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Technopreneurship and Innovation System as Strategic Drivers for Commercializing Powerwall Technology

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Abstract

Powerwall is a lithium-ion battery energy storage technology designed to store electricity from renewable sources and improve energy efficiency. Despite the growing urgency for renewable energy adoption in Indonesia, Powerwall's market penetration remains limited. This paper explores the strategic role of technopreneurship and innovation systems in accelerating Powerwall commercialization, using PT BATEX as a case study. The research applies a literature review, stakeholder interviews, and the Entrepreneurship & Innovation System Development Framework are used to analyze technopreneurship development, technology push, and market pull dynamics, as well as the Business Model Canvas, innovation models, and regulatory context. Findings indicate that the current technopreneurship model lacks adaptability, with marketing efforts still focused on conventional end-user approaches. As an improvement strategy, we proposed innovative business models such as leasing, pay-as-you-go, and property bundling, along with systematic digital consumer education. Cross-sector collaboration through open innovation, particularly with property developers and solar panel providers, is also essential. Furthermore, supportive government regulations are critical to strengthening the residential energy storage market. In conclusion, technological readiness alone is insufficient. A strong technopreneurship ecosystem, progressive policy support, and flexible business strategies are vital to ensure successful commercialization and large-scale adoption of Powerwall.

Keywords
Technopreneurship, Innovation System, Powerwall, Commercialization, Business Model Canvas

1. Introduction
Indonesia has declared its commitment to achieving Net Zero Emissions by 2060 as part of its response to global climate change challenges, thus accelerating the transition toward renewable energy utilization, including the development of solar energy (Ministry of Energy and Mineral Resources Regulation No. 10/2025). According to data from the Ministry of Energy and Mineral Resources (2024), the government aims to establish an integrated solar panel industry, capitalizing on a solar energy potential exceeding 3,200 GW. However, the current utilization remains limited, with installed capacity reaching only approximately 200 MW. Rooftop photovoltaic systems are experiencing steady growth, reaching 149.2 MWp, predominantly driven by the industrial, commercial, and residential sectors (Infien Energy, 2024).

The expansion of rooftop solar networks and charging station infrastructure is expected to stimulate growing demand for advanced energy storage systems such as the Powerwall. Powerwall is a lithium-ion battery-based energy storage solution designed to optimize energy consumption at residential, commercial, and industrial scales. This system stores surplus energy during periods of excess generation and supplies electricity during peak demand or intermittency in renewable generation. Nevertheless, Powerwall commercialization in Indonesia encounters multiple barriers, including high upfront capital costs, limited financial incentives, and technological challenges related to local adaptation. Public awareness and acceptance of Powerwall technology remain relatively low, with most consumers still relying on centralized electricity grids. The successful adoption of Powerwall will depend heavily on the establishment of enabling policies and regulatory frameworks, such as tax incentives, net metering regulations, simplified grid interconnection procedures, and the implementation of comprehensive safety and performance standards, all of which can significantly enhance market penetration.

Powerwall offers several key advantages, including improved energy management efficiency, operational cost savings, and enhanced reliability of electricity supply. The system facilitates load shifting by utilizing stored energy during peak tariff periods, resulting in substantial reductions in electricity expenditures. Moreover, Powerwall integration supports the broader adoption of renewable energy sources, reduces dependency on fossil fuels, and contributes to national carbon emission reduction goals. Its automatic backup capabilities further strengthen energy security at the household level, mitigating the impacts of power disruptions. A study by Uddin et al. (2025) emphasizes the importance of integrating energy storage with green building infrastructure to improve efficiency and reduce dependence on the main power grid. Bridging the gap between advanced technologies and market adoption requires a technopreneurship approach supported by a robust innovation system. Technopreneurship, which combines technological innovation with an entrepreneurial mindset, can facilitate commercialization by connecting research, industry, and government (Sutopo, 2019).

According to previous research, Uddin et al. (2025) underscore the critical importance of integrating energy storage systems with green building infrastructure to enhance energy efficiency and reduce dependence on centralized power grids. Bridging the gap between advanced technologies and their market adoption requires a technopreneurship approach supported by a robust innovation ecosystem. Technopreneurship, which combines technological innovation with an entrepreneurial mindset, serves as a key enabler of commercialization by fostering linkages among research. Institutions, industry players, and government agencies (Sutopo, 2019). In the absence of such an approach, even mature technologies remain vulnerable to the so-called "valley of death," a critical phase in which innovations fail to reach the market due to financing gaps, weak stakeholder networks, and insufficient validation mechanisms (Carayannis et al., 2015).

Previous research on innovation systems offers valuable frameworks for navigating the complexities of technology commercialization. Sakti et al. (2021) employed a technopreneurship development model integrated with the Business Model Canvas (BMC) to guide the development of a smart backpack product. Similarly, Pratiwi et al. (2021) examined the commercialization pathway of wastewater treatment technology, emphasizing the necessity of strong institutional support, inter-organizational collaboration, and well-defined commercialization strategies to overcome the "valley of death" and achieve market viability. Additional studies further highlight the significance of user trust and satisfaction in driving technology adoption, as evidenced in the case of AI-based Safe Entry Stations within healthcare settings (Rahardja et al., 2024). Furthermore, technopreneurship has been demonstrated to enhance the competitiveness of small and medium-sized enterprises (SMEs) through product, process, and organizational innovation (Machmud et al., 2022).

This paper aims to explore the strategic role of technopreneurship and innovation systems in enabling the market deployment of Powerwall technology, taking the case study of PT BATEX. By leveraging lessons from previous studies and adopting a structured commercialization framework, this paper argues that integrated collaboration among government, industry, academia, and entrepreneurs can accelerate the deployment of Powerwall systems as a catalyst for Indonesia's renewable energy transition and sustainable economic growth.

1.1 Objectives

The main objectives of this research are:

1. To investigate how technopreneurship innovation systems act as a strategic driver in the commercialization of Powerwall technology.
2. To propose an effective business model strategy for PT BATEX to address the commercialization challenges of Powerwall in the Indonesian market.
3. To analyze the influence of cross-sector collaboration and government regulations on the commercialization ecosystem of Powerwall technology.

In addition, this research also aims to provide insights for entrepreneurs, policymakers, and stakeholders involved in energy storage innovation.

2. Literature Review

2.1 Adoption of Renewable Energy

The adoption of renewable energy at the regional level is influenced by various multidimensional factors, including public behavior, technological innovation, policy support, and enabling infrastructure. A study conducted in Malaysia by Lam et al. (2025) revealed that household behavioral intention to adopt rooftop solar panels is significantly affected by performance expectancy, price value, facilitating conditions, and environmental concern, with social influence emerging as a key qualitative factor. Meanwhile, research by Han et al. (2025) on G-20 countries emphasized the crucial role of technological innovation in driving renewable energy use and reducing CO_2 emissions, further supported by elements such as economic freedom and financial advancement. On the other hand, the stability of renewable energy integration into the grid largely depends on the availability of battery energy storage systems (BESS), as discussed by Osezua and Tomomewo (2025), who highlighted the strategic importance of policy frameworks and technological advancement in countries like China, Japan, and South Korea. Collectively, the literature underscores that regional renewable energy adoption strategies must embrace a holistic approach that integrates technical, economic, social, and policy dimensions to ensure a sustainable and context-specific energy transition.

2.2 Innovation as a Management Process

Innovation as a management process refers to a structured approach used by organizations to develop, implement, and manage new ideas to create added value. From a management perspective, innovation encompasses various aspects, including products, services, business processes, business models, and marketing strategies (Damanpour, 2020). As a management process, innovation involves the systematic application of knowledge, skills, and creativity to generate new products, services, or processes with added value. Innovation management requires the integration of various elements such as technology, human resources, information, and organizational infrastructure in order to solve problems and create new business opportunities (Carayannis et al., 2015). Effective innovation management also addresses the inherent risks and uncertainties in technological development, emphasizing the need for skilled leadership, investment in research and development (R&D), and a culture that supports continuous improvement and adaptation. Innovation management is not just an internal process but an integral business strategy for achieving long-term growth and sustainability of the organization.

2.3 Innovation System

The innovation system is a framework that includes various actors such as companies, universities, research institutions, government, and civil society organizations, as well as the interactive relationships among them that promote the creation, diffusion, and utilization of knowledge and technology. Innovation plays a crucial role in achieving a competitive advantage in the global marketplace. Firms that consistently engage in innovation are more likely to expand their market share and enhance their profitability (Carayannis et al., 2015).

The key elements of this innovation system include actors, networks, institutions, processes, and policies. The interactions among these elements create a complex and dynamic innovation ecosystem, where each actor plays a strategic role in driving innovation through activities such as R&D, technology transfer, and commercialization. System innovation is a comprehensive change in the socio-technical system that encompasses technological aspects, institutional frameworks, user practices, and business models (Geels, 2002). System innovation is necessary to overcome structural barriers, including regulation, market readiness, and resistance from the conventional energy system.

2.4 Technological Entrepreneurship (Technopreneurship)

Technopreneurship is the combination of technology and entrepreneurship, where business actors (technopreneurs) leverage technological innovation to create disruptive products, services, or business models. According to Audretsch et al. (2021), Technopreneurship represents a convergence of technology and entrepreneurship, involving the creation of new ventures based on technological innovations that generate both economic and social impacts. Technopreneurs play a critical role in commercializing research outcomes and technologies through spin-offs, start-ups, or strategic partnerships. An enabling technopreneurship ecosystem is typically characterized by effective technology transfer mechanisms, access to capital, and close collaboration among academia, industry, and government (Carayannis et al., 2015).

Technopreneurship is a process focused on transforming creative ideas into valuable business opportunities through the mastery and utilization of technology. This concept combines two main elements: entrepreneurship, which is oriented toward exploiting new business opportunities, and technology, which encompasses the knowledge, skills, and technical tools used in the creation and development of innovative products or services (Khodabandeh Avili, 2023). Technopreneurship plays a role in the digital economy, which is also a key driver in the era of the 4.0 Industrial Revolution.

2.5 Business Model Canvas (BMC)

The Business Model Canvas (BMC) is a strategic tool for business planning developed by Alexander Osterwalder and Yves Pigneur. This tool is used to systematically visualize a business model through nine key elements. According to research by Wirtz et al. (2020), the main advantage of BMC lies in its visual and collaborative approach, enabling business teams to analyze, evaluate, and develop business models effectively (Fritscher & Pigneur, 2021). In addition, the BMC is also used in the development of sustainable business, where companies consider environmental and social aspects in their business models (Bocken et al., 2020). Thus, the BMC remains relevant as a business planning tool that is adaptive to various industry trends. On this occasion, the researcher uses the Business Model Canvas (BMC) to analyze the feasibility of selling power walls in the surrounding community, which is perceived to have great potential in the future.

3. Methods

This study adapts the Technological Entrepreneurship Development Framework by Khodabandeh Avili (2023) in his study *"Development of a Framework for the Growth of Technological Entrepreneurship in FMCG Companies."* It also refers to the framework proposed by Pratiwi et al. (2021) in their work *"A Framework for Developing Technopreneurship and Innovation System: Comparative Study of the Development of Waste Water Treatment Machine Technology,"* which combines the approaches of Market Pull vs. Technology Push, Closed vs. Open Innovation, and incorporates the Innovation Process and Technology Transfer Office (TTO) as critical components in the technology commercialization process.

The combination of these frameworks provides a comprehensive methodological foundation for analyzing and developing the technological entrepreneurship system and innovation processes in the commercialization of Powerwall technology in the Indonesian context. This research employs a qualitative case study method using both primary and secondary data sources. Primary data were collected through semi-structured interviews and discussions with key stakeholders from PT BATEX, the developer of Powerwall, as well as two representatives from housing developer companies in the Solo area. The interviews involved four informants, conducted in a hybrid format (in-person and virtual), with each session lasting approximately 45–60 minutes. The interviews explored key themes such as technology adoption barriers, current business models, regulatory perceptions, market readiness, and collaborative innovation opportunities. Secondary data were obtained through literature reviews, including academic journals, industry reports, regulatory documents, and internal company materials relevant to renewable energy storage and commercialization strategies.

To ensure the reliability of the findings, triangulation was performed by cross-referencing information from interviews with secondary sources and internal documents. Furthermore, member-checking was conducted with PT BATEX representatives to validate the interpretation of the interview results. The qualitative data were analyzed using thematic analysis, where interview transcripts were coded and categorized into major themes aligned with the conceptual framework, such as technopreneurial readiness, innovation ecosystem linkages, and commercialization bottlenecks. Figure 1 illustrates the Entrepreneurship and Innovation System Development Framework used in this study to structure the analysis and draw strategic insights.

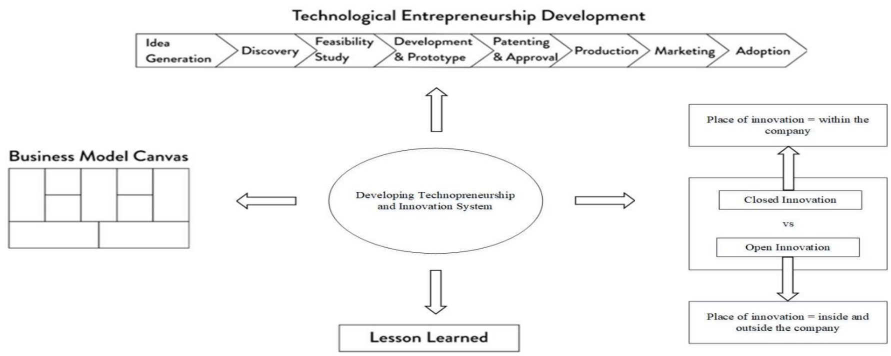

Figure 1. Entrepreneurship & Innovation System Development Framework

4. Data Collection

This study collected data through direct observation, semi-structured interviews, and discussions conducted at PT Batex Energi Mandiri. The primary objective of data collection was to gain an in-depth understanding of the company's internal conditions, technological capabilities, and strategic objectives in developing and commercializing Powerwall technology, including the business models currently employed. In addition, a perception survey was conducted with two housing developers in the Solo area to assess their views on the value, cost, and interest in adopting Powerwall, providing a preliminary indication of market potential.

The semi-structured interviews involved four key informants, including two members of PT BATEX management (the Operations Director and Head of R&D) and two property developers. The interviews were conducted in both in-person and virtual formats, with each session lasting approximately 45–60 minutes. The main themes explored in the interviews included:

- Barriers to the adoption of energy storage technologies in the local market,
- Existing and planned marketing and business strategies,
- Cross-sector collaboration opportunities (academia, government, housing),
- Evaluation of technology readiness and regulatory challenges,
- Exploration of innovative business models such as leasing, bundling, and pay-as-you-go systems.

All data were analyzed using the Entrepreneurship and Innovation System Development Framework, which maps the interconnections between internal capabilities, the innovation ecosystem, and market needs to support the development and commercialization of Powerwall.

To enhance the validity and reliability of the findings, data triangulation was applied by cross-verifying insights from interviews with field observations and secondary data, including literature reviews and internal company reports. Additionally, a member-checking process was conducted with PT BATEX informants to confirm the interpretation of interview results. The qualitative data were analyzed through thematic analysis, involving the identification and categorization of recurring themes related to commercialization challenges, innovation strategies, and the technopreneurship ecosystem within the Indonesian renewable energy market.

5. Results and Discussion

The literature review emphasizes that technological entrepreneurship emerges from the complex interaction between innovative ideas, technological capabilities, institutional support, and the utilization of an open and collaborative innovation ecosystem. According to Siyanbola (2011), the development process of technopreneurship generally involves several key stages: idea generation, discovery, feasibility study, prototype development, patenting and approval, production, marketing, and adoption. These stages also form the foundation for the development of PT

BATEX's Powerwall, which originated from observations of local market needs related to renewable energy.

The development of technological entrepreneurship within higher education institutions and industry requires the adoption of open innovation models, the sharing economy paradigm, and the Quintuple Helix Innovation Model (QHIM), which emphasizes the importance of cross-sector collaboration (Rosienkiewicz et al., 2024). Moreover, according to the Resource-Based View (RBV) approach presented by Ahn et al. (2022), a company's internal technological capabilities, such as R&D capacity, mastery of battery cell design, prototype development, and patent acquisition, constitute unique resources that provide long-term competitive advantages for technology-based startups.

5.1 Technological Entrepreneurship Development

- **Idea Generation**
  The idea for the Powerwall emerged from the growing demand for reliable and environmentally friendly household energy storage solutions, particularly to support the integration of electric vehicles and renewable energy sources in Indonesia. The main inspiration was drawn from similar technologies such as the Tesla Powerwall, which has demonstrated the ability to efficiently manage and store energy for household use while contributing to grid stability. The concept was developed through internal research involving collaboration between the R&D team and external studies. The development process focused on advanced battery materials, particularly Lithium Iron Phosphate (LFP), battery cell design, and sophisticated battery management systems (BMS) to ensure optimal performance, safety, and long-term product durability.

- **Discovery**
  The initial exploration involved formulating a Powerwall concept compatible with local solar panel systems and household or building electrical infrastructure in Indonesia. The idea evolved into a modular design, integrated with local inverters and battery management systems (BMS), as well as cloud-based monitoring for real-time energy usage tracking.

- **Feasibility Study**
  Technical evaluations and market trends indicated a need for renewable energy storage, though adoption remained low due to high initial costs and limited consumer literacy. The feasibility study included laboratory testing and pilot trials with selected users over a certain period. The results from this phase informed decisions on further development.

- **Development of Prototype**
  The company developed prototypes of battery cells and packs, including integration with solar panel systems, as Powerwall technology. The prototypes were tested to ensure quality, safety, durability, and performance under high-temperature conditions. Early user trials were conducted to collect feedback for final design iterations.

- **Patenting and Approval**
  The innovations were registered for patents (active materials, production processes, battery designs). Testing and certification were carried out to meet national standards through government agencies.

- **Production**
  Mass production is conducted at PT BATEX facilities, prioritizing the use of local materials and efficient processes. Initial production scaling was based on market demand forecasts to ensure that each unit produced had a clear market opportunity or as part of a pilot project with strategic partners. This approach minimizes the risk of overproduction. The process is supported by a modular production system, allowing Powerwall configurations to be customized according to customer needs.

- **Marketing**
  The current marketing strategy is primarily focused on the B2C segment (end consumers), with plans to expand into B2B segments (corporate, office, or residential property sectors). Market education is carried out to increase the adoption of Powerwall technology. The marketing strategy emphasizes product values such as energy efficiency, clean energy support, and smart monitoring. Public education and outreach are conducted through social media and webinars highlighting the benefits of Powerwall.

  PT Batex's marketing strategy for the Powerwall product currently faces several challenges that significantly limit market penetration. The current marketing efforts have yet to implement systematic and comprehensive consumer education programs that effectively communicate the benefits, functionality, and added value of

Powerwall technology, particularly through optimal use of digital media channels. In addition, financing options such as leasing, green credit, and energy mortgages remain underdeveloped and have not been widely promoted, further restricting consumer access and adoption.

- **Adoption**
  Powerwall has already been implemented at the household level. The company continues to improve features based on user feedback (such as mobile application integration, backup capacity, and design aesthetics). Promotional offers such as free installation during the initial weeks aim to change user perceptions regarding the product's high upfront cost, which can ultimately help reduce electricity bills. Collaborations with solar panel installers, institutions, government agencies, and the private sector help accelerate adoption in the national market.

  Based on the interview, it was found that currently the market penetration of Powerwall is running relatively slowly, which directly impacts the company's business growth. The biggest barriers are that the government still provides minimal tax incentives and feed-in tariffs, and the lack of understanding and awareness among the public causes resistance to the adoption of clean energy technologies. The low market penetration also decreases the confidence and interest of external partners such as property developers, academics, and the government to engage in innovation collaborations. This condition has resulted in sales volume not reaching a sufficiently wide scale, hence the selling price remains non-competitive in the market. To address this, more aggressive and educational marketing strategies are needed, along with synergy with the government and other stakeholders to create an ecosystem that supports the widespread adoption of Powerwall technology.

5.2 Technical Specification of Powerwall

PT BATEX has developed a Powerwall energy storage system that utilizes Lithium Iron Phosphate ($LiFePO_4$) battery cells, which are well-regarded for their high thermal stability, enhanced safety, and extended cycle life compared to other lithium-ion chemistries such as Nickel Manganese Cobalt (NMC) and Lithium Cobalt Oxide (LCO). $LiFePO_4$ batteries typically offer 3,000 to 5,000 full charge cycles, making them highly durable for long-term energy storage applications. They support a high Depth of Discharge (DoD) of approximately 90–95%, enabling users to utilize most of the battery's capacity efficiently without significantly affecting its lifespan.

In this Powerwall system, the battery adopts a 4-series and 48-parallel cell configuration, delivering a nominal voltage of 12.8 V and a capacity of 62.4 Ah, resulting in a total energy output of 824 Wh. The system features a low internal resistance

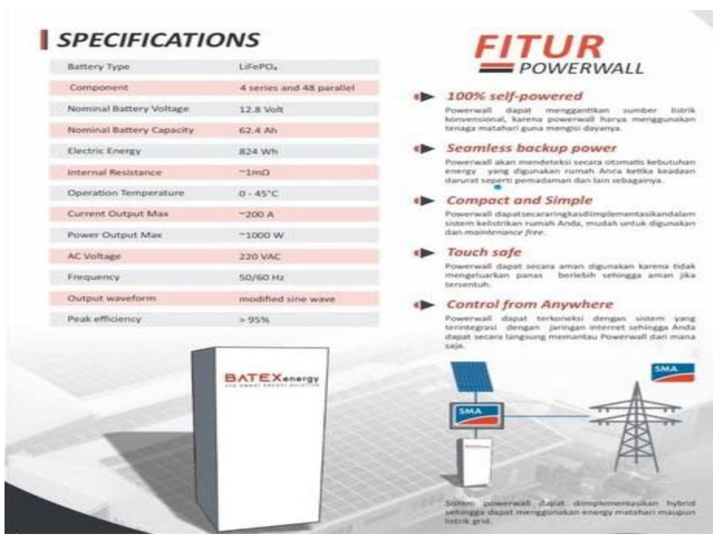

Figure 2. Powerwall Design

of about 1 milliohm and achieves peak efficiency over 95%, providing up to 1,000 W of output power, which is sufficient to support critical household loads such as lighting, refrigeration (Figure 2), and light electronics. Although the energy density of $LiFePO_4$ is lower than NMC, resulting in larger and heavier batteries for the same capacity, the technology is favored for its superior safety and chemical stability. Moreover, the Powerwall's modular design offers flexibility to scale capacity according to user requirements, making it an ideal solution for residential renewable energy systems.

5.3 Technology Push and Pull Market

Product innovation strategies are generally categorized into two main approaches: technology push and market pull. The innovation strategy adopted by PT BATEX in the development of its Powerwall product represents a combination of both Technology Push and Market Pull approaches. The Powerwall is developed using advanced lithium-ion battery technology, resulting from extensive research and innovation (Technology Push), while it is simultaneously designed to meet the growing market demand for efficient and environmentally friendly energy storage solutions (Market Pull). In line with previous research findings, Roslan et al. (2022) demonstrated that a strategic combination of technology-push and market-pull policies effectively complements each other in driving technology adoption and increasing the utilization of renewable energy, particularly residential-scale photovoltaic systems in Asia-Pacific countries.

This dual approach accelerates adoption by ensuring the product remains technologically advanced while being accessible, relevant, and valuable to end-users. It also supports the broader transition to sustainable energy by enabling homes to become more energy independent, reducing carbon footprints, and stabilizing the electricity grid. Case studies of companies such as Tesla demonstrate that balancing Technology Push and Market Pull is essential for product success in competitive markets. Tesla has successfully integrated battery technology innovation with a deep understanding of market needs in electric vehicles and energy storage, allowing for the accelerated adoption of new technologies on a large scale.

5.4 Business Model Canvas

BMC is a strategic management framework designed to systematically analyze, develop, and visualize a company's business model (Osterwalder & Pigneur, 2010). It offers a structured approach that breaks down a business into nine key elements, allowing organizations to clearly understand how value is created, delivered, and captured across their operations. BMC offers significant strategic advantages in business development, particularly within the context of technological innovation. Based on interviews with PT BATEX, it was found that the marketing strategy for the Powerwall product lacks partnerships with property developers and remains focused primarily on direct sales to end consumers. PT BATEX has yet to fully accommodate collaboration, with engagement still limited to external stakeholders such as government agencies and universities. Furthermore, the absence of innovative business models such as leasing schemes, pay-as-you-go systems, or bundling with property developments restricts market penetration, particularly in the residential and commercial segments that are highly sensitive to upfront costs.

- **Key Partners**
  Identifies all partners who play important roles in the company's value chain, starting from raw material procurement to product distribution. Partners may include material suppliers, manufacturing partners, logistics providers, technology collaborators, research institutions, and government agencies that offer regulatory support or incentives.

- **Key Activities**
  This includes all core activities that the company must perform to deliver its value proposition. Activities cover research and development (R&D), product design development, quality testing, production processes, marketing, customer service, and market education to boost product adoption.

- **Key Resources**
  Key resources are the main assets required to operate the business model, create value, and maintain customer relationships. These resources can be physical (factories and production equipment), financial (working capital and investments), intellectual (patents, technology, and technical knowledge), and human resources (R&D teams, production staff, and marketing personnel).

- **Value Propositions**
  Describes the unique value or advantages offered by the company that differentiate it from competitors. The value proposition includes flexible storage capacity, modular designs customizable to consumer needs, easy integration with local electrical systems, and smart monitoring features that provide real-time energy usage control.

- **Customer Relationships**
  Explains how the company builds and maintains relationships with customers. Relationships may be personal (technical assistance and after-sales service), automated (app notifications), or ongoing education to improve consumer understanding of energy storage technology benefits.

- **Customer Segments**
  Groups target markets based on customer needs and characteristics. For Powerwall, customer segments include households, small to medium businesses, commercial sectors, eco-friendly property developers, educational institutions, and industrial zones implementing renewable energy systems.

- **Channels**
  Refers to the media or distribution pathways the company uses to deliver its value proposition to customers. These include direct sales, partnerships with solar panel installers, digital platforms for promotion and education, participation in energy exhibitions, and collaborations with green property developers.
- **Cost Structure**
  Outlines all costs incurred in operating the business model, such as production costs, battery material procurement, technology development, product certification, marketing, after-sales service, and logistics and distribution expenses.

- **Revenue Streams**
  Revenue is generated from each customer segment. Revenue can come from one-time payments or ongoing payments due to additional after-sales services. Powerwall's revenue streams include product unit sales, installation services, regular maintenance, premium cloud-based monitoring services, and potential B2B partnerships generating additional income.

Based on the discussion of the business model design, a detailed elaboration of the nine components of BMC for Powerwall has been developed. This business model systematically illustrates how Powerwall creates, delivers, and captures value through technological innovation, strategic partnerships, and addressing the needs of diverse customer segments. The comprehensive visualization of the Powerwall BMC resulting from this research is presented in Figure 3, highlighting the integration of key elements that support the product's growth and sustainability in the renewable energy market.

Key Partners	Key Activities	Value Propositions	Customer Relationships	Customer Segments
• Research institutions supporting regulation and innovation • Government • PLN (grid integration) • Property developers and solar panel installers • Financial institutions (customer financing schemes). • Logistics companies	• Research and development • Manufacturing • Quality control • Technical performance test and market validation • Marketing and sales • Installation services • Software updates for energy management.	• Independent lithium-ion battery energy storage solution • Efficient integration with solar panels and smart inverters • Real-time energy monitoring • Environmentally friendly, supporting the clean energy transition • Locally produced with competitive pricing • Customizable specifications .	• Free initial installation as an incentive • Technical assistance and after-sales support • Customer education via digital content for transparency on usage and performance • Warranty programs and BMS firmware updates.	• Residential homeowners, small- to medium-sized businesses • Green property developers • Offices and commercial buildings • Government and public institutions (e.g., schools, health centers) • Early adopters of green technology.
	Key Resources		**Channels**	
	• Battery design patents and materials • Proprietary software • Manufacturin g facilities, • Intellectual property, skilled workforce, especially in R&D and energy system engineering		• Direct sales through internal marketing teams • Collaboration with solar panel installers and property developers • Social media and educational webinars • Participation in exhibitions • Partnerships with PLN and B2B e-commerce platforms.	

Cost Structure	Revenue Streams
• Research and development costs • Investment in local production and raw materials • Certification and legal compliance costs (SNI, patents) • Marketing and market education expenses • After-sales service and feature development.	• Sales of Powerwall units • Bundled packages with solar panels and inverters • Installation and energy system consultation services • Subscription or installment payment models (e.g., pay-as-you-save) • Potential technology licensing for B2B.

Figure 3. Business Model Canvas for Powerwall

5.5 Close Innovation and Open Innovation

Closed Innovation is an approach where idea development, research, and commercialization are conducted entirely within the company, allowing full control over proprietary knowledge. However, it may limit flexibility and slow adaptation to market changes. In contrast, Open Innovation involves actively sourcing and integrating external ideas, technologies, and knowledge, enabling faster innovation, greater adaptability, and broader collaboration to meet evolving market demands.

The Powerwall developed adopts an open innovation approach. This collaborative model accelerates product development, enables the integration of relevant new features, and optimizes both production and distribution processes. Moreover, open innovation supports Powerwall in enhancing the renewable energy ecosystem by expanding partnerships that strengthen distribution, installation, and after-sales services, thereby accelerating the adoption of energy storage technology across various market segments (Table 1).

Table 1. Implementation of Open Innovation in Powerwall Product

Aspect	Implementation
External Collaboration Partners	Universities (battery material research), government agencies (certification, regulatory support), PLN (grid integration), solar panel installers (installation partnerships), and Green property developers (market expansion).
Access to External Knowledge	Adoption of global best practices (e.g., Tesla Powerwall benchmarking), integration of academic research findings into product development, and incorporation of customer feedback from early adopters.
Technology Integration	Integration of cloud-based smart monitoring, modular design for capacity flexibility, and compatibility with local solar power infrastructure and PLN grid systems.
Acceleration of Product Development	Faster prototype testing and validation through collaborative field trials and pilot projects with strategic partners.
Market Expansion	Partnership plan with solar installers and property developers to access the residential and commercial customer segments, as well as participation in energy exhibitions and renewable energy forums.
Service Enhancement	Joint development of installation, maintenance, and after-sales service networks with partners to strengthen customer satisfaction and adoption rates.
Strengthening Renewable Energy Ecosystem	Creation of a collaborative network that supports the broader adoption of renewable energy technologies, contributing to national energy transition goals.

5.4 Regulatory Challenges

The commercialization of energy storage technologies like the Powerwall faces significant regulatory barriers, primarily due to the lack of clear legal and policy frameworks in many regions of Indonesia. Regulatory uncertainty and limited fiscal incentives have reduced investor and consumer confidence, resulting in slow adoption rates. This aligns with Roslan et al. (2022), who found that successful residential renewable energy adoption depends on a strategic mix of market-pull policies (e.g., feed-in tariffs, tax incentives) and technology-push measures (e.g., capital grants). Regions lacking integrated regulations tend to experience slower technology diffusion and weaker investor interest.

Bali Province exemplifies how strong local regulations, such as Governor Regulation No. 45 of 2019 on Clean Energy, can promote rooftop solar adoption and create a favorable environment for energy storage technologies like the Powerwall. In contrast, Central Java lacks specific policies for residential renewable energy, leading to stagnation in innovation and reliance on individual homeowner demand rather than systematic development. This comparison reinforces the conclusion that clear, progressive, and supportive regional regulations are crucial to accelerating the adoption of Powerwall technology. Well-designed local policies not only enhance energy efficiency and local energy independence but also lay the groundwork for building a sustainable and inclusive renewable energy ecosystem.

5.5 Leason Learned

The lessons learned from this paper indicate that technopreneur analysis and innovation systems are crucial components in assisting companies to identify and evaluate various challenges from multiple perspectives. This comprehensive understanding serves as a solid foundation for designing product development strategies that align with market needs and demands. The application of the Business Model Canvas (BMC) plays a strategic role in accelerating the adoption of Powerwall technology. However, the lack of diversified business models, such as leasing schemes, pay-as-you-go options, or integration with property sales, hinders the optimal adoption of Powerwall. Furthermore, expanding the customer segment by involving housing developers emerges as an effective strategy. By establishing partnerships with property developers, Powerwall products can be directly integrated into housing projects as part of renewable energy solutions, thereby broadening the customer base.

Open innovation through cross-sector collaboration involving universities, regulatory bodies, and industry partners is essential. Regulatory influence is a critical determinant of innovation success. This study reveals that the absence of progressive regulations can be a significant barrier. A comparison between Bali Province (which has pro-clean energy regulations) and Central Java demonstrates that regional policies strongly affect the ecosystem in adopting new technologies. Moreover, technological readiness alone is insufficient without market education. Even when technology and product quality are well-prepared, market success is not guaranteed without intensive and inclusive public education programs. Without such education, consumer resistance to new technologies remains high.

6. Conclusion

This article emphasizes that the commercialization of Powerwall technology requires more than just technological readiness. A systemic approach that integrates technopreneurship, open innovation, and business models relevant to local market conditions is essential. The case study of PT BATEX illustrates that the combination of technology push and market pull, if not supported by a conducive ecosystem such as favorable regulations, extensive market education, and adaptive business models, can cause advanced technologies to become trapped in the "valley of death."

The success of Powerwall depends not only on its technical performance but also on its ability to become part of a broader innovation ecosystem. The government plays a crucial role in creating a supportive environment through fiscal incentives, regulatory backing, and the integration of technology into national strategic programs. On the other hand, industry players and technopreneurs must actively foster open collaboration with various stakeholders to ensure sustainable and impactful technology adoption. This study provides both conceptual and practical contributions to the development of policies and commercialization strategies for renewable energy technologies in developing countries and serves as a foundation for further research on sustainable energy innovation systems in Indonesia.

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