid

Organizational learning is associated with knowledge expansion, which is crucial for a business' capacity for innovation and performance. It is an essential resource for organizational survival and gaining a competitive edge. Various academics have long recognized the importance of learning orientation to total company performance (Slater, 1994). To increase their organizational capacity in acquiring, developing, and combining knowledge assets, several businesses have established departments whose only purpose is to acquire and share information from within and outside the company. Comlek et al. (2012) states that knowledge discovery perspective and system orientation are two aspects of organizational learning capacity that positively influence

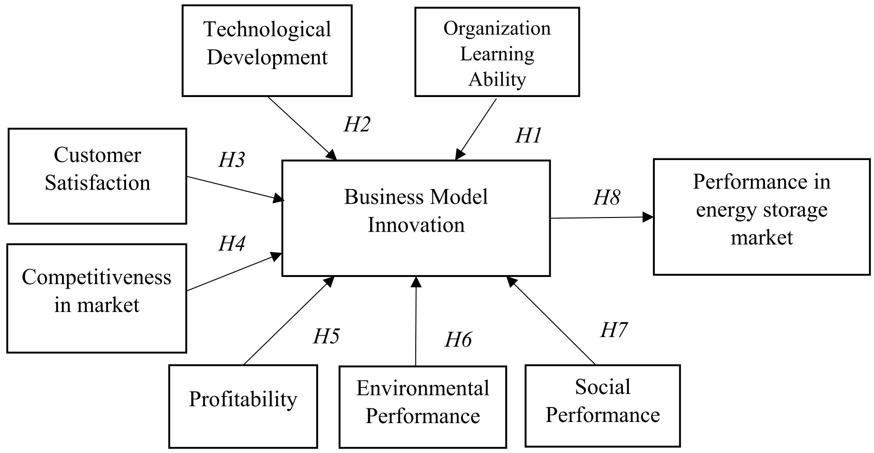

Fig. 2. Research model.

a company's creative performance. The organization's values will improve with learning. As a result, the higher the learning orientation, the better the company's performance. Therefore, the first research hypothesis is expressed as follows:

Hypothesis 1. (H1): Organization learning ability significantly affects business model innovation in the smart grid.

3.2. *Role of technological development in business model innovation in smart grid*

As new technology reconfigures the business model, technological competency is vital in achieving the efficiency of firms in terms of manufacturing process and innovation. It involves a company's ability to create, absorb, adapt, use, and transfer technology (Mori et al., 2016). A company's technical competence helps it produce and deliver innovative products and services more efficiently and effectively that best match customer requirements, enhancing the success of innovation and performance. Many studies claim that technological advancements have an impact on corporate performance. These technologies are "methods and designs for transferring matter, energy, and information from one state to another in pursuit of a goal or goals in the context of the system's changing technical architecture, particularly if massive volumes of variable renewables are integrated" (Taylor and Helfat, 2009). The second research hypothesis, based on literature and theory, is:

Hypothesis 2. (H2**)**: Technological development significantly affects business model innovation in the smart grid

3.3. *Role of customer satisfaction in business model innovation in smart grid*

Understanding consumers' expectations and behaviors is critical in a smart grid because it is at the core of the energy market's evolution. Satisfied customers utilize new business models, whereas entrants employ business models to attract new customers (Bohnsack et al., 2014). Each consumer group should be explained in terms of the type of relationship a firm should establish. The public's opinions about technology are related to acceptance and adoption intentions. Jones (2021) contends that social support is important for Grid-scale electrical energy infrastructure. A European Environment Agency (EEA) also stated that energy consumer preferences will impact new technology acceptance. Customer satisfaction with energy storage could play a big role in determining how much of it is deployed in the future (Hamelink and Opdenakker, 2019). Thus, the third hypothesis examines smart grid consumer satisfaction and innovation & it is written as follows:

Hypothesis 3. (H3): Customer satisfaction significantly business model innovation in the smart grid

3.4. *Role of competitiveness of market in business model innovation in smart grid*

Competitive pressures in any firm have pushed business model innovation to the top of CEOs' priority lists for improving performance. Business models allow new firms to commercialize innovative ideas and innovations at the initial stage. Secondly, businesses might see their innovative model as a source of growth or competitive advantage (Karami and Madlener, 2021). For businesses to continue investing in innovation, they need to see a return on their money. When it comes to overall cost, storage systems must be cost-competitive with analogous non-storage options that are accessible to electric utilities. This includes considering the costs of installing and integrating the system and the prices of all the subsystem components. Integrating storage to compete with standard options for quicker flexibility response assistance would be challenging because of the high cost of RE-integrating technologies (Das et al.,2020). Accordingly, the effect of market competitiveness on business model innovation in the smart grid is proposed as follows:

Hypothesis 4. (H4): Market competitiveness significantly affects smart grid business model innovation.

3.5. *Role of profitability in business model innovation in smart grid*

It is well understood that a firm's value can be maximized by reducing its capital expenditure. Financial performance is considered an important factor in determining a business's success. Evaluating the firm's productivity, profitability, and market premium performance is critical (Omondi and Muturi, 2013). The most popular indicator for measuring firm performance is profit maximization through more efficient and effective resource utilization (Arifin, 2019). Energy storage should be valued for providing multiple benefits at once. For ESS to be used on a big scale, it must conduct a comprehensive and methodical analysis of its costs and benefits, offering utilities and consumers immediate advantages (Liu et al., 2020). Considering the literature and theory reviewed, the following is how the fifth research hypothesis is expressed:

Hypothesis 5. (H5): Profitability significantly affects business model innovation in smart grid

3.6. *Role of social performance in business model innovation in smart grid*

The energy storage business is in its early development stages, and some systematic solutions are to be developed. Also, social and economic forces like electricity producers, power grids, and consumers must be invited to be involved in business innovation. Corporate social performance is an important aspect of corporate success that has received little empirical attention. Enduris claims that business model innovation has resulted in a highly socially responsible business model and increased social performance. Human interactions and relations are the basis of society. Numerous studies in other fields also indicate the importance of public opinion or social behaviors (Chapman and Hewitt-Dundas, 2018; Park, 2019). Therefore, the sixth hypothesis is stated as follows:

Hypothesis 6. **(**H6): Social Performance significantly affects business model innovation in smart grid

3.7. Role of environmental performance in business model innovation in smart grid

External elements that present constraints and opportunities for technical improvements are referred to as the context in which business is conducted. It's the awareness to analyze the relationship between human activities, environmental quality, and the commitment to cut carbon emissions (Mei et al., 2016). According to Yenneti (2016), socio-environmental concerns, disputes over shared property resources, social inclusion, and the influence on people's livelihoods are essential for solar project success. Several different factors can either encourage or discourage innovation. These factors include the regulatory environment, the industrial structure, the customer relationships, demands from external stakeholders, and competitive pressure. In addition, Gupta and Gupta (2021) propose that environmental practices and performance outcomes have a direct relationship. As a result, the seventh hypothesis that may be derived from this model is developed as follows:

Hypothesis 7. (H7): Environmental Performance significantly affects business model innovation in smart grid

3.8. Role of business model innovation in improving the performance of energy storage market

Introducing a fundamentally changed business model within an existing business model is known as business model innovation (Markides, 2006). Velu (2015) claims that BMI is critical for organizational transformation and business renewal. Organizations' competitive positions and chances of survival appear to be influenced by business model innovation. It requires recognizing and applying fundamentally distinct types of value capture, value proposition, and value generation on an existing firm. According to Anwar (2018), enterprises seek competitive advantage using various resources in today's globalized and dynamic market. Previous research has found that business plan innovation is often considered a significant factor in a firm's ability to continue operating successfully and prosper, especially in developing sectors. Therefore, the proposed hypothesis is written as follows:

Hypothesis 8. (H8): Business model innovation significantly impacts growth in the performance of the energy storage market

3.9. Performance of energy storage market

Many empirical studies have concluded that innovation is the most important determinant of firm performance (Mone et al., 1998). According to Gronum et al. (2016), business model innovations consist of various variables that significantly influence organizational performance when implemented into a business model developed on certain value themes. Firms must develop an innovative business model for a competitive edge and greater financial performance (Anwar, 2018). Santos and Brito (2012) defined firm performance as the satisfaction of a company's activities in terms of market value, financial growth, profitability, employee and customer satisfaction, environmental performance, and social performance.

4. Research methodology

Fig. 3 provides a research framework for improving the performance of the energy storage market with the help of integrated methodologies of CFA and SEM. The data used in this study was obtained from an online questionnaire sent out to several professionals with an extensive understanding of the power business and the energy storage sector. There are nine different factors included in the research model. Each aspect was assessed using multiple items from the questionnaire. The growth of performance for the energy storage business through innovation in the grid industry was assessed using a "confirmatory factor analysis" (CFA) technique and a "structural equation modeling" (SEM) approach. This research employed a seven-point Likert scale since it is easy to use, more accurate, and better represents a respondent's real assessment (Likert, 1932; Finstad,2010). Earlier academics also considered the seven-point scale the optimum option for surveys requiring usability assessments (To and Ngai, 2006; Tiwari and Suresha, 2021). The questionnaire form for each item was rated on a seven-point Likert scale, with one being strongly disagreed with and seven strongly agree. The notations are (1) for "strongly disagree," (2) for "moderately disagree," (3) for "slightly disagree," (4) for "neutral," (5) for "slightly agree," (6) for "moderately agree," and (7) for "strongly agree." SPSS-AMOS was used to test structural equation models using observed data. This methodology investigates the linear structural relationships that exist between latent constructs (factors) in path models that are either recursive or non-recursive.

4.1. Data collection

Quantitative methods were employed for research. Following a thorough examination and review of the criteria, the contents of the questionnaire were carefully developed. This questionnaire has 33 questions about nine criteria evaluated in expert interviews, as illustrated in (Appendix A). At the time, various researchers, academics, and industry professionals from the power and energy storage industries were interviewed. In this study, expert opinions are employed to develop vital information about the performance of the energy storage sector. The questionnaires were gathered from experts, high-ranking government officials, industry representatives, researchers, and academics working in India's power sector. They were given nearly 250 questionnaires, but only 184 were completed and returned. The real effective return rate was 73.57 % since eight surveys were returned as invalid. To further understand the link between ESS organization performance and innovation, data was analyzed using AMOS-SPSS 20.

This study focuses on people with extensive industrial and educational experience and a good mix of genders. Individuals from various age groups, ranging from 20 to 60 years old, were surveyed. There were 57 replies from the private sector, 45 respondents from the public sector, 25 respondents from government organizations, and 57 respondents from academia among the 184 respondents. These respondents comprise industry professionals (from energy utilities and renewable firms), government and policy representatives, academic researchers, technology specialists in smart grids and digital systems, financial and investment analysts, as well as consultants and industry experts. This diverse composition enables the study to capture a wide range of perspectives related to operational performance, policy frameworks, technological advancements, and market dynamics in the energy storage sector. The demographic details of the data sample are described below in Table 2.

4.2. Confirmatory factor analysis (CFA)

A CFA will often include one of its components as an estimate of an a priori measurement model. In this model, the observable variables are mapped into the latent constructs by referring to both theory and the results of the previous testing. The CFA is a multivariate statistical analysis for measuring variables that accurately represent the number of

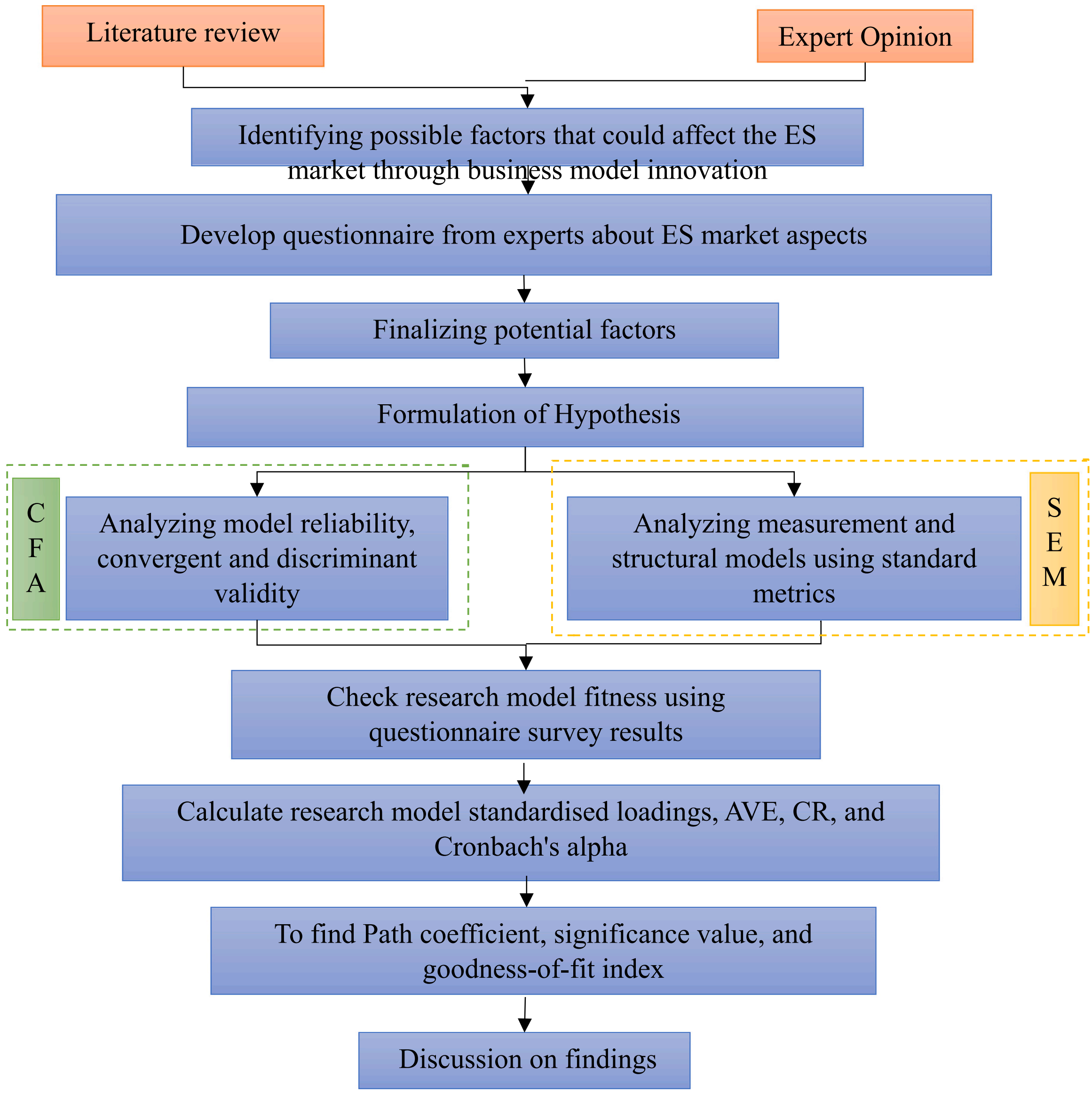

Fig. 3. Research framework for improving the performance of the Energy storage market.

latent constructs. CFA provides a more thorough investigation of convergent and discriminant validity than the more conventional multitrait-multimethod analysis (Campbell and Fiske, 1959). It's used to confirm the factor structure of several observable variables. CFA will be evaluated to see if it has convergent and discriminant validity. Convergent validity testing determines if items can adequately represent their associated component by assessing their correlation. Discriminant validity, on the other hand, is used to identify statistical discrepancies between two components (Fornell and Larcker, 1981). CFA will confirm the validity of the model by giving standardized item loadings, composite reliability (CR), average variance extracted (AVE), and internal consistency (Cronbach's alpha values) for each value. Eq. 1 shows how to carry out the average variance:

$$\mathrm{AVE} = \frac{\sum \lambda\hat{}2}{n} \tag{1}$$

The following Eq.2 calculates composite reliability:

$$\mathrm{CR} = \frac{(\sum \quad \lambda)\hat{}2}{(\sum, \quad \lambda i \quad)\hat{}2 + \sum(\varepsilon i)} \tag{2}$$

Where (λ) represents standardized loading for corresponding item *i*

ε indicates the value of the error variance observed for item '*i*'

'n' represents the number of values that have been observed in a certain latent variable

And Eq. 3 estimates error variance:

$$\varepsilon i = \quad 1 \quad - \quad \lambda i2 \tag{3}$$

4.3. *Structural equation modeling (SEM)*

It is a multivariate statistical technique that explains how several unobserved variables relate (Markus, 2012; Hair et al.,2010). SEM seems more of a confirmatory methodology than an exploratory one (Kline, 1998; Kanungo and Savla, 2005). Since it is mostly dependent on covariance analysis, it demonstrates the degree of relationship between variables and the degree of variability within those variables (Kline, 2005). The following characteristics of SEM have been emphasized in earlier research (Kline, 2005; Hair et al., 2010): (1) It has the potential to estimate several numerous and connected connections. (2) It can calculate measurement errors and designate latent ideas in dependent connections; (3) It can construct a model that can compute all the different sets of relationships. The SEM method includes evaluations of multiple regression and maximum likelihood estimates. It includes

Table 2
Demographic distribution of the sample.

Items	Gender	N	Percentage (%)
Gender	Male	118	64.13
	Female	66	35.87
Age	20–30	42	22.82
	30–40	57	30.97
	40–50	47	25.54
	Above 50	38	20.65
Qualification	Secondary	-	-
	Graduate	60	32.60
	Postgraduate	66	35.86
	Higher Education	58	31.52
Organization	Public	45	24.45
	Private	57	30.97
	Other Organization	25	13.58
	Academics	57	30.97
Year of Experience	< 5 years	42	22.82
	5–15 years	58	31.52
	15–25 years	60	32.60
	> 25 years	24	13.04
Knowledge about BMI and ES Industry	Excellent	47	25.54
	Good	77	41.84
	Average	38	20.65
	Below average	22	11.95

factor analysis, regression, and route analysis. SEM includes computation and structural models. This model considers interrelationships between variables and survey questions (indicators) that measure attributes. Using structural equation modeling, researchers may examine how accurately the observable variables will represent latent (unobserved variables) constructs. The structural equation model (SEM) establishes the proposed structure mathematically and investigates causal relationships among latent factors.

This study uses CFA and SEM to evaluate the respective measurement models used. Once the fit indices value for the research model has been obtained, the path model may be developed to test the proposed hypothesis (Gowen et al., 2006). The relationships between hidden constructs are explained using a path model. The validity and applicability of the path model may be assessed using the model fit indices, significance value, and direction of estimated parameters. Table 3 lists the threshold value for several SEM fit indices.

5. Results

5.1. Classic assumption test

Before proceeding with further analysis, it is essential to examine normality, multicollinearity, and the presence of outliers. Descriptive statistics for each measured variable are presented in Appendix B (1). The inspection of the data revealed that there were no outliers, unengaged replies, or missing values. Here, no value was found to be missing in datasets, so the data was evenly spread across all variables. Normality of the data set was assessed using skewness and kurtosis measures derived from descriptive statistics. The maximum absolute value for skewness is 1.873, and for kurtosis, 5.866, respectively, for the measured variables. Hair et al. (2010), Byrne (2010), and Eckstein et al. (2015) all argue that for univariate statistics, skewness should be between −2 and + 2, and kurtosis should be between −7 and + 7. Based on the results, the normality assumption is considered satisfied. Subsequently, linear regression analysis is employed to assess multicollinearity in the research model by identifying correlations among the independent variables. Here, SPSS was used for a regression analysis to check for multicollinearity. The models had a maximum VIF (variance inflation factor) of 3.237 (Threshold <5), so there won't be any significant issues with multicollinearity (Hair et al.,2010). So, it makes sense to keep all the latent constructs. Also, Harman's single-factor method is used to investigate the problem of common method bias (Harman, 1976; Podsakoff and Organ, 1986). Exploratory factor analysis (EFA) is used with this method by considering all the measurement items in the model. The results of EFA show that the first factor explains 38.73'% (i.e., having a threshold value less than 50%) from total variance. This means that "common method bias" (CMB) does not exist in the sample data. Therefore, it is unlikely that common method biases have affected the results of the statistical analyses. Finally, to test non-response bias, early and late waves of returned surveys were compared following the approach suggested by Armstrong and Overton (1977). Here, *t*-tests in this case do not reveal any statistically significant differences between the early and late groups, indicating that non-response bias was not a concern. (Appendix B (2)).

Table 3
The threshold value for fit indices of SEM.

Fit indices	Threshold value	References
Chi-square to degree of freedom ratio (Chi^2/ df)	< 3	(Anderson and Gerbing, 1988; Kaynak and Hartley, 2006, Shah and Ward, 2007)
Goodness of Fit indices (GFI)	> 0.90	(Moon et al.,2012; Kaynak and Hartley, 2006)
Adjusted Goodness of Fit indices (AGFI)	> 0.80	(Gowen et al., 2006; Moon et al., 2012)
Comparative Fit indices (CFI)	> 0.90	(Kaynak and Hartley, 2006; Moon et al., 2012)
Non-Normed Fit Index (NFI)	> 0.90	(Kaynak and Hartley, 2006; Shah and Ward, 2007)
P close	> 0.05	(Gowen et al., 2006)
Root-mean-square error (RMSEA)	< 0.08	(Kaynak and Hartley, 2006; Shah and Ward, 2007)

5.2. Measurement model, validity and reliability

Anderson and Gerbing's (1988) two-step technique was employed to assess the validity and reliability of the model. The structural model was then tested to see if the research hypothesis and model fitness could be validated. The first step is to analyze validity using SEM and CFA by the software SPSS-AMOS 20, which covers both convergent and discriminant validity. Testing for convergent validity involves determining whether the items that comprise a latent variable (factor) can accurately represent their respective components. The purpose of conducting a discriminant validity test is to determine the statistical difference between one variable and another variable. Fornell and Larcker (1981) state that the composite reliability (CR) should be larger than 0.7, and the average variance extracted (AVE) must be greater than 0.5. Table 4 displays all the standardized loadings, the composite reliability (CR) value, the average variance extracted (AVE) value, and the Cronbach's alpha value. The measured model has strong convergent validity as each value of the AVE exceeds 0.5 and CRs exceeds 0.7. All extracted components' Cronbach's alpha values are higher than 0.7, suggesting strong internal consistency.

To validate the discriminant validity test, factor correlation coefficient values are compared with the square root of the AVE. Specifically, the square root of the Average Variance Extracted (AVE) for each latent construct was compared to the correlations between latent constructs to assess discriminant validity. The measured model demonstrates strong discriminant validity, as the square root of the average variance extracted (AVE) exceeds the correlation coefficients, consistent with the criteria proposed by Fornell and Larcker (1981). The correlation coefficient, r, is evaluated on a scale of −1–1. Table 5. shows the results for these discriminant validities.

Table 4
Standardized item loadings, AVE, CR, and Cronbach's alpha.

Factors	Items	Standardized loadings	AVE	CR	Alpha
Organization Learning Ability	OLA1	0.92	0.835	0.938	0.938
	OLA2	0.95			
	OLA3	0.87			
Technological development	TD1	0.93	0.842	0.955	0.954
	TD2	0.92			
	TD3	0.92			
	TD4	.90			
Customer satisfaction	CS1	0.89	0.806	0.943	0.942
	CS2	0.91			
	CS3	0.93			
	CS4	0.86			
Competitiveness in market	CM1	0.91	0.748	0.922	0.930
	CM2	0.85			
	CM3	0.92			
	CM4	0.77			
Profitability	PR1	0.84	0.712	0.881	0.881
	PR2	0.83			
	PR3	0.86			
Environmental Performance	EP1	0.91	0.828	0.951	0.950
	EP2	0.92			
	EP3	0.91			
	EP4	0.90			
Social Performance	SP1	0.85	0.775	0.932	0.932
	SP2	0.91			
	SP3	0.87			
	SP4	0.89			
Business Model Innovation	BMI1	0.71	0.614	0.864	0.848
	BMI2	0.81			
	BMI3	0.81			
	BMI4	0.80			
Performance in ES market	PF_ESM1	0.87	0.752	0.901	0.899
	PF_ESM2	0.82			
	PF_ESM3	0.91			

Table 5
Result of discriminant validity test.

	OLA	TD	CS	CM	PR	EP	SP
OLA	***0.913***						
TD	0.342	***0.917***					
CS	0.371	0.454	***0.897***				
CM	0.402	0.367	0.528	***0.864***			
PR	0.365	0.349	0.487	0.520	***0.843***		
EP	0.405	0.265	0.374	0.381	0.325	***0.909***	
SP	0.151	0.185	0.255	0.191	0.257	0.213	***0.880***

5.3. Structural model results

Secondly, AMOS-SPSS 20 was utilized to perform structural equation modeling on the proposed model. Table 6. lists all the path coefficients for relevant hypotheses and their significant p-values (Note: $^{**}p < 0.001$, $^{*}p < 0.005$). The study model supports all eight hypotheses from H1 to H8. Table 5 shows the research model's actual values. Chi2/df stands for the "Chi-square to degree of freedom ratio," GFI stands for "Goodness of Fit Index," CFI stands for "Comparative Fit Index," AGFI stands for "Adjusted Goodness of Fit Index," NFI stands for "Non-Normed Fit Index," and RMSEA stands for "Root Mean Square Error of Approximation." Table 7 shows that all fit indices are near suggested levels, implying that the research model is a good fit. Except for the GFI value, all indices values have a true range above the prescribed thresholds, but according to Greenspoon and Saklofske (1998), the value between range ($0.8 < GFI<0.9$) also fulfills the acceptable fit model.

Seven hypotheses related to business model innovation—stemming from organizational learning ability, technological development, customer satisfaction, market competitiveness, profitability, environmental performance, and social performance—were confirmed, leading to the eighth hypothesis concerning the overall performance of the energy storage market. Fig. 4. depicts the completed research model and the values of its path coefficients. These coefficients represent the strength and direction of the relationships between each independent and dependent variable. The higher the standardized path coefficient, the stronger the influence of that indicator on Business Model Innovation (BMI) and the performance of the energy storage market. The indicators were ranked in descending order based on their standardized coefficients to emphasize their relative importance. According to the findings, profitability plays a crucial role in driving the performance of the energy storage industry, followed by market competitiveness, technological advancement, organizational learning capability, customer satisfaction, environmental performance, and social performance. These elements positively impact the energy storage market's performance through grid innovation.

The findings confirm that business model innovation (BMI) serves as a significant mediating mechanism between organizational, technological, and strategic factors (OLA, TD, CS, CM, PR, EP, and SP) and firm performance (PF_ESM). All antecedent variables exhibit a positive and significant influence on BMI, indicating their role as key enablers of business model transformation. In turn, BMI demonstrates a strong and significant impact on PF_ESM ($\beta = 0.757$, $p < 0.001$), highlighting its critical role in translating firm capabilities into performance outcomes. This suggests that the effect of these antecedents is not direct but is channeled through BMI, which reconfigures value creation and delivery processes. Therefore, BMI acts as a higher-order capability that bridges firm resources and performance, reinforcing its central role in achieving

Table 7
Model fit values.

Fit indices	Recommended values	Actual values obtained	Interpretation
Chi^2/ df	< 3	1.260	Excellent
GFI	> 0.90	0.843	Acceptable
AGFI	> 0.80	0.809	Excellent
CFI	> 0.90	0.978	Excellent
NFI	> 0.90	0.904	Excellent
P close	> 0.05	0.988	Excellent
RMSEA	< 0.08	0.038	Excellent

Table 6
Path coefficients and P- significance value.

Hypothesis	Path	Path Coefficient		P- Significance value	Decision
		Unstandardized	*Standardized*		
H1	OLA → BMI	0.105**	.183	.000	Supported
H2	TD → BMI	0.114**	.201	.000	Supported
H3	CS → BMI	0.103*	.166	.004	Supported
H4	CM → BMI	0.166**	.205	.000	Supported
H5	PR → BMI	0.220**	.289	.000	Supported
H6	EP → BMI	0.089*	.148	.004	Supported
H7	SP → BMI	0.085*	.146	.002	Supported
H8	BMI → PF_ESM	0.116**	.757	.000	Supported

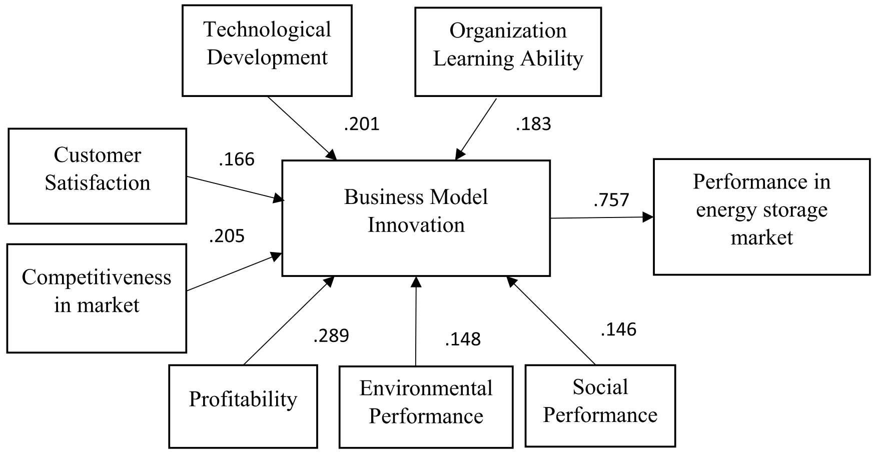

Fig. 4. Standardized path coefficient research model.

sustainable and resilient outcomes. These findings highlight the critical importance of aligning technological and organizational capabilities with business model transformation."

The overall performance of the energy storage market is in terms of market growth, profitability, and ROI. The significant positive relationship shows that innovation in business models improves ESS market performance, indicating better value creation and competitiveness. It reflects the increasing adoption of ESS technologies over the last five years, highlighting sustained market growth and expansion. Additionally, it indicates that profitability has improved with smart grid innovations, suggesting higher efficiency and better return on investment (ROI). Overall, the findings imply that business model innovation and smart grid advancements contribute not only to technological adoption but also to stronger financial performance and market expansion.

6. Discussion and findings

The model comprises 561 different sample moments and 462 ° of freedom. All indicators specified to their common factors in this study model have a high standardized factor loading. The related tables provide all the analytical results for the study model. The proposed model has strong convergent and discriminant validity; the findings for validity parameters are provided in Tables 2 and 3. Table 4 shows that all hypotheses were significant. The table contains regression estimates for standardized and unstandardized path coefficients and their significant value. Positive path coefficients are present in all path coefficients. The results indicate that profitability is an important factor in improving the energy storage market's performance, followed by competitiveness in the market, technological development, organizational learning ability, customer satisfaction, environmental performance, and social performance. The findings suggest enterprises should consider their environmental performance to detect consumer needs and competition by exploring new marketing opportunities and business models. The results of this research model imply that the parameters listed in Table 6 for the fit indices are appropriate. From Fig. 4. profitability is a very important factor for improving performance in the energy storage market through innovation in a grid structure, followed by competitiveness in the market, technological development, organization learning ability, customer satisfaction, environmental performance, and social performance. All these factors positively impact on the performance growth of the energy storage market. The results of SEM analysis are as follows: (1) Profitability influences business model innovation in the power industry; therefore, the advantages of storage systems in smart grids and their long-term financial benefits are vital for the sector's social marketing and performance. (2) Market competitiveness positively affected business model innovation in the electricity sector, demonstrating that cost competition in the industry and customer interactions affect future demand and investment returns. (3) Technological development positively impacts business model innovation in the power industry as it allows solving complicated problems and developing new solutions while considering the varied viewpoints provided by knowledge usage. (4) Organizational learning ability positively impacts business model innovation in the power industry because it aids in creating, retaining, and transferring knowledge inside an organization, which improves over time as it acquires experience. (5) Customer satisfaction positively impacts business model innovation in the power sector, as it is an important indicator that predicts business growth and revenue generated through innovative technology (energy storage). Also, it's a crucial component of a business's objectives for retaining consumers. (6) It is essential to evaluate CO2 emission savings from the environment since they are connected to pro-environmental behaviors because environmental performance will strongly influence business model innovation in the power industry. (7) Finally, social performance pressure has positively impacted business model innovation in the power sector because social confidence is an important factor for deploying any new technology to achieve sustainable energy systems with greater acceptance of energy storage technologies. As a result, studying these causal links assists us in properly comprehending and identifying crucial elements related to the innovation of new technology, which in turn aids in enhancing the ESS market.

The findings indicate that business models emphasizing profitability, technological advancement, and market competitiveness are most effective in the energy storage sector. Specifically, models emphasizing value-added services through smart grid integration, performance-based contracting, and customer-centric innovation are preferred, as they align economic viability with technological progress and user engagement. In terms of technology, advanced battery systems, intelligent energy management platforms, and grid-interactive storage technologies are key enablers. Consumer response is expected to be positively influenced by improved service reliability, lower energy costs, and participation in demand-side programs. The social marketing benefits of promoting long-term financial gains from storage systems will enhance consumer awareness and adoption. Table 8 summarizes how each factor drives specific business model preferences, technologies needed and expected consumer outcomes. Thus, the study demonstrates that in the smart grid-driven energy landscape, performance gains are 'unlocked' not merely through technological advancement, but through business model innovation that aligns these capabilities with market and sustainability objectives."

6.1. *Strategic implications of business model innovation for shaping energy futures*

This study plays a significant role in understanding how business

Table 8
Business models, technologies, and consumer impact.

Factor	Preferred business model	Technologies needed	Stakeholder-specific outcomes (India Context)
Profitability	- Energy-as-a-Service (EaaS) - Pay-per-use or leasing models	- Battery Energy Storage Systems (BESS) - AI-driven energy optimization platforms	- Distributed Storage Integrators: Reduced capital burden, scalable deployment - Financing Institutions: New financing models and revenue streams - Consumers (urban & rural): Lower upfront costs and affordable energy access
Market Competitiveness	-Dynamic pricing models - Platform-based energy trading	- Smart meters - Blockchain for P2P trading	Grid Companies (DISCOMs): Better demand-side management - Energy Startups/Platforms: Growth in P2P trading ecosystems - Regulators: Need for transparent and competitive pricing frameworks
Technological Development	Innovation-driven models (e.g., R&D partnerships, tech incubators)	- Grid-integrated storage - Advanced forecasting and control systems	Grid Operators: Improved grid stability and flexibility - Tech Providers: Increased demand for advanced solutions - Policymakers: Encouragement of domestic innovation and "Make in India" initiatives
Organizational Learning	Adaptive and collaborative models - Knowledge-sharing networks	- Internal digital platforms - CRM and ERP systems with learning analytics	Energy Firms: Improved strategic decision-making - Integrators: Faster adaptation to regulatory and market changes - Consumers: Better service quality and responsiveness
Customer Satisfaction	- User-centered models - Bundled services (storage + maintenance + insights)	- Mobile apps for energy use tracking - Personalized energy management tools	- Service Providers: Higher customer retention and engagement - Consumers: Ease of use, transparency, and trust - Digital Platforms: Expansion of smart energy services
Environmental Performance	Green energy models - Carbon-credit integrated offerings	- Renewable integration tech - Carbon tracking software	- Policymakers: Progress toward net-zero and sustainability goals - Energy Firms: Participation in carbon markets - Society: Reduced emissions and cleaner energy adoption
Social Performance	Inclusive business models (targeting rural/low-income groups)	Decentralized mini-grid systems - Low-cost battery tech	- Government & NGOs: Rural electrification and energy inclusion - Startups: Opportunities in decentralized energy markets - Communities: Improved energy access and socio-economic development

model innovation (BMI) are important in the energy storage sector and responds to future energy market. Energy futures—deals with financial derivatives, predicting future energy prices and strategic anticipations of long-term energy transitions—to adapt their models and operations to future-oriented uncertainties and opportunities. This research contributes by identifying the critical enablers driving innovation in business models and highlighting their implications for the evolution of the energy market in India.

Firstly, profitability, identified as the most influential driver in this study, is closely linked to energy futures. Energy futures markets provide forward pricing signals that help storage providers and utilities forecast revenue streams, manage investment risks, and determine the financial viability of long-duration storage projects. The importance of aligning future pricing expectations with innovative service offerings is emphasized by demonstrating how profitability influences business model decisions, including energy-as-a-service (EaaS), time-of-use arbitrage, and shared ownership. These models depend on predictable long-term returns, which are shaped by expectations in energy futures markets. Secondly, market competitiveness reflects the increasing liberalization and decentralization of the electricity market, where energy futures inform bidding strategies, peak load planning, and infrastructure investment decisions. Consequently, the results provide a roadmap for designing adaptive business models capable of remaining viable across diverse future energy price scenarios. Thirdly, technological development is a response to and a determinant of energy futures. Emerging technologies such as grid-scale battery storage, AI-powered energy management, and blockchain-enabled peer-to-peer trading are creating new possibilities for energy futures trading and real-time market operations. The study demonstrates that firms must innovate to address current needs while remaining relevant in a future characterized by digitalized, decarbonized, and decentralized energy systems. By linking these innovations to practical business models, the research highlights how technology adoption today establishes the foundation for future energy strategies.

Moreover, organizational learning and customer satisfaction are crucial to navigating and capitalizing on future energy market shifts. Firms that build internal capabilities for sensing market trends and rapidly innovating in response are better positioned to benefit from long-term transitions, such as the shift to prosumer-based grids or dynamic pricing regimes informed by futures markets. Additionally, ensuring high customer satisfaction through transparent, affordable, and sustainable services will be essential to foster public trust in future-facing energy systems. Finally, by incorporating environmental and social performance into the business model innovation framework, this study aligns with the broader objectives of energy futures, which are increasingly influenced by sustainability targets, ESG compliance, and principles of a just transition. The results imply that future business models must be economically viable, socially inclusive, and environmentally resilient—key pillars of long-term energy planning and policy.

Hence, this study contributes to shaping energy future thinking by offering a multi-dimensional view of the factors determining business models' success in a rapidly evolving energy ecosystem. It enables stakeholders to bridge current capabilities with future needs, ensuring that innovation today leads to sustainable, profitable, and inclusive outcomes in tomorrow's energy sector.

7. Theoretical and managerial implications

Building information modeling is considered a revolutionary discovery in the electricity industry. This model demonstrates how these variables may positively or negatively impact the expansion of the energy storage market in the power sector and figure out how to capture the prospects of a sustainable future. The industry can help to revitalize the value of the energy storage sector through the factors that influence business model innovation. This study helps to identify how businesses may utilize their business models to commercialize ideas and technology while also profiting by providing value to their consumers. Also, to achieve continuous development in the storage market and realize business model innovation, it is crucial to strengthen the organization's learning ability as per employee satisfaction, discover how to manage customer satisfaction, control technology development to create maximum profitability at low-cost investment, adapt to the ever-changing external environment. The energy storage markets must examine several impacting factors to reduce cognitive biases. Firms should leverage the advancement of information and technology to increase efficiency and effectiveness. These results give important guidelines and suggestions for enhancing the performance of the energy storage market through innovation in business models. Furthermore, the market should focus on cultivating its employees' innovation capability and consciousness. The market should examine the internal and external factors influencing an industry's business model innovation. According to the managerial perspective, the electricity service provider should focus on generating profitability of innovative models considering market competitiveness, technological development, organizational learning ability, customer satisfaction, environmental performance, and social performance to improve energy storage market performance. They must also grasp how storage improves renewable energy systems and smart appliances.

8. Conclusion

This paper helps managers to understand why business innovation is considered important for the energy storage sector and how it helps grow the market by reducing obstacles to renewable energy consumption, benefiting the economy and the environment. The paper's outcomes support the idea that innovations conducted in firms have a positive significance in improving performance. Business model innovation has a major impact on company performance, making it an essential invention for the energy industry. Growth plans need innovation to enter new markets, increase market share, and gain a competitive edge. Companies have begun to recognize the significance of innovation because of increased competition in global marketplaces. Upgrading the power sector is considered a remarkable innovation that is contributing to ESS market growth. As a result, knowing the variables influencing the growth of the energy storage industry is becoming increasingly critical for businesses interested in constructing more efficient grid systems. This research aimed to answer questions about which factors are critical for business model innovation in smart grids and how these aspects affect the performance of the energy storage industry. In this article, a structural model comprising numerous factors influencing the performance rate of an ESS market is empirically tested. As it enables academics to use cutting-edge data in their research, structural equation modeling is helpful. CFA is applied to assess the validity and reliability of the research model. Meanwhile, SEM is used to determine whether a model is suitable for its intended purpose and to validate the underlying premise of the model. This model gives empirical insights into how these factors might affect business model innovation and the expansion of the energy storage sector, both favorably and adversely. This study's findings may apply to various economies and regulated companies. Understanding the precise nature of innovations will assist organizations in prioritizing market and technological strategies, which a suitable action plan will follow. From a theoretical perspective, the study extends the literature by empirically validating the interconnected role of strategic, operational, and social factors in shaping energy sector innovation. Practically, it provides a roadmap for stakeholders to prioritize investments and policy measures that support BMI for long-term energy sustainability.

8.1. Limitations and future scope

The study incorporates respondents from diverse stakeholder groups, each contributing distinct perspectives to ensure a comprehensive analysis. Industry professionals provide practical insights into operational performance and implementation challenges, while government and policy respondents offer an understanding of regulatory frameworks and market development. Academic respondents contribute theoretical and analytical perspectives, and technology experts highlight advancements in smart grid and energy storage technologies. Financial respondents provide insights into investment feasibility and risk assessment, whereas consultants and industry analysts offer strategic and cross-sectoral viewpoints. Together, these perspectives enable a holistic understanding of the factors influencing energy storage market performance. Although the study includes respondents from diverse stakeholder groups, their views may not fully represent all key decision-making entities influencing the Indian energy storage market. In particular, the representation of higher-level policymakers and emerging private sector innovators may be limited. Therefore, the findings should be interpreted with caution, and future studies are encouraged to include a broader and more targeted sample of decision-makers. Futhermore, the geographic scope is limited to India, which may restrict the generalizability of the findings to other countries with different regulatory, economic, and technological environments.

Future research can build on this work by including longitudinal data, exploring region-specific regulatory impacts, or integrating consumer behavior more directly into the model to assess adoption and usage of storage technologies. Building on the strong mediating role of business model innovation observed in this study, future research can explore several promising directions. First, the inclusion of moderating variables such as regulatory support, firm size, and market maturity may provide deeper insights into the conditional effects of BMI on performance. Second, longitudinal studies are needed to capture the dynamic evolution of business model innovation and its long-term impact on performance outcomes. Third, given the relatively strong influence of profitability and competitiveness on BMI, future work may investigate how financial and market pressures drive different forms of business model transformation. Additionally, the integration of emerging digital technologies such as AI and IoT offers a fertile ground to examine how digitalization enhances BMI effectiveness. Finally, extending this framework across different industries and incorporating sustainability-oriented innovation perspectives can further enrich the understanding of BMI as a strategic mechanism for achieving superior performance.

CRediT authorship contribution statement

Bishal Dey Sarkar: Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Formal analysis. **Laxmi Gupta:** Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Sandeep Jagtap:** Writing – review & editing, Visualization, Supervision, Project administration, Funding acquisition, Formal analysis.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

Appendix A. The scale and items

Organization Learning Ability (OLA)
OLA−1: Organization's learning ability is the key to competitive advantage.
OLA−2: Learning ability improves the basic values of this organization
OLA−3: It is a key commodity necessary towards organizational survival.
Technological Development (TD)
TD−1: Technological capability significantly relate to firm performance.
TD−2 Technological development brings operational benefits to firm
TD−3: Technological development may lead to new and better ways to treat and solve the social problem
TD−4: Technological development brings out efficiency in system
Customer Satisfaction (CS)
CS−1: Emphasize innovative/modern actions to increase customer retention
CS−2: Actions were incorporated in order to strengthen customer relationships.
CS−3: Consumer attitude and consumer relation is valuable
CS−4: Employee satisfaction is critical in business model innovation
Competitiveness in market (CM)
CM−1: Competition among market provide motivation for new technology
CM−2: Competitive advantage is considered as important part for BMI
CM−3: Knowledge about different competitive technologies in market is important
CM−4: Cost competition is important while innovation
Profitability (PR)
PR−1: Revenue Growth should be considerably high
PR−2: Economic value should be considerably added
PR−3: Return on assets, services, investments should be high
Environmental Performance (EP)
EP−1: How concerned are you about the environment & pollution
EP−2: Environment Projects keep on priority
EP−3: Considering Recyclables units
EP−4: Considering Pollutant's emission during innovation
Social Performance (SP)
SP−1: Social Projects are part of business innovation
SP−2: Being socially responsible is a way to promotes competitiveness.
SP−3: Social performance is essential part of sustainable innovation
SP−4: Minority employments should be considered
Business Model Innovation (BMI)
BMI−1: Grid industry prefer to upgrade system with new technology in grid
BMI−2: In the upcoming future storage technologies is a very important need
BMI−3: Deployment of battery integration in grid is necessary
BMI−4: How likely innovation is important in terms of range and usage satisfaction
Performance of energy storage market (PF_ ESM)
PF_ ESM−1: Improvement in innovative business model, result in greater ESS market performance.
PF_ ESM−2: Introduction of ESS technology has increased over the last 5 years
PF_ ESM−3: Overall profitability of energy storage market increased with innovation in grid.

Appendix B

(1) Descriptive statistics for measured variables

Construct Variable	Mean		Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	SE	Statistic	Statistic	Statistic	SE	Statistic	SE
OLA−1	4.89	.098	1.330	1.770	-.404	.179	-.539	.356
OLA−2	4.99	.095	1.282	1.645	-.571	.179	-.202	.356
OLA−3	5.07	.089	1.210	1.465	-.361	.179	-.383	.356
TD−1	5.48	.091	1.237	1.530	-.607	.179	-.323	.356
TD−2	5.43	.088	1.194	1.47	-.512	.179	-.467	.356
TD−3	5.55	.092	1.253	1.571	-.722	.179	-.149	.356
TD−4	5.48	.088	1.192	1.420	-.578	.179	-.345	.356
CS−1	5.55	.084	1.135	1.287	-.656	.179	.103	.356
CS−2	5.59	.081	1.098	1.205	-.840	.179	.914	.356
CS−3	5.65	.083	1.126	1.268	-.871	.179	.787	.356
CS−4	5.57	.083	1.129	1.274	-.800	.179	1.062	.356
CM−1	5.64	.072	.976	.953	-.938	.179	1.740	.356
CM−2	5.66	.073	.995	.990	-.931	.179	1.428	.356
CM−3	5.72	.072	.973	.947	-.881	.179	1.620	.356

(*continued on next page*)

(*continued*)

Construct Variable	Mean		Std. Deviation	Variance	Skewness		Kurtosis	
CM−4	5.61	.072	.974	.949	-.810	.179	1.472	.356
PR−1	5.99	.066	.899	.809	-.753	.179	.366	.356
PR−2	5.85	.068	.926	.858	-.662	.179	.452	.356
PR−3	5.97	.068	.923	.851	-.694	.179	.114	.356
EP−1	5.28	.084	1.138	1.294	-.652	.179	.582	.356
EP−2	5.30	.083	1.132	1.282	-.701	.179	.937	.356
EP−3	5.30	.090	1.216	1.478	-.555	.179	.103	.356
EP−4	5.29	.083	1.130	1.277	-.633	.179	.723	.356
SP−1	5.71	.090	1.214	1.474	-.838	.179	.331	.356
SP−2	5.73	.088	1.193	1.423	-.729	.179	-.244	.356
SP−3	5.71	.087	1.174	1.378	-.701	.179	-.114	.356
SP−4	5.60	.087	1.179	1.389	-.753	.179	.207	.356
BMI−1	6.27	.063	.857	.734	−1.292	.179	1.802	.356
BMI−2	6.24	.066	.898	.806	−1.224	.179	1.299	.356
BMI−3	6.48	.053	.724	.524	−1.383	.179	1.595	.356
BMI−4	6.18	.064	.865	.749	−1.174	.179	1.773	.356
PF_ESM−1	6.30	.069	.942	.888	−1.876	.179	5.373	.356
PF_ESM−2	6.16	.071	.967	.935	−1.873	.179	5.866	.356
PF_ESM−3	6.29	.071	.957	.917	−1.986	.179	5.702	.356

(2) Non-Response Test

Construct Variable		N	Mean	Std. Deviation	t-Statistic	Sig. (2- tailed)
OLA	Early	80	5.05	1.194	-.216	.829
	Late	80	5.09	1.236		
TD	Early	80	5.47	1.203	-.538	.592
	Late	80	5.57	1.056		
CS	Early	80	5.63	1.100	.212	.833
	Late	80	6.60	.967		
CM	Early	80	5.61	.940	-.759	.450
	Late	80	5.73	.892		
PR	Early	80	5.70	.834	−1.035	.357
	Late	80	6.11	.802		
EP	Early	80	5.26	1.164	−1.008	.316
	Late	80	5.45	.947		
SP	Early	80	5.58	1.191	-.612	.542
	Late	80	5.70	1.021		
BMI	Early	80	6.23	.739	-.859	.393
	Late	80	6.34	.714		
PF_ESM	Early	80	6.30	.868	.875	.384
	Late	80	6.18	.949		

Data availability

Data will be made available on request.

References

Amir, M., Deshmukh, R.G., Khalid, H.M., Said, Z., Raza, A., Muyeen, S.M., Sopian, K., 2023. Energy storage technologies: an integrated survey of developments, global economical/environmental effects, optimal scheduling model, and sustainable adaption policies. J. Energy Storage 72, 108694.

Ancillai, C., Sabatini, A., Gatti, M., Perna, A., 2023. Digital technology and business model innovation: a systematic literature review and future research agenda. Technol. Forecast. Social. Change 188, 122307.

Anderson, J.C., Gerbing, D.W., 1988. Structural equation modeling in practice: a review and recommended two-step approach. Psychol. Bull. 103 (3), 411–423.

Anwar, M., 2018. Business model innovation and SMEs performance—does competitive advantage mediate. Int. J. Innov. Manag. 22 (7), 1850057.

Arifin, Z., 2019. How is utility firm dealing with disruptive technologies? Empirical research of Indonesia electricity company. IEEE Technol. & Eng. Manag. Conf. 1–8.

Armstrong, J.S., Overton, T.S., 1977. Estimating nonresponse bias in mail surveys. J. Mark. Res. 14 (3), 396–402.

Avancini, D.B., Rodrigues, J.J., Martins, S.G., Rabêlo, R.A., Al-Muhtadi, J., Solic, P., 2019. "Energy meters evolution in smart grids: a review". J. Clean. Prod. 217, 702–715.

Bala, S.K., Babu, B.C., Bala, S., 2012. A review on development of smart grid technology in India and its future perspectives. Stud. Conf. Eng. Syst. 1–6.

Bhatti, H.J., Danilovic, M., 2018. Business model innovation approach for commercializing smart grid systems. Am. J. Ind. Bus. Manag. 8 (9), 2007–2051.

Bhola, P., Chronis, A.G., Kotsampopoulos, P., Hatziargyriou, N., 2023. Business model selection for community energy storage: a multi criteria decision making approach. Energies 16 (18), 6753.

Bohnsack, R., Pinkse, J., Kolk, A., 2014. Business models for sustainable technologies: exploring business model evolution in the case of electric vehicles. Res. Policy 43 (2), 284–300.

Bulut, M., Özcan, E., 2024. How to build a state-of-the-art battery energy storage market? Challenges, opportunities, and future directions. J. Energy Storage 86, 111174.

Byrne, B.M. (2010). Structural equation modeling with AMOS: Basic concepts, applications, and programming (2nd ed.). Routledge.

Campbell, D.T., Fiske, D.W., 1959. Convergent and discriminant validation by the multitrait-multimethod matrix. Psychol. Bull. 56 (2), 81.

Chapman, G., Hewitt-Dundas, N., 2018. "The effect of public support on senior manager attitudes to innovation". Technovation 69, 28–39.

Chasin, F., Paukstadt, U., Gollhardt, T., Becker, J., 2020. Smart energy driven business model innovation: an analysis of existing business models and implications for business model change in the energy sector. J. Clean. Prod. 269, 122083.

Chen, S., Chen, H.H., Shen, T., 2020. Suitable business models for innovation in different levels of the smart grid energy industry. Environ. Progress. & Sustain. Energy 39 (1), 13275–13283.

Choi, D., Shamim, N., Crawford, A., Huang, Q., Vartanian, C.K., Viswanathan, V.V., Sprenkle, V.L., 2021. Li-ion battery technology for grid application. J. Power Sources 511, 230419.

Das, P., Mathuria, P., Bhakar, R., Mathur, J., Kanudia, A., Singh, A., 2020. Flexibility requirement for large-scale renewable energy integration in Indian power system: technology, policy and modeling options. Energy Strategy Rev. 29, 100482.

Eckstein, D., Goellner, M., Blome, C., Henke, M., 2015. The performance impact of supply chain agility and supply chain adaptability: the moderating effect of product complexity. Int. J. Prod. Res. 53 (10), 3028–3046.
Finstad, K., 2010. The usability metric for user experience. Interact. Comput. 22 (5), 323–327.
Fornell, C., Larcker, D.F., 1981. Evaluating structural equation models with unobservable variables and measurement error. J. Mark. Res. 18 (1), 39–50.
França, C.L., Broman, G., Robert, K.H., Basile, G., Trygg, L., 2017. "An approach to business model innovation and design for strategic sustainable development". J. Clean. Prod. 140, 155–166.
Franzò, S., Natalicchio, A., Frattini, F., Magliocca, P., 2023. How digital technologies enable business model innovation in the energy sector: an empirical study of Italian energy service companies. IEEE Trans. Eng. Manag.
Government of India. (2015). India's Intended Nationally Determined Contribution: Working towards climate justice. Ministry of Environment, Forest and Climate Change. https://unfccc.int/sites/default/files/NDC/2022-06/INDIA%20INDC%20TO%20UNFCCC.pdf (Accessed on 23 June 2026).
Gowen, C.R., Stock, G.N., McFadden, K.L., 2006. Knowledge management as a mediator for the efficacy of transformational leadership and quality management initiatives in U.S. health care. Health Care Manag. Rev. 31 (3), 213–223.
Greenspoon, P.J., Saklofske, D.H., 1998. Confirmatory factor analysis of the multi-dimensional students' life satisfaction scale. Personal. Individ. Differ. 25 (5), 965–971.
Gronum, S., Steen, J., Verreynne, M.L., 2016. Business model design and innovation: unlocking the performance benefits of innovation. Aust. J. Manag. 41 (3), 585–605.
Gupta, A.K., Gupta, N., 2021. Environment practices mediating the environmental compliance and firm performance: an institutional theory perspective from emerging economies. Glob. J. Flex. Syst. Manag. 22 (3), 157–178.
Gupta, L., Shankar, R., 2022. Adoption of battery management system in utility grid: an empirical study using structural equation modeling. Glob. J. Flex. Syst. Manag. 23 (4), 573–596.
Gupta, L., Shankar, R., 2023. Modelling barriers of battery integration in smart grid. Int. J. Energy Sect. Manag. 17 (3), 617–642.
Gupta, L., Shankar, R., 2024. Soft-system management framework for power supply and grid integration issues. foresight.
Hair, J.F., Black, W.C., Babin, B.J., Anderson, R.E., 2010. Multivariate Data Analysis, 7th Edition). Prentice Hall, NJ.
Hamelink, M., Opdenakker, R., 2019. How business model innovation affects firm performance in the energy storage market. Renew. Energy 131, 120–127.
Harman, H.H., 1976. Modern Factor Analysis, 2nd ed. University of Chicago press.
Hee, O.C., Hui, O.K., Rizal, A.M., Kowang, T.O., Fei, G.C., 2018. Determinants of innovative performance in the service industry: a review. Int. J. Acad. Res. Bus. Soc. Sci. 8, 379–388.
Ilieva, I., Rajasekharan, J., 2018. Energy storage as a trigger for business model innovation in the energy sector. 2018 IEEE international energy conference (ENERGYCON). IEEE, pp. 1–6.
Jindal, A., Shrimali, G., 2022. At scale adoption of battery storage technology in Indian power industry: enablers, frameworks and policies. Technol. Forecast. Social. Change 176, 121467.
Jones, C.R., Hilpert, P., Gaede, J., Rowlands, I.H., 2021. Batteries, compressed air, flywheels, or pumped hydro? Exploring public attitudes towards grid-scale energy storage technologies in Canada and the United Kingdom. Energy Res. & Social. Sci. 80, 102228.
Kanungo, S., Savla, A., 2005. Relating information technology investment and organizational productivity: an empirical study. J. Adv. Manag. Res. 2 (1), 7–20.
Karakaya, E., Nuur, C., Hidalgo, A., 2016. Business model challenge: lessons from a local solar company. Renew. Energy 85, 1026–1035.
Karami, M., Madlener, R., 2021. Business model innovation for the energy market: Joint value creation for electricity retailers and their customers. Energy Res. & Social. Sci. 73, 101878.
Kaynak, Hale, Hartley, Janet L., 2006. Using replication research for just-in-time purchasing construct development. J. Oper. Manag. 24 (6), 868–892.
Kishore2021, Smart Grid Technology, ⟨https://www.lumenci.com/post/smart-grid-technology⟩.
Kline, R.B., 1998. Software review: software programs for structural equation modeling: Amos, EQS, and LISREL. J. Psychoeduc. Assess. 16 (4), 343–364.
Kline, R.B., 2005. Principles and Practice of Structural Equation Modeling 2nd ed, 3. Guilford, *New York*.
Koohi-Kamali, S., Tyagi, V.V., Rahim, N.A., Panwar, N.L., Mokhlis, H., 2013. Emergence of energy storage technologies as the solution for reliable operation of smart power systems: a review. Renew. Sustain. Energy Rev. 25, 135–165.
Kubli, M., Puranik, S., 2023. A typology of business models for energy communities: current and emerging design options. Renew. Sustain. Energy Rev. 176, 113165.
Kumar, A.R., Shrimali, G., 2021. Role of policy in the development of business models for battery storage deployment: Hawaii case study. Energy Policy 159, 112605.
Li, Y., Li, Y., Ji, P., Yang, J., 2015. Development of energy storage industry in China: a technical and economic point of review. Renew. Sustain. Energy Rev. 49, 805–812.
Li, T., Shi, Z., Han, D., Zeng, J., 2023. Agglomeration of the new energy industry and green innovation efficiency: does the spatial mismatch of R&D resources matter? J. Clean. Prod. 383, 135453.
Likert, R., 1932. A technique for the measurement of attitudes. Arch. Psychol. 22 (140), 55.
Liu, J., Hu, C., Kimber, A., Wang, Z., 2020. Uses, cost-benefit analysis, and markets of energy storage systems for electric grid applications. J. Energy Storage 32, 101731.
Liu, J., Hu, H., Yu, S.S., Trinh, H., 2023. Virtual power plant with renewable energy sources and energy storage systems for sustainable power grid-formation, control techniques and demand response. Energies 16 (9), 3705.
Liu, J., Lu, C., Ma, X., Li, Y., 2024. Evaluation of value-added efficiency in energy storage industry value chain: Evidence from China. J. Energy Storage 82, 110478.
Ma, Q., Razo-Zapata, I.S., de Kinderen, S., Kaczmarek-Heß, M., 2025. MOVING towards smart grids. Bus. & Inf. Syst. Eng. 1–22.
Markides, C., 2006. Disruptive innovation: In need of better theory. J. Product. Innov. Manag. 23 (1), 19–25.
Markus, K.A. (2012), "Principles and practice of structural equation modeling by Rex B. Kline.
Massa, L., Tucci, C.L., Afuah, A., 2017. A critical assessment of business model research. Acad. Manag. Ann. 11 (1), 73–104.
Mei, N.S., Wai, C.W., Ahamad, R., 2016. Environmental awareness and behavior index for Malaysia. Procedia-Social. Behav. Sci. 222, 668–675.
Midttun, A., Piccini, P.B., 2017. Facing the climate and digital challenge: European energy industry from boom to crisis and transformation. Energy Policy 108, 330–343.
Mone, M.A., McKinley, W., Barker III, V.L., 1998. "Organizational decline and innovation: a contingency framework". Acad. Manag. Rev. 23 (1), 115–132.
Moon, K.K.-L., Yi, C.Y., Ngai, E.W.T., 2012. An instrument for measuring supply chain flexibility for the textile and clothing companies. Eur. J. Oper. Res. 222 (2), 191–203.
Mori, C.D., Batalha, M.O., Alfranca, O., 2016. A model for measuring technology capability in the agrifood industry companies. Br. Food J. 118 (6), 1422–1461.
Mori, A., Zhang, K., 2024. Networked sustainable business model innovation and sustainable energy transitions: a case study of incumbent Chinese manufacturers in 2010–2022. Environ. Innov. Soc. Transit. 53, 100911.
Moriarty, P., Honnery, D., 2016. Can renewable energy power the future. Energy Policy 93, 3–7.
Narayanamoorthy, S., Brainy, J.V., Shalwala, R.A., Alsenani, T.R., Ahmadian, A., Kang, D., 2023. An enhanced fuzzy decision making approach for the assessment of sustainable energy storage systems. Sustain. Energy Grids Netw. 33, 100962.
Olabi, A.G., Onumaegbu, C., Wilberforce, T., Ramadan, M., Abdelkareem, M.A., Al–Alami, A.H., 2020. "Critical review of energy storage systems". Energy 214, 118987.
Olajiga, O.K., Ani, E.C., Olatunde, T.M., Sikhakane, Z.Q., 2024. Assessing the potential of energy storage solutions for grid efficiency: a review. Eng. Sci. & Technol. J. 5 (3), 1112–1124.
Omondi, M.M., Muturi, W., 2013. Factors affecting the financial performance of listed companies at the Nairobi securities exchange in Kenya. Res. J. Financ. Account. 4 (15), 99–105.
Park, E., 2019. Social acceptance of green electricity: evidence from the structural equation modeling method. J. Clean. Prod. 215, 796–805.
Phogat, P., Dey, S., Wan, M., 2025. Powering the sustainable future: a review of emerging battery technologies and their environmental impact. RSC Sustain. 3 (8), 3266–3306.
Podsakoff, P.M., Organ, D.W., 1986. Self-reports in organizational research: problems and prospects. J. Manag. 12 (4), 531–544.
Pollitt, M.G., 2012. Lessons from the history of independent system operators in the energy sector. Energy Policy 47, 32–48.
Rana, M.M., Uddin, M., Sarkar, M.R., Meraj, S.T., Shafiullah, G.M., Muyeen, S.M., Jamal, T., 2023. Applications of energy storage systems in power grids with and without renewable energy integration—a comprehensive review. J. Energy Storage 68, 107811.
Reza, M.S., Hannan, M.A., Ker, P.J., Mansor, M., Lipu, M.H., Hossain, M.J., Mahlia, T.I., 2023. Uncertainty parameters of battery energy storage integrated grid and their modeling approaches: a review and future research directions. J. Energy Storage 68, 107698.
Santos, J.B., Brito, L.A.L., 2012. Toward a subjective measurement model for firm performance. BAR-Braz. Adm. Rev. 9, 95–117.
Schwidtal, J.M., Piccini, P., Troncia, M., Chitchyan, R., Montakhabi, M., Francis, C., Kiesling, L., 2023. Emerging business models in local energy markets: a systematic review of peer-to-peer, community self-consumption, and transactive energy models. Renew. Sustain. Energy Rev. 179, 113273.
Shah, R., Ward, P.T., 2007. Defining and developing measures of lean production. J. Oper. Manag. 25 (4), 785–805.
Shomali, A., Pinkse, J., 2016. The consequences of smart grids for the business model of electricity firms. J. Clean. Prod. 112, 3830–3841.
Slater, S.F., 1994. market oriented isn't enough: building a learning organization. Mark. Sci. Inst. 94–103.
Sułek, A., Borowski, P.F., 2024. Business models on the energy market in the era of a low-emission economy. Energies 17 (13), 3235.
Taabodi, M.H., Niknam, T., Sharifhosseini, S.M., Aghajari, H.A., Shojaeiyan, S., 2025. Electrochemical storage systems for renewable energy integration: a comprehensive review of battery technologies and grid-scale applications. J. Power Sources 641, 236832.
Taylor, A., Helfat, C.E., 2009. Organizational linkages for surviving technological change: complementary assets, middle management, and ambidexterity. Organ. Sci. 20 (4), 718–739.
Tiwari, P., Suresha, B., 2021. Moderating role of project innovativeness on project flexibility, project risk, project performance, and business success in financial services. Glob. J. Flex. Syst. Manag. 22 (3), 179–196.
To, M.L., Ngai, E.W., 2006. Predicting the organisational adoption of B2C e-commerce: an empirical study. Ind. Manag. & Data Syst. 106 (8), 1133–1147, 2006.

Van der Linden, S., 2006. Bulk energy storage potential in the USA, current developments and future prospects. Energy 31 (15), 3446–3457.
Velu, C., 2015. Business model innovation and third-party alliance on the survival of new firms. Technovation 35, 1–11.
Wang, X., Shen, Y., Su, C., 2024. Exploring the willingness and evolutionary process of public participation in community shared energy storage projects: evidence from four first-tier cities in China. J. Clean. Prod. 472, 143462.
Yang, D., Lv, Y., Ji, M., Zhao, F., 2024. Evaluation and economic analysis of battery energy storage in smart grids with wind–photovoltaic. Int. J. Low. -Carbon Technol. 19, 18–23.
Yang, H., Rui, X., Yu, Y., 2026. Advances in battery technologies for smart grids in 2025. Nat. Rev. Clean. Technol. 2 (1), 11–12.
Yenneti, K., 2016. The grid-connected solar energy in India: structures and challenges. Energy Strategy Rev. 11, 41–51.
Zabihi, A., Parhamfar, M., 2025. Decentralized energy solutions: the impact of smart grid-enabled EV charging stations. Heliyon 11 (13).
Zhang, H., Gao, S., Zhou, P., 2023. Role of digitalization in energy storage technological innovation: evidence from China. Renew. Sustain. Energy Rev. 171, 113014.
Zhang, Y., Gevorgian, V., Wang, C., Lei, X., Chou, E., Yang, R., Li, Q., Jiang, L., 2017. Grid-level application of electrical energy storage: Example use cases in the United States and China. IEEE Power Energy Mag. 15 (5), 51–58. https://doi.org/10.1109/MPE.2017.2708860.
Zhang, D., Shafiullah, G.M., Das, C.K., Wong, K.W., 2025. Optimal allocation of battery energy storage systems to improve system reliability and voltage and frequency stability in weak grids. Appl. Energy 377, 124541.