ESTA JOURNAL
Energy Storage Technology and Applications

Article

jurnal.uns.ac.id/esta

Lessons learned of business strategy of supercapacitor battery and lithium-ion battery: A comparative study

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Received: 06-06-2024; Revised: 05-11-2024; Accepted: 04-03-2026; Published: 10-03-2026

ABSTRACT: The escalation of carbon emissions has accelerated the demand for sustainable energy storage solutions. One of the keys to this growth is understanding the business strategy of developing and implementing energy storage technologies such as lithium-ion batteries and supercapacitors. This is done by exploring the innovation and entrepreneurship system of a successful company as a business strategy lesson by providing technology commercialization research based on comparative research currently conducted by established battery companies. This research provides a holistic view of the successes and challenges in both batteries by analyzing the dynamics of market conditions and the latest developments in both batteries. This research utilizes a quantitative comparative method to provide complementary insights and ensure robust conclusions. This research resulted in a proposal for the manufacture of lithium-ion batteries and supercapacitors. On the other hand, this research can be used for start-ups in establishing businesses in the renewable energy industry. This research is a step forward in the literature gap regarding the sustainable transformation of energy storage as well as, providing a better view of the future prospects of both technologies in the energy storage industry.

Keywords: Comparative Study, Sustainable Energy Storage, Lithium-Ion Battery, Supercapacitor, Business Strategy.

1. INTRODUCTION

Indonesia's energy consumption continues to increase by around 7-8% every year. The majority of Indonesia's energy consumption, around 90%, comes from fuel oil (BBM). And the transportation sector's fuel consumption accounts for 88%. Indonesia's energy consumption deficit is expected to continue to widen. The combustion of fossil fuels leads to the accumulation of anthropogenic greenhouse gases (GHGs), contributing significantly to global climate change[1]. One way to reduce carbon emissions is to implement electric vehicles in the transportation sector. However, there are still many issues that need to be

further researched on the commercialization of electric vehicles, such as the selection of the right battery energy storage component. Battery component analysis is very important in the supply chain because one of the factors that can increase consumer interest is battery performance and durability [1]. Choosing the right battery technology is crucial to ensure that electric vehicles can compete effectively with existing internal combustion engine vehicles on the market. However, achieving commercialization of electric vehicles requires the right business strategy to adopt electric vehicles globally.

A global strategy is essential for a company to cover its entire network of subsidiaries and partners, it is implemented in many countries simultaneously and increases synergies in many countries [2]. Business strategy today involves determining the optimal strategic direction for a company's product and service offerings, as well as the market saturation and the degree of market saturation that exists as well as, the internal and external market environment in which, it is imperative that companies operate to consider the competition and most importantly the customer value proposition [3]. Central and local governments are pushing digitalization as a strategic priority to address the digital revolution, launch major projects, and increase public awareness of research as well as introduce new collaboration and funding models, while digitalization also opens up opportunities for research collaboration between academic institutions and industry. Startups, companies with less than 20 employees that operate digitally, are important in addressing technological challenges and opportunities, with the potential to create new innovations and shift the market paradigm from traditional to virtual according to the needs of the Millennial generation [4]. The World Economic Forum (WEF) has identified innovation as one of the pillars of measuring a country's competitiveness [5].

Start-ups are often associated with technology and innovation because as small companies, they can be agents of change and creators of innovation, and have the ability to adopt new technologies more quickly than large companies. As a result, rapid development and identification with technology characterize start-up companies due to their ability to innovate, adapt to new technologies, and capitalize on specialized market needs, supported by an enabling environment, strategic associations, and technology business incubators [6]. This paper provides a review of the commercialization of lithium-ion battery and supercapacitor technology innovations based on comparative research of the two batteries. Lithium-ion batteries and supercapacitors are two key components that play an important role in electric vehicles as the main power source. This study will provide an overview of the business model for commercialization of lithium-ion batteries and supercapacitors. This study provides priorities that can be used by technology-based startups to commercialize both batteries. This paper provides an overview of technology commercialization based on a comparative study of battery companies.

2. MATERIALS AND METHODS

Chapter 2 of this research will take an in-depth look at the methods and materials used in the development of hybrid energy storage systems based on lithium-ion batteries and supercapacitors. In this chapter, we will explain in detail the characteristics and advantages of each technology, as well as how these two

technologies can be integrated to create a more efficient and reliable system.

2.1 Resources and Capabilities

Several countries play an important role in the battery technology manufacturing industry and hold a significant share of the global market [7]. These countries are home to major battery manufacturers and often have well-developed supply chains and infrastructure to support large-scale battery production. Some of the major battery technology producing countries are China, Japan, South Korea, the United States, Germany, and India. These countries have major electric vehicle companies such as Tesla, Inc and hold a significant share of the global market [7].

The figure 1 illustrates that China is the country that has the highest rate of lithium-ion battery production in 2021. Several countries that are leading manufacturers of lithium-ion batteries also dominate the supercapacitor market. In China, the demand for supercapacitors is expected to grow at the highest growth rate in the world in the long term to achieve carbon neutrality by 2060. With the increasing demand in downstream market sectors such as electric vehicles, the overall market share is expected to reach super capacity in China will continue to expand [7]. Government policy support is encouraging many new players to enter the market. On the other hand, Japan is transitioning to electric vehicles, a trend that supports the transportation infrastructure vital to the country's economy.

Major Japanese automakers such as Toyota are collaborating with other companies such as Mazda to develop electric vehicle technology, including various electric cars. This is creating additional demand for supercapacitors. The supercapacitor market itself is highly competitive, dominated by a few large companies that have invested heavily in industry. With a focus on international expansion, these large companies are utilizing collaborative strategies to increase their market share and profits. Companies such as Eaton Corporation PLC, Maxwell Technologies Inc now owned by Tesla Inc, for that matter are some of the key players of the market [6].

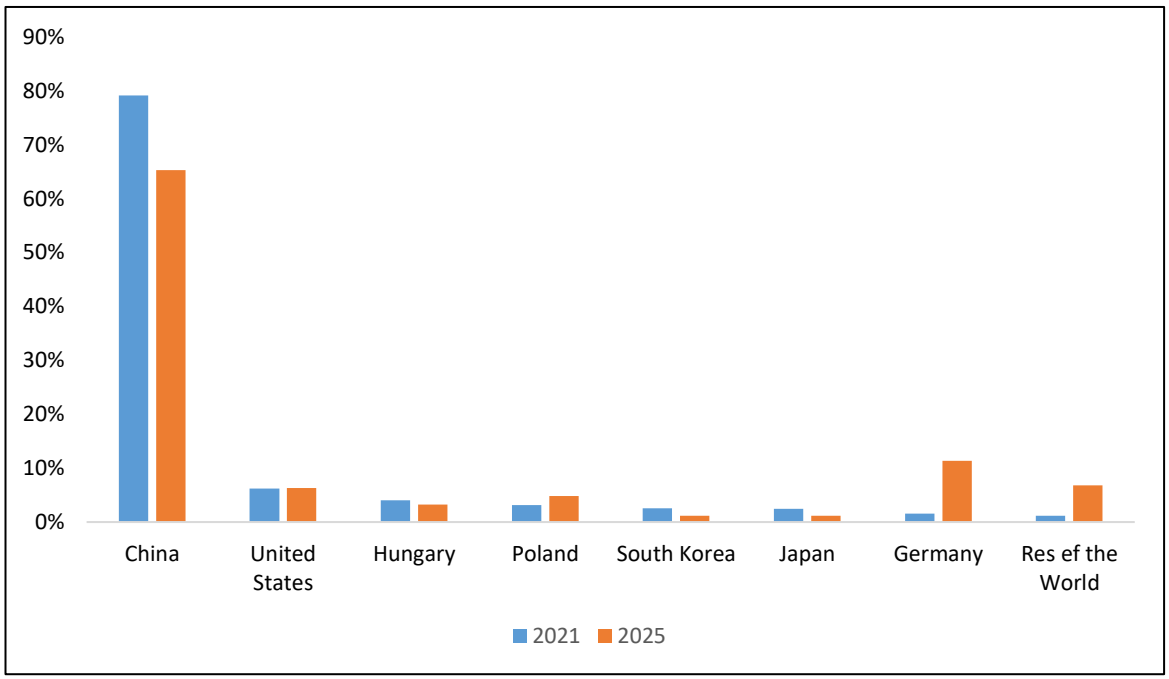

Figure 1. Countries with Battery Production Capacity 2021 - 2025

Figure 2. Lithium Ion Battery
(Source: Mordor Intelligence)

Figure 3. Supercapacitors
(Source: Mordor Intelligence)

The supercapacitor market is currently valued at $549.1 million. It is expected to reach a value of USD 1,114.60 million in the next five years, with a compound annual growth rate (CAGR) of 13.19% during this period [8]. Supercapacitors offer an alternative to conventional electric car batteries with the advantages of fast charging and better temperature stability. In addition, supercapacitors have greater flexibility than standard batteries. For example, Maxwell is developing lead-acid batteries integrated with supercapacitors to replace conventional car batteries [8].

2.2 Battery Materials

Lithium-ion batteries are currently the primary choice for use in electric vehicles. Several studies aim to improve conventional lithium-ion battery technology with a focus on improving energy density, durability, efficiency, and built-in safety [9]. To be the optimal choice for electric vehicles, batteries should have the properties of high energy density, light weight, resistance to high temperatures, high efficiency, high discharge rate, and guaranteed safety. In the energy storage system (ESS) there are 2 types, namely:

a. Lithium-ion Battery

Lithium-ion batteries are one variant of secondary batteries that are rechargeable and have environmentally friendly properties because they do not contain hazardous materials, such as those found in older batteries such as NI-Cd and Ni-MH batteries [10]. The advantages of these batteries are obvious compared to other secondary batteries, especially in their outstanding energy storage stability (capable of lasting up to 10 years or more), high energy density, no memory effect, and relatively lighter weight when compared to other types of batteries. Therefore, with the same weight, lithium-ion batteries are capable of producing twice the energy compared to batteries of other types [10]. To find out about the working principle of lithium batteries, it is necessary to table what are the constituent components of lithium-ion batteries.

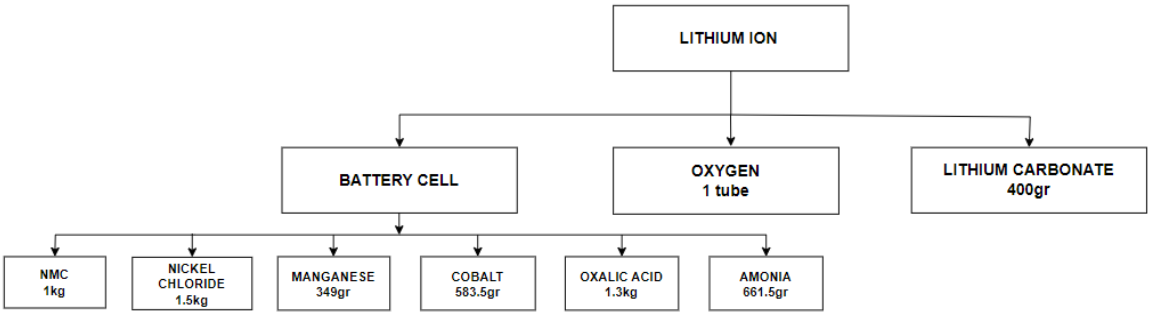

Figure 4. LIB Bill of Material Component Schematic

b. Supercapacitor

Supercapacitor is an energy storage device that has similarities to a battery [8]. Supercapacitors are derived from carbon technology, specifically carbon nanotubes. The carbon technology applied in these capacitors creates a very large surface area with a very small separation distance. Each supercapacitor consists of two electrodes immersed in a conductive solution or conductive polymer called an electrolyte. These electrodes are separated by a separator made of dielectric material. This separator not only serves to avoid charge overlap between the two electrodes, but also has electrical properties that affect the overall performance of the supercapacitor [8]. To find out about the working principle of lithium batteries, it is necessary to table what are the constituent components of supercapacitors.

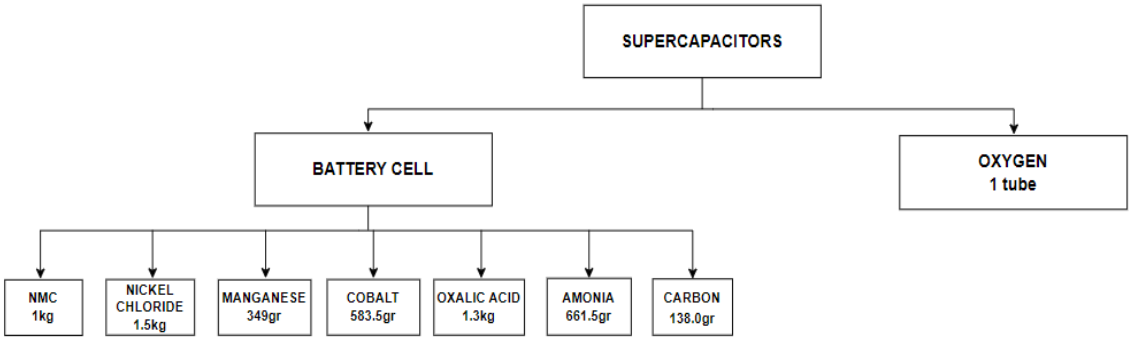

Figure 5. Schematic of Supercapacitors Bill of Materials Components

2.3 Formulation and Strategy

Each type of battery has several characteristics, when a user is about to select a particular type of battery, many factors must be considered. Aspects such as initial cost, lifetime, weight, volume, response to temperature, and charging time all play an important role in the battery selection process.

Table 1 is a table of characteristics of lithium-ion batteries and supercapacitors.

In this research, the analytical tool used to generate business strategy solutions is SWOT analysis which helps identify the company's strengths, weaknesses, opportunities and threats. By using SWOT analysis, this research can develop a more effective business strategy based on a thorough understanding of the internal and external factors affecting the business [11]. It involves determining the goals of a company or business project and

Table 1. Battery Characteristics

Characteristics	Lithium-Ion	Supercapacitors
Working Temperature	0 °C ~ 45 °C	-40 °C ~ 65 °C
Discharge Temperature	-20 °C ~ 60 °C	-40 °C ~ 65 °C
Charging Time	20 minutes ~ 2 hours	10 seconds ~ 5 minutes
Usage Age	3 ~ 10 years	18 - < 25 years
Specific Energy (Wh/kg)	150 ~ 300	2.5 ~ 15
Specific Power (W/kg)	1000 ~ 3000	500 ~ 5.000
Cost Per Unit of Energy ($/kwh)	$ 103 ~ $ 310	$ 100
Cost Per Unit of Power ($/kw)	$ 516 ~ $ 1,550	$ 134 ~ $ 532

identifying internal and external factors that are supportive and conducive to achieving those goals. The technique was invented by Albert Humphrey, who led a research project at Stanford University in the 1960s and 1970s, using data from the Company's [11]. SWOT Analysis Theory is a theory used to plan things related to SWOT. SWOT stands for, S is Strength, W is Weakness, O is Opportunity, and T is Threat. SWOT is often used to analyze the conditions under which a plan will be drawn up to implement a work program [11].

A battery is a device that converts chemical energy into electrical energy through electrochemical oxidation and reduction reactions [12]. One type of battery that is commonly used in Indonesia is a lithium-ion battery [13]. However, lithium-ion batteries have drawbacks such as limited energy capacity and limited lifespan, so they need to be replaced within a certain period of time. This forces old batteries that are almost out of power to be treated as e-waste and become a problem for the environment. The main source of raw materials for lithium-ion batteries is primary mining [14]. Supercapacitors thus form a complementary hybrid solution to lithium-ion batteries, helping to overcome the shortcomings associated with these battery technologies. The use of supercapacitors in combination with lithium-ion batteries can improve the overall performance of energy storage systems by overcoming some of the drawbacks of traditional battery technology [8].

Supercapacitors are efficient energy storage systems, capable of storing energy through electrical double layers and remote reaction [8]. Double layer capacitors (EDLCs) work by storing charge along the surface of the active material, providing highly durable performance over long periods of time. Therefore, increasing the surface area of carbon can improve the performance of EDLC supercapacitor devices. Supercapacitor technology is currently receiving considerable attention in the field of electrical energy storage, mainly because it has a higher energy density than conventional capacitors and a higher energy density than batteries [8]. Other benefits of supercapacitors include fast charging and long lifespan.

Supercapacitors as an energy storage medium that was previously limited to supporting batteries or fuel cells in hybrid energy storage, is now starting to be considered as a unique energy storage medium [8]. Several researchers have shown the potential of supercapacitors as the sole source of energy storage in electric vehicles, especially in Indonesia. It is technically feasible and has several advantages over batteries in terms of continuous operation, longevity and efficiency [8].

2.4 Methodology

Case studies are taken from lithium-ion batteries and supercapacitors that have developments in the commercialization of electric vehicle production, especially in electric motorcycles. The research methodology used to compare the strengths and weaknesses of both types of batteries as well as opportunities to be used as a strategy to deal with existing threats will help researchers understand the commercialization process of lithium-ion batteries and supercapacitors is strategic management. The strategic management process is a series of commitments, decisions, and actions necessary for an organization to achieve strategic competitiveness and achieve above-average profitability [15]. The strategic planning process includes inputs in the form of internal and external

environments that are incorporated into the vision and mission statements [16]. The first step is to analyze the condition of resources and capabilities on both batteries. From there, the vision and mission can be easily formed. The second step is to take strategic action where the strategies of both batteries are reviewed to identify lessons learned and analysis that will be a reference for future development. Next, the researcher analyzed the strategy formulation and implementation. Finally, the researcher outlines the strategic competitiveness of these two batteries to explain how to achieve above-average profits.

Figure 6 describes the development of lithium-ion batteries and supercapacitors that will be marketed to the public. Data was collected from several sources of research and information related to the development of these batteries. A literature search was also conducted using the keywords lithium-ion battery and supercapacitor from various scientific sources such as ScienceDirect, Elsevier and Google Scholar to collect data related to the two types of batteries.

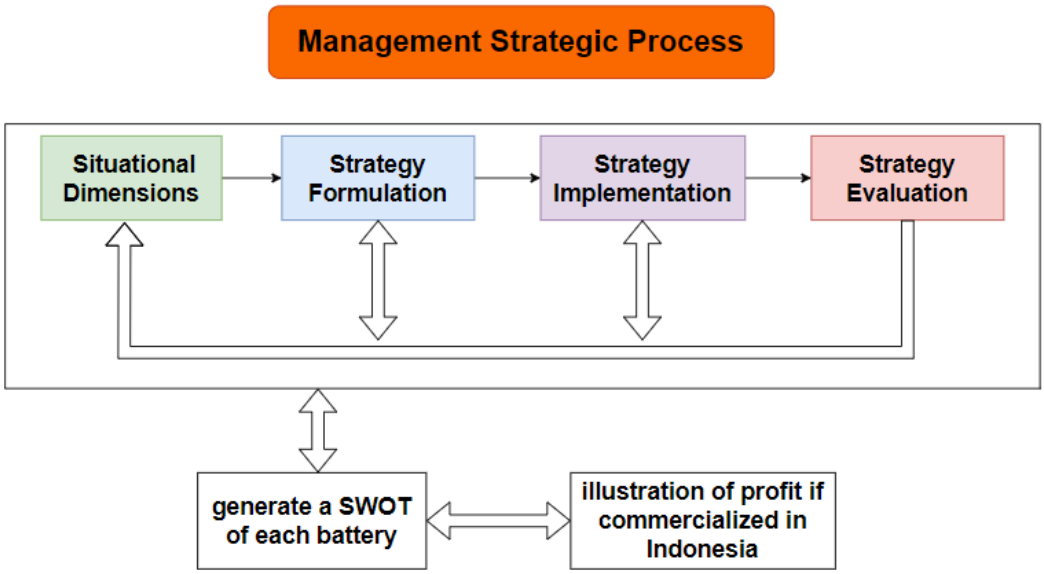

Figure 6. Management Strategic Process

3. RESULTS AND DISCUSSION

Having described the characteristics of lithium-ion and supercapacitor technologies, relevant conclusions can be drawn to build a SWOT analysis, thus enabling a more comprehensive assessment of their strengths, weaknesses, opportunities and threats in the specific application and market context. Therefore, a thorough understanding of the characteristics of each of these technologies can help develop more effective strategies in a competitive business environment.

To build a comprehensive SWOT analysis of lithium-ion battery and supercapacitor technologies, the key characteristics of these two technologies must be understood. Lithium-ion batteries have high energy density, long cycle life, and light weight, making them ideal for portable electronics and electric vehicles. The main raw materials used include Nickel Chloride ($NiCl_2.6H_2O$), Manganese Sulphate ($MnSO_4.H_2O$), Cobalt Sulphate ($CoSO_4.7H_2O$), Oxalic Acid, Lithium Carbonate (Li_2CO_3), and ammonia (NH_3). In the SWOT analysis, the main strengths of lithium-ion batteries are their high energy density and long cycle life. However, their weaknesses include complex measurement devices and a challenging

signal to noise ratio. Its opportunities include advanced fault detection capabilities and online diagnosis, while its threats are safety concerns due to high current and market acceptance challenges.

In contrast, supercapacitors offer high power density, long life, and a wide operational temperature range, making them suitable for applications that require fast charge and discharge cycles. Supercapacitors use the same raw materials as lithium-ion batteries, plus carbon to increase capacitance. The strengths of supercapacitors include environmental friendliness and high power density, but have drawbacks such as high cost and lower energy density. The main opportunities for supercapacitors are their use in hybrid electric vehicles and IoT applications. Threats include limited voltage range and the need for voltage balancing. With the abundant supply of nickel in Indonesia, there is a great opportunity to establish a domestic supercapacitor industry, support nickel downstreaming policies, and position Indonesia as a major player in the global electric vehicle industry.

Therefore, the abundant supply of nickel in Indonesia opens up opportunities for the establishment of a supercapacitor industry in the country. Therefore, Indonesia's natural resource potential could be a key factor in the development of the local superpower industry [7]. Reporting from the news, that currently, Indonesia's nickel ore production is indeed the largest in the world with 1.6 million tons in 2022. Then, a nickel downstream policy emerged to support the electric vehicle battery industry. Thus, Indonesia hopes to become a major player in electric vehicles in the world [7].

4. CONCLUSION

This research highlights that supercapacitors have significant technical advantages over lithium batteries, including fast charging, longer lifetime, and better resistance to charge and discharge cycles. In addition, the potential of supercapacitors as a hybrid solution with lithium-ion batteries has been demonstrated, providing an optimal combination of supercapacitor charging speed and lithium-ion battery energy storage capability. Given Indonesia's technical advantages and abundant nickel resources, the creation of a domestic supercapacitor industry could be a promising strategic move to support the development of sustainable new energy technologies. However, from an economic point of view, a deeper and more comprehensive study needs to be carried out, also considering aspects of lifespan, maintenance, and infrastructure.

ACKNOWLEDGMENT

We would like to thank Mrs. Silvi Istiqomah and Mr. Dominggu Bayu Baskara as Supervisors and Lecturers, Telkom University Examiners, and Mr. Dian Ahmad Pratama Bunayah Sudian as Research Respondents in the battery field at Sebelas Maret University (UNS).

AUTHOR CONTRIBUTION

Conceptualization, S.I. and D.B.B.; methodology, S.I..; software, S.I. and B.F.A.; validation, S.I. and D.B.B.; formal analysis, B.F.A.; investigation, B.F.A.; resources, S.I.; data curation, S.I. and B.F.A.; writing—original draft preparation, B.F.A.; writing—review and editing, S.I. and B.F.A.; visualization, S.I.; supervision, D.B.B. All authors have read and agreed to the published version of the manuscript.

REFERENCES

[1] Ahmad, D., Bunayah, P., Istiqomah, S., and Hisjam, M., 2021, Optimization of Network Design for Charging Station of Electric Car with Center of Gravity Method : A Case Study*, Proc. Second Asia Pacific Int. Conf. Ind. Eng. Oper. Manag.* Surakarta, Indonesia. Sept 14-16.

[2] Istiqomah, S., Sutopo, W., and Astuti, R. W., 2020, Lesson learned of business strategy for commercializing an e-motor cycle technology: A comparative study*, Proc. Int. Conf. Ind. Eng. Oper. Manag. Surakarta*, *Indonesia.* August *10 - 14*.

[3] Yeshitila, D., Kitaw, D., Jilcha, K., and Muchie, M., 2020, Situational and Mixed Business Strategy Analysis for Market Competitiveness: An Exploration in Context of Africa, *Int. J. Glob. Bus. Compet.*, 15 (2), 106–120.

[4] Saputra, T., Fajri, A., Rizky, M., Barokah, S., and Sutabri, T., 2024, Challenges and Opportunities in the Start-Up Ecosystem, *Indones. J. of Multidiscipl*., (1) 2, 164–170.

[5] Choeriyah, S. S., and Noviaristanti, S., 2021, University Innovation Ecosystem Model (Case Study in Bandung Techno Park), *J. Apl. Bisnis dan Manaj.*, 7 (2), 451–464.

[6] Khuan, H., Andriani, E., and Rukmana, A. Y., 2023, The Role of Technology in Fostering Innovation and Growth in Start-up Businesses, *West Sci. J. Econ. Entrep.*, 1 (3), 124–133.

[7] Dwiyono, A., Andreas Navalino, R. D., Yudho Prakoso, L., Manukallo Danga, C., and Widyastuti Wulaningsih, R., 2023, Indonesia's Economic Defense Strategy: The Nickel International Trade Dispute, *J. Econ. Bus. UBS*, 12 (3), 1830–1838.

[8] Lystianingrum, V., 2019, Supercapacitors as Alternative Energy Storage for Electric Buses in Indonesia: Potential and Challenges, *Researchgate*, Nov 10 - 30.

[9] Wijaya, N. M. A., Kumara, I. N. S., and Divayana, Y., 2021, Battery and Charger Development to Support Electric Bike Corrections in Indonesia, *J. SPEKTRUM*, 8 (1), 13 - 15.

[10] Maiorino, A., Cilenti, C., Petruzziello, F., and Aprea, C., 2024, A review on thermal management of battery packs for electric vehicles, *Appl. Therm. Eng.*, 238, 13594311.

[11] Octasylva, A., Nurida, N., and Mahardika, M., 2020, Marketing Strategy of PT Sari Melati Kencana Outlet ITC BSD using SWOT Analysis, *J. IPTEK*, 4 (1), 1–9.

[12] Tristiani, R. I., Amanda, D., and Dharmoputro, S., 2019, The Effect of Green Brand Positioning, Attitude Toward Green Brand and Green Brand Knowledge on Green Purchase Intention on Gesits Motorbikes in Jakarta City, *e-Proceeding Manag.*, 6 (1), 357–361.

[13] M. Thowil Afif and I. Ayu Putri Pratiwi, 2015, Comparative Analysis of Lithium-Ion, Lithium-Polymer, Lead Acid and Nickel-Metal Hydride Batteries for Electric Car Use - Review, *J. Rekayasa Mesin*, 6 (2), 95–99.

[14] Deni Cahyadi and Daniel Fajar Puspita, 2022, Urban Mining of Used Lithium Batteries as an Alternative Source of Lithium Battery Raw Materials, *J. Reksa Bumi*, 1 (2), 43–44.

[15] Kawuri, A. L., and Hisjam, M., 2023, Lesson Learned in Developing and Implementation a Global Business Strategy in Agriculture Companies: A Comparative Study, *Proc. Int. Conf. Ind. Eng. Ope. Manag*. Istanbul, Turkey, March 7 - 10.

[16] Srikandi, D., Hisjam, M., Asia, U. M., and Yogyakarta, D. I., 2022, Commercializing a Technology use

Global Business Strategy approach: A Lesson Learned from HVAC Companies, *Proc. Int. Conf. Ind. Eng. Ope. Manag*. Istanbul, Turkey, March 7 - 10.