POLITECNICO DI TORINO

Master's Degree in Management Engineering

Master of Science Thesis

Business Model Innovation in the Renewable Energy Storage Market: An Empirical Analysis of Leading Global Battery Energy Storage System Companies

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Abstract

The growing need to reduce dependence on fossil fuels has accelerated the global energy transition through sustainable energy sources. However, the intermittent nature of some renewable energy sources poses significant challenges in terms of continuity and reliability. In this context, energy storage technologies are emerging as key solutions to address these challenges, prompting companies to innovate their business models (BMs) in order to enhance competitiveness in a rapidly evolving market. The purpose of this study is to analyze how the leading players in the Battery Energy Storage Systems (BESS) sector are innovating their BMs and whether Cross-Industry Innovation (CII) dynamics are emerging in the process. This research draws on the academic literature that classifies Business Model Innovation (BMI) practices and examines the application of CII to BMs. Using publicly available information, an analysis was conducted on the BMI strategies adopted by 19 listed companies among the world's leading Energy Storage Systems players, according to Bloomberg's Energy Storage Tier 1 List (April 2024). The findings highlight the different approaches embraced by the companies and reveal the presence of CII dynamics in the implementation of BMI. The present study is not without its limitations. Notably, it is based on a limited sample of selected companies and relies on information from public online sources, which in some cases proved to be incomplete. The results contribute to the academic debate on BMI in the energy sector, offering new research perspectives on the correlation between the strategies adopted and their impact on companies in terms of competitiveness and value creation. Future research could benefit from a quantitative approach to examine the effects of the identified BMI practices on firm performance.

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Acronyms

aaS as-a-Service

AC Alternating Current

ARPA-E Advanced Research Project Agency-Energy

B2C Business to Consumer

BESS Battery Energy Storage System

BM Business Model

BMI Business Model Innovation

BMS Battery Management System

BNEF Bloomberg New Energy Finance

BTM Behind-the-Meter

C&I Commercial & Industrial

CI Cross Industry

CII Cross Industry Innovation

DOE Department of Energy

EBA European Battery Alliance

EPC Engineering, Procurement and Construction

EMS Energy Management System

ESA Energy Storage Association

ESaaS Energy Storage as a Service

EV Electric Vehicles

EU European Union

FERC Federal Energy Regulatory Commission

FTM Front-of-the-Meter

GEMS Greensmith Energy Management Systems

IEA International Energy Agency

IRENA International Renewable Energy Agency

ICE Internal Combustion Engine

ITC Investment Tax Credit

LCOS Levelized Cost of Storage

LFP Lithium Iron Phosphate

Li-ion Lithium Ion

NaS Sodium-solfur

NMC Nickel Manganese Cobalt

O&M Operation & Maintenance

PHS Pumped Hydro Storage

PPA Power Purchase Agreement

PPP Public-Private Partnerships

PV Photovoltaic

RBV Resource Based View

RES Renewable Energy Sources

SMES Superconducting Magnetic Energy Storage

SSB Solid State Battery

UPS Uninterruptible Power Supplies

V2B Vehicle to Building

V2G Vehicle to Grid

V2V Vehicle to Vehicle

VRFB Vanadium Redox Flow Batteries

1 The Evolution of Energy Storage

1.1 Introduction to Energy Storage

Energy storage technologies are undergoing a phase of rapid evolution, driven by the growing need for reliable and sustainable energy sources. Over the past decades, energy demand has significantly increased, fueled by factors such as industrial expansion, technological advancements, and global population growth. In fact, global energy demand rises annually by 1% to 2%, with a consistently upward trend, except for sporadic declines following periods of crisis, such as those that occurred in the early 1980s and in 2009 (Ritchie, Roser, & Rosado, 2020), as shown in Figure 1.

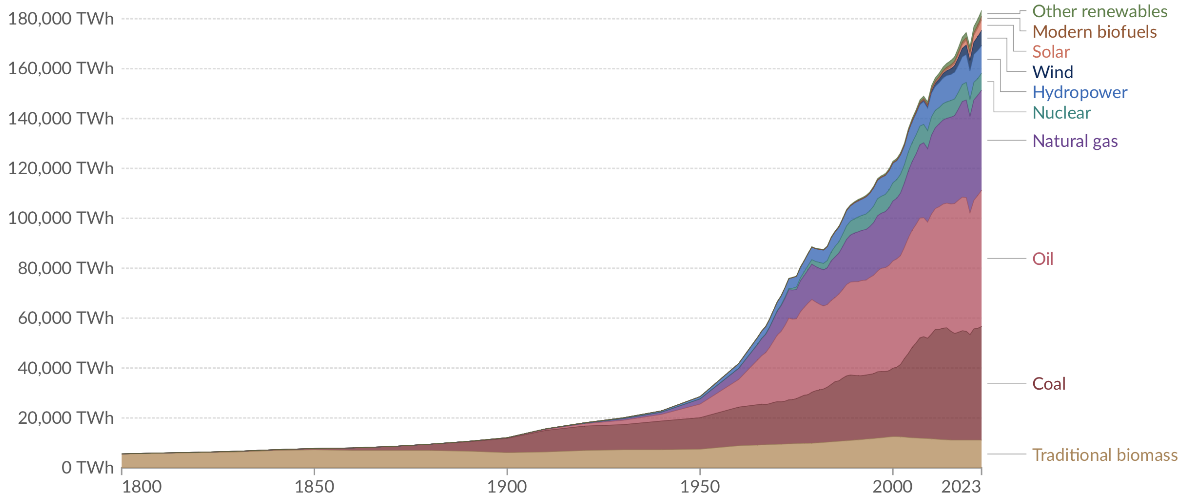


Figure 1: Global primary energy consumption by source (Ritchie, Roser, & Rosado, 2020).

This increase in energy demand places significant pressure on existing systems, which are often unable to respond sustainably and resiliently to modern needs (IEA, 2020). Moreover, awareness of the environmental consequences associated with fossil fuel use has created a global urgency to reduce carbon emissions and mitigate climate change, as evidenced by the growing number of global conferences on the topic and international agreements, such as the Paris Agreement. This agreement aims to achieve a 55% reduction in emissions compared to 1990 levels and to limit global warming to 1.5 degrees Celsius by the end of the century (European Parliament, 2019). This transition to a low-impact energy system is at the core of sustainable development policies, which are integrated strategies aiming to meet present needs without compromising the ability of future generations to meet their own. These strategies focus on balancing economic growth, social inclusion, and environmental protection (Brundtland Commission, 1987). In this context, the integration of Renewable Energy Sources (RES) has become critically important in national and international energy strategies, contributing to the reduction of fossil fuel use and encouraging the shift towards cleaner energy models.

The global renewable energy capacity is in a phase of rapid growth. According to the International Renewable Energy Agency (IRENA), by the end of 2023, the global renewable energy generation capacity had reached approximately 3,870 GW, marking a 13.9% increase compared to the previous year. This growth represents a net addition of 473 GW in renewable capacity. Solar energy led the expansion, contributing nearly 345.5 GW, followed by wind energy with an addition of 116 GW. Hydropower recorded a modest growth of 7 GW, while bioenergy and geothermal energy grew by 4.4 GW and marginally, respectively (IRENA, 2024).

Energy storage is used to meet various needs, including stabilizing electrical systems, managing demand peaks, and improving the efficiency of energy networks (Oxford Institute for Energy Studies, 2024). With the rapid increase in the adoption of RES, these needs have become even more critical. The integration of renewable energy into the grid presents challenges due to the variable and unpredictable nature of resources such as wind and sunlight. For example, wind energy production depends on wind patterns, while solar energy production is influenced by daylight and weather conditions (Rey et al., 2023). These factors cause fluctuations in energy supply, which can lead to grid instability and energy shortages during periods of low production. Energy storage systems help mitigate these challenges by storing excess energy generated during high-production periods and releasing it during low-production periods, thus balancing supply and demand and improving grid stability (Wei et al., 2023).

In addition to environmental and economic incentives, the push toward renewable energy and energy storage is shaped by a growing need for energy independence and long-term resilience, particularly in light of recent geopolitical tensions, such as the war in Ukraine (IRENA, 2023). These events have highlighted the risks of heavy reliance on imported fossil fuels, especially in regions like Europe, where energy security remains vulnerable to external disruptions. In fact, European countries have historically relied heavily on natural gas and oil imports from Russia, a dependence that has become increasingly precarious as the conflict persists. In 2021, over 40% of the European Union's gas imports came via Russian pipelines (Council of European Union). This situation has underscored the potential consequences of relying on energy sources controlled by politically unstable regions, prompting renewed urgency to secure alternative and local energy supplies. In response, European countries have accelerated renewable energy projects, not only to meet climate goals but also to reduce strategic dependence on external suppliers and build resilience against supply disruptions (European Commission).

Governments and private institutions worldwide have recognized the importance of large-scale energy storage technologies to support the transition to renewable energy. In the United States, large-scale storage has been identified as a critical technology for revitalizing the economy, ensuring national energy security, and achieving New Deal for Energy goals. The U.S. Department of Energy's Grid 2030 plan emphasizes the need for advanced storage solutions to meet future energy demands (Reihani et al., 2016). Similarly, Japan has prioritized energy storage as a security technology following the Fukushima nuclear disaster, promoting the implementation of storage systems through subsidies and policy initiatives (Li, Gao & Ruan, 2018). Europe, too, has embraced energy storage as a strategic sector, recognizing its potential to enhance energy grid stability and efficiency (European Commission), while China is ready to play a significant role in the sector's future development due to substantial investments and rapid expansion in battery manufacturing capacity. According to the International Energy Agency (IEA), China accounts for over 70% of global lithium-ion battery production capacity, positioning it as a leader in the energy storage market (IEA, 2024).

1.2 Different types of Energy Storage Systems

Energy storage systems can be classified into various types based on the technology employed. To provide a broader understanding of current solutions, the main types are briefly described below, focusing on the distinctive features that make each type of energy storage suitable for specific applications, along with their primary advantages and disadvantages.

1.2.1 Mechanical Energy Storage Systems

Mechanical energy storage includes technologies such as pumped hydro storage and flywheels. According to the International Hydropower Association, pumped hydro storage (PHS) is the most widely used large-scale energy storage technology globally, accounting for over 94% of the world's long-duration energy storage capacity (International Hydropower Association). It is a mature technology, used for decades to store large amounts of energy by pumping water to a higher elevation during periods of low demand and releasing it to generate electricity during periods of high demand (Pickard, 2012). Despite its widespread use, PHS faces challenges related to site selection, environmental concerns, and the development of advanced turbine technologies (Wei et al., 2023).

Flywheel energy storage, on the other hand, stores energy in the form of rotational kinetic energy. Flywheels are known for their long life, high energy density, and ability to provide high-quality energy. They are particularly suitable for applications in the aerospace industry and other services requiring high-quality energy. Flywheels can charge and discharge energy quickly, making them ideal for short-term energy storage and grid stabilization. However, their use is limited to specific applications due to their relatively low storage capacity compared to other technologies (Werfel et al., 2012).

1.2.2 Electrochemical Energy Storage Systems

Electrochemical energy storage systems, particularly batteries, have become one of the most widely used technologies for both stationary and mobile energy applications.

Lead-acid batteries, the oldest type of rechargeable battery, have been widely used for energy storage in small and medium scale systems. Their high charge/discharge efficiency and low operational costs (Luo et al., 2015) make them suitable for integration with renewable energy sources and for emergency power systems in telecommunications and data centers (Posada et al., 2017). However, lead-acid batteries face significant challenges, primarily related to their short lifespan and environmental impact. The disposal of lead and sulfuric acid, both toxic substances, raises environmental concerns that limit their sustainability (Zou et al., 2018). Efforts to improve the performance of lead-acid batteries focus on extending their lifespan and improving deep discharge capabilities. Additionally, research is ongoing to integrate this technology into renewable energy systems, particularly in applications such as wind energy and photovoltaic energy integration (Zou et al., 2018). Despite these efforts, the limitations of this type of battery, including their relatively short lifespan and issues related to hazardous waste disposal, continue to drive the development of alternative battery technologies.

Among the latest electrochemical energy storage systems, lithium-ion (Li-ion) batteries have emerged as a dominant technology due to their high energy density, long cycle life, and lower environmental impact compared to lead-acid batteries. These batteries are widely used in electric vehicles (EVs), portable electronics, and increasingly, in large-scale energy storage systems (Wang, Yi & Xia, 2012). Their advantages include fast charge and discharge capabilities, a relatively low self-discharge rate (i.e., the ability of a battery to maintain its charge over time with minimal loss), and high efficiency, with some Li-ion batteries achieving charge/discharge efficiencies above 95% (Wang, Yi & Xia, 2012). However, Li-ion batteries also present some challenges. They are subject to thermal runaway, which can pose safety risks, including fires or explosions. Additionally, the production of Li-ion batteries is expensive, and the extraction of lithium and other raw materials, such as cobalt, can have significant environmental and social impacts (Wang et al., 2012). It is expected that Li-ion batteries will play a key role in the future of energy storage, particularly with advancements in battery technology that improve safety, performance, and economic accessibility (Machín & Márquez F, 2024).

Sodium-sulfur (NaS) batteries represent another important electrochemical energy storage technology. These batteries have been successfully implemented in large-scale storage applications, particularly for grid-level storage and the integration of renewable energy sources (BASF Stationary Energy Storage GmbH, 2023). NaS batteries offer high specific energy, long operational life, and excellent charge/discharge efficiency, making them particularly suitable for applications requiring the storage of large amounts of energy over extended periods. For example, NaS batteries have been used in Japan to store excess energy generated by wind and solar plants, which is then released during periods of high demand or low generation (Colthorpe, 2023). However, NaS batteries also have some limitations. They require high operating temperatures to function effectively, which increases their operational costs and limits their applications to specific use cases. Additionally, safety concerns related to the highly reactive nature of sodium, which can ignite when in contact with air or moisture, must be carefully managed through the use of advanced containment and monitoring systems (Eng et al., 2021).

1.2.3 Electromagnetic Energy Storage Systems

Electromagnetic energy storage systems, such as Superconducting Magnetic Energy Storage (SMES) systems and supercapacitors, offer unique advantages for certain applications, particularly those that require rapid charge and discharge cycles and high power. SMES systems store energy in the magnetic field generated by a superconducting coil and can discharge energy almost instantaneously with minimal losses. This makes them ideal for applications that require high-quality power, such as grid stabilization and frequency regulation (Olabi et al., 2021). SMES also have the advantage of long operational lifetimes, as they do not suffer from the wear and degradation associated with chemical batteries (Wei et al., 2023). However, SMES technology is currently limited by the high cost of superconducting materials and the need for cryogenic cooling to maintain the superconducting state (Rong & Barnes, 2017).

Supercapacitors, another type of electromagnetic energy storage, store energy by accumulating positive and negative charges on two plates separated by an insulating material (Linder & Robinson, 2015). These systems have a much higher power density than conventional batteries, allowing for much faster charge and discharge cycles. However, they have a relatively low energy density, meaning they can store only small amounts of energy compared to batteries. This makes supercapacitors particularly suited for applications that require short bursts of power, such as in EV and renewable energy systems that need quick responses to changes in energy delivery (Wei et al., 2023).

1.2.4 Focus on Battery Energy Storage Systems (BESS)

In this work, the studies and analyses conducted below will primarily focus on a specific type of Energy Storage, the Battery Energy Storage System (BESS). To facilitate understanding of the upcoming chapters, a brief description of the components that make up a BESS, along with their respective functions, is provided below.

The main components of a BESS (Chatrung, 2019) are:

- Battery Modules: These are the fundamental units that store energy through electrochemical processes. There are different types of batteries that can be used, some of which were described in section 1.2.2.
- Power Conversion System (PCS): Its primary function is to manage the conversion of energy stored in the batteries, which is in direct current (DC), into usable energy for the grid or end applications, which is in alternating current (AC), through a device called an Inverter. Conversely, the PCS is also responsible for converting AC to DC when the batteries need to be charged, using a device called a Rectifier, which performs the reverse process of the inverter. The PCS helps maintain stable energy flow, minimizing issues such as voltage fluctuations or disturbances, and is crucial within the BESS, as without this component, the batteries could not interface with the grid efficiently and safely.
- Battery Management System (BMS): This system monitors and manages the performance, safety, and lifespan of the battery modules. Among the functions it performs, it tracks essential parameters such as voltage, current, and temperature of each battery module and provides real-time diagnostics to detect any anomalies or hazardous conditions. The BMS also plays a key role in maximizing energy efficiency and storage capacity.
- Energy Management System (EMS): The EMS oversees the entire operation, optimizing energy flows and ensuring efficient integration with other energy resources.

Figure 2 shows a schematic diagram of a BESS.

Moreover, BESS can be divided into three main segments based on application and scale (McKinsey & Company, 2023):

- Front-of-the-Meter (FTM) Installations: these are large-scale systems, typically managed by utilities, with a capacity usually exceeding 10 megawatt-hours (MWh). They are directly integrated into the electric grid to provide services such as frequency regulation, load balancing, and energy arbitrage.

- Behind-the-Meter (BTM) Commercial and Industrial Installations: designed for commercial and industrial users, these solutions have a capacity ranging from 30 kilowatt-hours (kWh) to 10 MWh. They are installed on the user side of the meter to manage energy consumption, reduce peak costs, and improve energy reliability.
- Behind-the-Meter (BTM) Residential Installations: smaller-scale systems, typically under 30 kWh, intended for residential use. They allow homeowners to store energy from renewable sources such as solar panels, providing backup power and optimizing energy consumption.

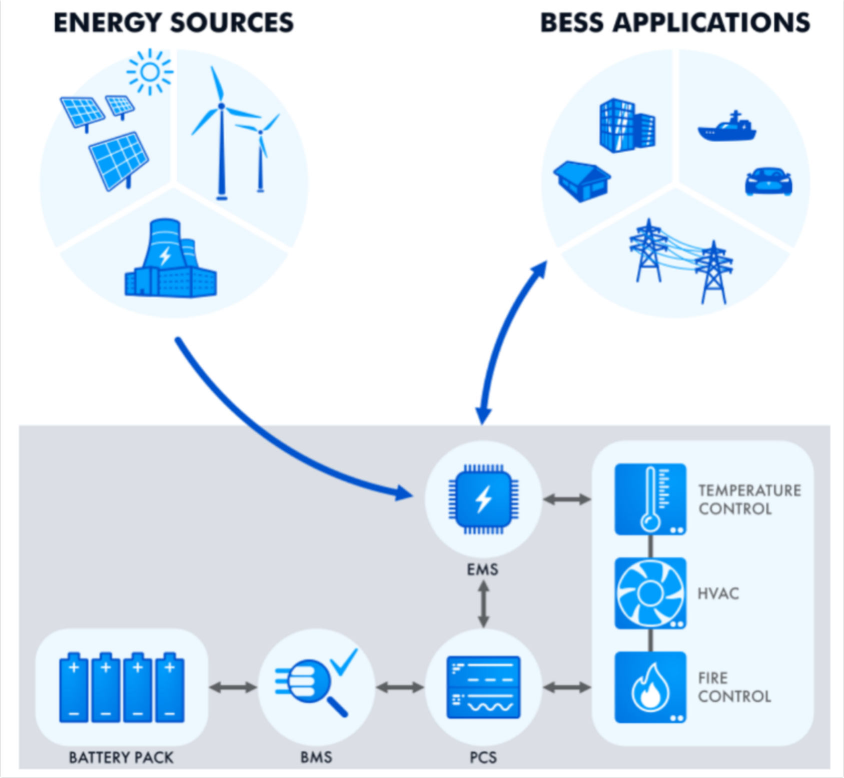


Figure 2: Battery energy storage system architecture (Solovev, 2021).

1.3 The Growing Importance of Energy Storage in Key Industries

Energy storage is emerging as a key element in sectors such as transportation, manufacturing, data centers, agriculture, and healthcare. These technologies address the unique energy requirements of each sector, promoting greater integration of renewable energy sources.

BESS offer numerous applications in the manufacturing sector, improving energy efficiency and reducing operational costs. Installing a BESS enables the reduction of energy demand peaks by using stored energy during low-demand periods, thus avoiding high costs associated with consumption peaks (peak shaving). Additionally, it allows energy consumption to be shifted from peak to off-peak hours, optimizing energy use and lowering expenses (load shifting). BESS also provide a reliable backup power source, ensuring operational continuity during grid outages (GoodEnough Energy). These applications are particularly valuable in energy-intensive sectors, such as steel production and chemicals, where grid stability is crucial to maintain continuous operations (World Steel Association; IEA).

Energy storage is proving equally transformative in the data center sector, where uninterrupted power is essential to keep servers operational. Energy storage systems, such as Uninterruptible Power Supplies (UPS) and large-scale batteries, ensure continuous operation in case of failures or grid outages. With the growing number of data centers driven by the expansion of cloud services and digital infrastructures, energy storage is being adopted to improve energy efficiency and integrate renewable energy sources, thereby reducing carbon footprints (Sagar, 2021).

In agriculture, BESS enable solar energy to be stored during the day and used during periods of high demand, ensuring a reliable and cost-effective energy supply. They also offer operational flexibility, allowing machinery to be used even during periods of low solar output. In rural areas with limited electrical infrastructure, BESS help overcome these challenges, ensuring operational continuity and optimizing energy resources (Farmers Weekly, 2024).

In healthcare, many medical devices, such as pacemakers, defibrillators, ventilators, and infusion pumps, require a constant energy supply to ensure optimal performance. In critical contexts where power outages could have severe consequences, battery storage provides a reliable emergency solution (FPR New Energy Technology). The healthcare sector could also generate new revenue streams by participating in ancillary services markets through BESS. This would contribute to the economic sustainability of the healthcare sector, which has faced financial challenges post-COVID-19, and support the transition to a net-zero future by 2050, enhancing energy system stability. This approach could also ease the pressure on public funding, improving the sector's environmental and economic sustainability (Bani Mustafa et al., 2021).

1.3.1 The Role of EVs in Energy Storage

In the automotive sector, oil consumption remains the primary driver of transportation systems worldwide. The IEA estimates that by 2030, even under a Net Zero Emissions by 2050 scenario, 80% of cars and vans will still be powered by internal combustion engines (ICEs). The increasing demand for oil (IEA, 2024), coupled with the progressive depletion of fossil fuel reserves (Energy Institute, 2024), has driven the development and adoption of alternative energy solutions, with EVs emerging as a viable option to address these challenges. EVs, powered by batteries, produce almost no tailpipe emissions and are significantly quieter than traditional vehicles with internal combustion engines (European Environment Agency, 2018). For these reasons, EVs have garnered significant interest from both industry and researchers as a clean and eco-friendly transportation solution, reducing dependency on oil.

The IEA forecasts that, under a scenario favorable to clean energy advancements, global oil demand could decrease by about one-third, reaching 66 million barrels per day by 2040, with the road transport sector accounting for over 60% of this reduction (Perkins, 2020). It is also estimated that by 2040, the global EV fleet could reach approximately 700 million units (Walz, 2023).

However, although EV usage offers many environmental and economic advantages, their large-scale adoption poses significant challenges to the existing electrical grid infrastructure. The introduction of a substantial number of EVs in concentrated areas leads to increased electricity demand, placing immense pressure on local grids. Since EVs require large amounts of energy for charging, this increased demand can cause voltage fluctuations, grid instability, and potential power supply shortages, particularly in areas with already high energy consumption. Furthermore, during periods of low demand, such as off-peak hours, excess energy generated often goes unused and is wasted (Bibak & Tekiner-Mog Ūlkoc, 2020).

To address these issues, technologies such as vehicle-to-grid (V2G), vehicle-to-building

(V2B), and vehicle-to-vehicle (V2V) have been introduced. V2G enables EVs to contribute energy back to the grid to stabilize supply, V2B allows EVs to provide renewable energy to buildings, while V2V facilitates energy transfer between two EVs. These innovations aim to enable bidirectional energy flow, where EVs not only draw energy from the grid but also return stored energy to the grid, power buildings, or recharge other vehicles. This helps balance supply and demand, providing a more stable energy system (Bibak & Tekiner-Mog Ūlkoc, 2020).

1.3.2 A focus on Vehicle-to-grid Technology

The rapid growth of EVs presents new opportunities for energy storage, particularly through V2G systems. Fundamentally, V2G technology allows EVs to act as mobile energy storage units, storing excess energy from the grid during periods of low demand and returning it to the grid during periods of high demand. This not only provides additional storage capacity and helps regulate voltage and frequency fluctuations, stabilizing the grid, but also balances supply and demand, improving the grid's overall efficiency (Bibak & Tekiner-Mog Ūlkoc, 2021).

EV owners can participate in V2G programs by charging their vehicles during off-peak hours, when electricity prices are lower, and selling the excess energy stored in their batteries back to the grid during peak periods at higher prices, thus generating a profit (Bibak & Tekiner-Mog Ūlkoc, 2020). However, despite the potential benefits of V2G technology, several barriers hinder its large-scale adoption. Among the main challenges are high initial costs, related to the need for substantial investments in bidirectional charging stations, communication systems, and energy management platforms to facilitate seamless integration and operation of V2G services (Bibak & Tekiner-Mog Ūlkoc, 2020), as well as concerns over battery degradation due to frequent charge and discharge cycles (Bhagavathy et al., 2021). Additionally, the stochastic nature of both EV usage and RES, such as solar and wind energy, introduces uncertainties that can affect grid reliability. Social concerns, such as issues related to privacy and the willingness of EV owners to participate in V2G programs, also play a role in the implementation of this technology (Au et al., 2014).

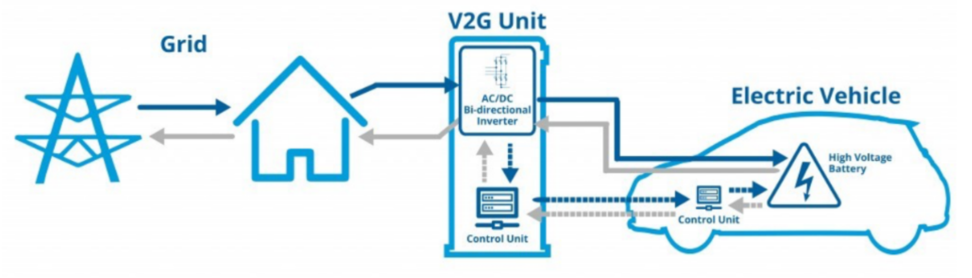


Figure 3: Schematic representation of V2G (Cleantech Group, 2019).

1.4 The Role of Policy and Regulation in Energy Storage Development

Although renewable energy policies have been widely adopted, BESS policies are a more recent development (Sani et al., 2020). These policies are essential to make energy storage a standard in households, businesses, and energy systems worldwide. One of the most critical aspects of energy storage policies concerns the regulation of electricity markets. In many regions, energy storage systems are not yet fully integrated into market structures, limiting their ability to provide essential services such as frequency regulation, demand response, and grid stabilization (Eller & Gauntlett, 2017). For BESS to reach its full potential, policymakers need to create an environment where storage systems can compete on a level playing field with other energy resources. This will unlock new opportunities for BESS deployment and enhance grid flexibility and resilience.

The Energy Storage Association (ESA) highlights three main areas of policy focus: increasing the value of BESS, facilitating access to storage systems, and creating new markets to foster competition (Cramer, 2017). To achieve these goals, various types of policies can be implemented by states. In particular, the Pacific Northwest National Laboratory has identified five main categories of state-level policies related to energy storage systems (Twitchell, 2019). These include:

- Procurement Targets: Mandating utilities to achieve specific implementation targets for energy storage systems;
- Regulatory Adjustments: Modifying existing energy regulations to remove barriers and encourage the adoption of these systems;
- Demonstration Projects: Funding and authorizing pilot projects to evaluate storage

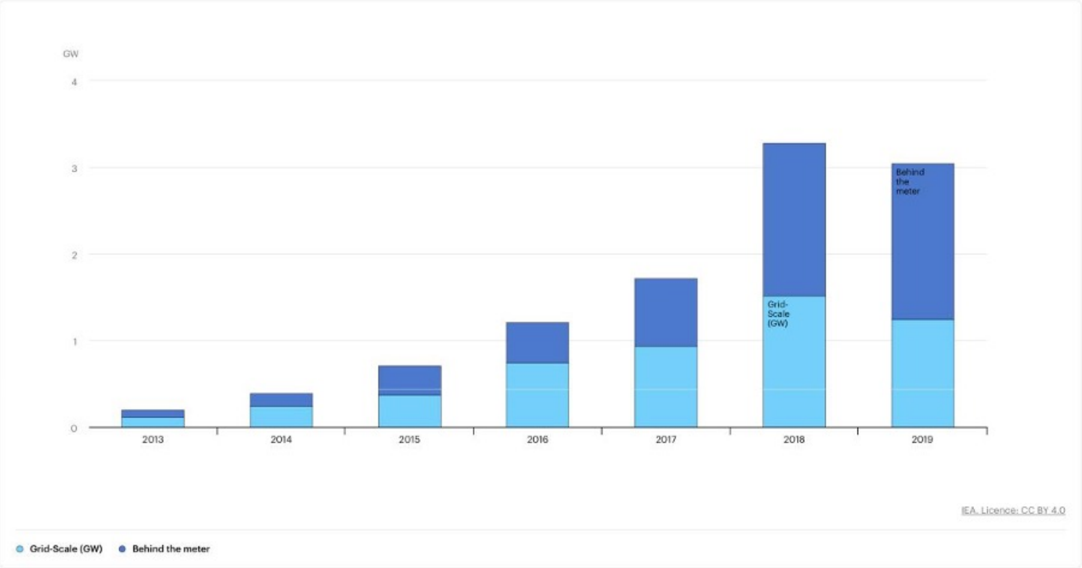
system performance;

- Financial Incentives: Providing subsidies and tax incentives for installed systems;
- Consumer Protection: Ensuring rights and protections for customers adopting storage systems through targeted policies.

In addition to these policies, regulations on battery recycling and disposal are becoming increasingly important, especially with the growth of electric vehicle markets. Ensuring environmentally responsible battery disposal and the sustainable sourcing of materials is a key objective for policymakers worldwide (Climate Foundation, 2023).

1.4.1 Impact of BESS Policy

The implementation of BESS policies has proven to have a substantial impact on the growth and deployment of storage technologies worldwide. One example is the period between 2013 and 2019, during which a significant global increase in BESS technology deployments occurred across various regions. The surge in installations during these years has been widely attributed to a combination of favorable policies, growing demand for renewable energy integration, and advancements in storage technology that made these systems more economically viable (Sani et al., 2020).



IEA. Licence: CC BY 4.0

Figure 4: Annual energy storage deployment, 2013-2019 (IEA, 2020).

However, by 2019, this upward trend experienced a slight slowdown, primarily linked to uncertainties and inconsistencies in regulatory frameworks across different markets. In several regions, the absence of clear and harmonized policies created confusion regarding the application and integration of energy storage systems into existing grids. Additionally, the complexities of aligning new technologies with outdated infrastructure and regulatory standards caused delays in the implementation of large-scale storage projects (Sani et al., 2020). Despite this temporary setback, the overall global trend continues to indicate an increasing reliance on energy storage as a key factor for low-carbon energy transitions. According to Statista (2024) data, the global increase in BESS capacity reached 74 GWh in 2023, and it is estimated that by 2030, growth could surpass the 400 GWh threshold, as shown in Figure 5.

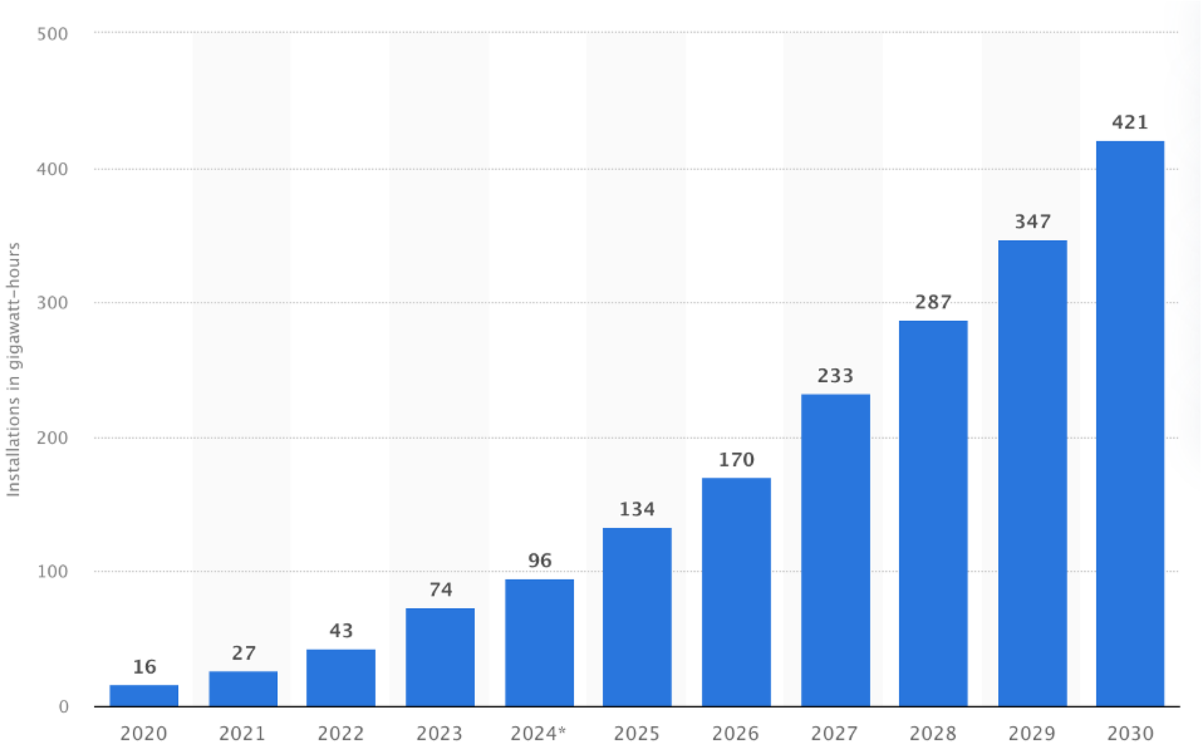


Figure 5: BESS capacity additions worldwide from 2020 to 2023, with forecasts to 2030 (Statista, 2024).

In the first half of 2023 alone, additional storage capacity reached 34.6 GWh (7.3 GWh for the residential sector and 27.3 GWh for large-scale power generation and the commercial and industrial sector), accounting for approximately 80% of the total capacity recorded in the previous year (43 GWh). It has been calculated that, regarding growth in the second half of 2023, China represented 43% of the global market, followed by the United States with 25.5% and Europe with 17%, collectively contributing 85.5% of the global growth recorded (Penny, 2023). This data reflects the regional dynamics characterizing the sector: China remains the global leader in lithium-ion battery production, supported by a highly vertically integrated supply chain (Wang, X., 2022) and strategic access to critical materials (Goldman Sachs, 2023). The United States stands out as a leader in technological innovation, driven by a dynamic ecosystem that fosters advanced research and the development of cutting-edge technologies (American Energy Society, 2020). Europe, on the other hand, is investing heavily in the research and development of innovative technologies, aiming to strengthen its production autonomy and reduce dependence on imports in the battery sector (Batteries European Partnership Association, 2024).

The following section provides an overview of the main BESS policies driving the adoption of these storage technologies to support renewable energy in Europe, the United States, and China. As described, these are the primary global markets driving adoption, offering a significant insight into the dynamics promoting large-scale deployment of storage systems.

1.4.2 Energy Storage System Policies Worldwide

The European Union (EU) has implemented a comprehensive policy framework to promote the development and integration of BESS as part of the transition toward a sustainable and resilient energy system. Among the key initiatives is the European Green Deal, which outlines the EU's strategy to achieve climate neutrality by 2050. This plan recognizes energy storage as a critical element for balancing supply and demand, ensuring grid stability, and supporting the integration of renewable energy (European Commission). In March 2023, the European Commission adopted a series of recommendations for the development of energy storage systems, analyzing the current EU regulatory, market, and financial framework for storage, identifying barriers and opportunities, and highlighting best practices to foster the sector's growth (European Commission).

The Battery Regulation, drafted in August 2023 by the European Commission, replaced the previous Battery Directive and aims to ensure that batteries have a reduced carbon footprint, use minimal harmful substances, and are effectively collected, reused, and recycled. This regulation supports the transition to a circular economy and strengthens the EU's strategic autonomy in battery production and recycling (European Commission, 2023). As early as 2017, through the European Battery Alliance (EBA), the EU emphasized sustainability, promoting the adoption of cleaner and more sustainable technologies, with a particular focus on electric vehicle markets (European Commission).

Several financial support measures have been introduced, including the Innovation Fund, which provides up to €10 billion in financial incentives for projects investing in technologies critical to the energy transition, including storage systems (European Association for Storage of Energy, 2021), and the Horizon Europe program, which allocates significant resources to energy storage projects. Notably, the BATT4EU partnership under Horizon Europe has allocated €925 million for collaborative battery projects for 2021-2027 (Batteries European Partnership Association). Additionally, various state aid schemes have been approved to support the deployment of large-scale energy storage systems. For example, the European Commission approved an Italian state aid of €17.7 billion to support the rollout of over 9 GW/71 GWh of storage capacity in Italy (Murray, 2023).

In the United States, energy storage regulation combines federal mandates with state initiatives to integrate storage into the energy market. At the federal level, the Inflation Reduction Act (IRA) of 2022 introduced significant tax incentives amounting to $370 billion to boost the BESS market (Jarbratt et al., 2023). The Federal Energy Regulatory Commission (FERC) has issued orders to facilitate BESS participation in electricity markets, such as Order 841 (2018), which requires regional transmission organizations and independent system operators to remove regulatory barriers for storage systems, enabling their participation in energy markets (Federal Energy Regulatory Commission, 2018), and Order 2222 (2020), which allows distributed energy resources, including BESS, to aggregate and participate in wholesale markets (Federal Energy Regulatory Commission, 2023).

The U.S. Department of Energy (DOE) has also allocated substantial funding for research, development, and demonstration projects related to energy storage technologies. Programs such as the Advanced Research Projects Agency-Energy (ARPA-E) and the DOE's Energy Storage Program focus on advancing BESS technologies and reducing costs (U.S. Department of Energy). At the state level, 23 states, along with the District of Columbia and Puerto Rico, are currently working to achieve a 100% clean energy target. Approximately 15 states have implemented specific policies to promote energy storage, including procurement targets, regulatory modifications, demonstration projects, economic incentives, and consumer protection measures. Moreover, some states have mandated the inclusion of energy storage in utility resource plans (Morgan Lewis, 2024).

China, which holds 38% of the global energy storage market (Zheng, 2024), set a target in its 14th Five-Year Plan (2021-2025) to install 30 GW of non-hydro energy storage capacity by 2025 (Murray, 2022). A noteworthy initiative requires new solar and wind projects to include energy storage systems, encouraging the deployment of BESS alongside renewables to enhance efficiency and reliability (Ng, 2022). For instance, the "Golden Sun" program launched in 2009 provided subsidies for photovoltaic projects integrated with storage systems, covering a significant percentage of total investment costs (International Energy Agency). China has also invested in several large-scale demonstration projects showcasing advanced energy storage technologies. One example is the world's largest flywheel energy storage system, with a capacity of 30 MWh, designed to test and promote innovative storage solutions (Maisch, 2024).

1.5 Barriers and challenges for BESS

The previous paragraphs described how the large-scale adoption of BESS represents a key element in the transition toward a sustainable energy future. However, numerous barriers and challenges hinder its widespread deployment. Among the main obstacles are the high costs associated with storage technologies, concerns related to performance and safety, and, importantly, the sustainability of these systems.

The upfront expense required to install energy storage systems, particularly large-scale systems, can be prohibitive. Although the cost of energy storage technologies has been steadily declining over the years, driven by advancements in battery technology and economies of scale, it is still not low enough to achieve widespread market penetration (Statista, 2024).

In the case of lithium-ion batteries, for example, the cost of raw materials such as lithium, cobalt, and nickel is a significant factor driving up production costs (Balakrishnan & Neef, 2023). Additionally, the complexity of manufacturing processes required to produce high-performance batteries further adds to their cost (Ghasemi et al., 2024). However, research is underway into alternative materials and production techniques that could reduce costs. For instance, sodium-ion batteries, which use more abundant and less expensive materials

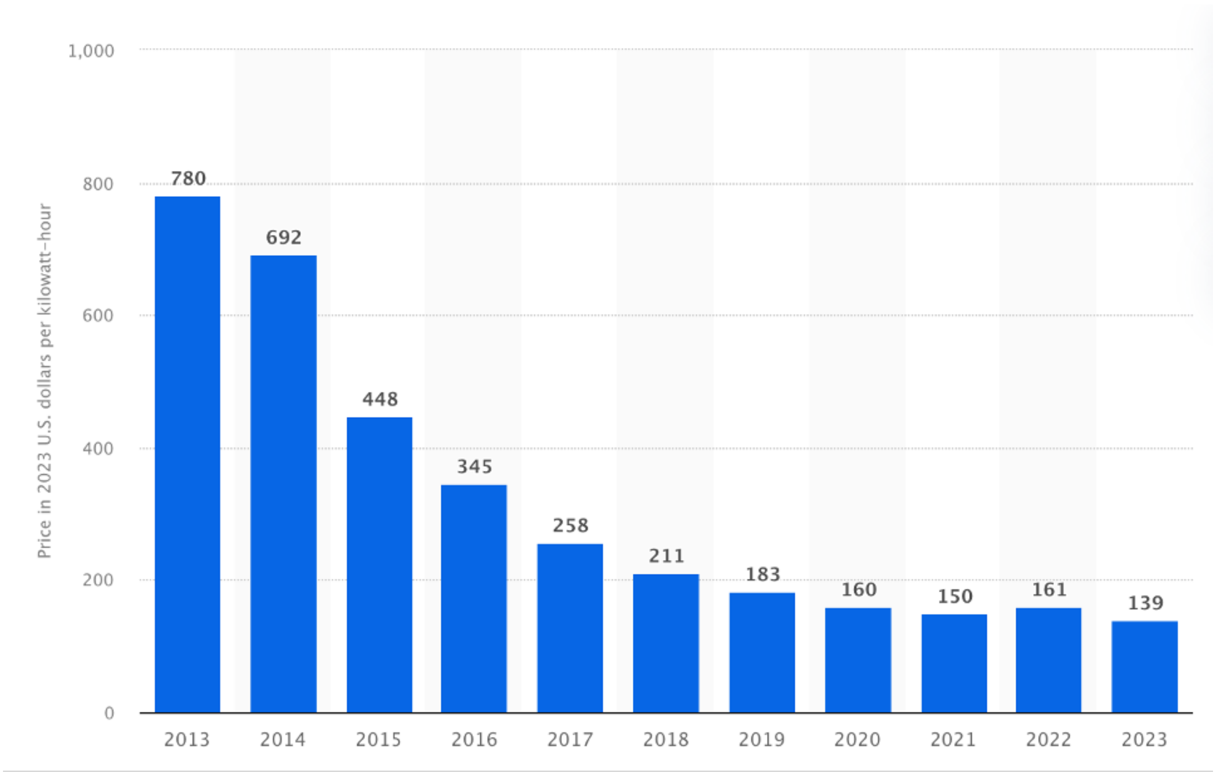


Figure 6: Lithium-ion battery price worldwide from 2013 to 2023 (Statista, 2024).

than lithium-ion batteries, may offer a more cost-effective solution (Gerald, 2024).

Performance and safety are critical concerns for energy storage technologies, especially when scaling up to meet grid demands. The performance of energy storage systems is influenced by various factors, including energy density, efficiency, and lifespan, which vary widely among different technologies, as described in paragraph 1.2. For example, while lithium-ion batteries offer high energy density, they face issues related to thermal runaway and degradation over time, which can lead to safety risks such as overheating and even fires (Wang et al., 2012).

From an environmental perspective, BESS play a crucial role in reducing greenhouse gas emissions and providing emergency energy during natural disasters (Sani et al., 2020). To enhance the sustainability of BESS, one approach is to develop more efficient recycling processes, particularly for lithium-ion batteries. Currently, the recycling rate for lithium-ion batteries is relatively low compared to other battery technologies, such as lead-acid batteries, which have an established recycling infrastructure—with a recycling rate of less than 5% in the EU for lithium batteries, compared to 99% for lead-acid batteries (Takefuji, 2024). However, advancements in recycling technologies and the implementation of stricter regulations on battery disposal could help improve the sustainability of lithium-ion batteries and other advanced battery technologies in the future.

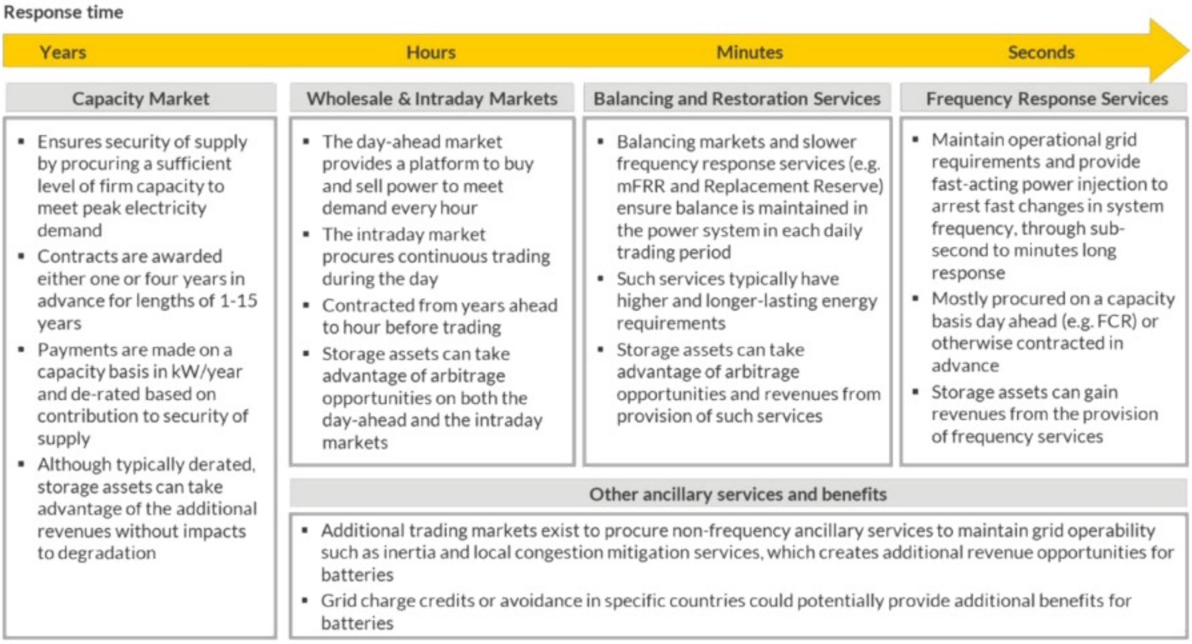
Alongside recycling, the concept of ”second-life” applications for used batteries is gaining traction. After their initial use in EVs or other high-demand applications, batteries retain a significant portion of their energy storage capacity. These used batteries can be repurposed for less demanding applications, such as stationary energy storage systems for homes or businesses (Ambrose, 2020). By extending the lifespan of batteries through second-life applications, the environmental impact of battery production and disposal can be significantly reduced.

1.5.1 Market Players and Strategies for competitiveness

In the competitive landscape of the BESS sector, key market players are adopting different strategies to maintain and enhance their market position. The incumbents in this market are companies with extensive experience in the energy and infrastructure industries. They are typically long-established battery manufacturers with significant expertise in producing batteries for industrial and consumer applications, with a strong presence in strategic sectors such as automotive and electronic devices (Ulrich, 2021). Their strength lies in leveraging synergies across these sectors (Terdiman, 2015; Kuhudzai, 2024). Moreover, leveraging their established market position, these companies can allocate greater resources to research and development (R&D) investments, which are essential for developing innovative technologies to improve battery energy density, lifespan, safety, and costs. For instance, Tesla increased its R&D investments by half a billion dollars from 2021 to 2022 and by one billion in 2023, reaching nearly $4 billion in investments (Macrotrends). However, technological innovations represent both an opportunity and a challenge. In fact, technological advancements, combined with large-scale production, reduce the costs of lithium batteries and other technologies, lowering barriers to entry and facilitating the entry of new players (Ziegler et al., 2021).

Additionally, the energy storage market represents a highly attractive opportunity for companies in the renewable energy sector, which are expanding their portfolios to include energy storage solutions to support the energy transition. In fact, to ensure an effective transition to green energy, it is essential to store the energy produced, as today’s most widely used renewable sources, while abundant, do not provide consistent production and require solutions to stabilize supply (Morris & Boshell, 2024). Investments in energy storage represent a strategic response, enabling the reduction of overall costs and accelerating the integration of renewables into energy grids. In this regard, Vic Shao, CEO of Green Charge Networks, a company specializing in energy storage, highlights how energy storage, especially in areas lacking centralized infrastructure, can enhance the power grid and, when combined with solar energy, ensure a reliable energy supply. He also notes that integrating solar energy and storage systems allows for the use of tax incentives, such as the federal Investment Tax Credit (ITC), reducing energy costs for consumers, particularly commercial and industrial users. This solution not only lowers monthly electricity bills but also addresses the challenges related to energy demand peaks (Renewable Energy World, 2016).

In a growing market like BESS (Mellow, 2024), incumbents must adopt various strategies to address increasing competition and remain competitive. First, these firms aim to expand their product range to meet diverse market needs (Liu, 2023) and diversify their revenue streams by participating in ancillary services, such as providing grid support for frequency balancing and rapid demand response (Oxford Institute for Energy Studies, 2024). Potential markets for energy storage and their average response times are illustrated in Figure 7.



Capacity Market

- Ensures security of supply by procuring a sufficient level of firm capacity to meet peak electricity demand
- Contracts are awarded either one or four years in advance for lengths of 1-15 years
- Payments are made on a capacity basis in kW/year and de-rated based on contribution to security of supply
- Although typically derated, storage assets can take advantage of the additional revenues without impacts to degradation

Wholesale & Intraday Markets

- The day-ahead market provides a platform to buy and sell power to meet demand every hour
- The intraday market procures continuous trading during the day
- Contracted from years ahead to hour before trading
- Storage assets can take advantage of arbitrage opportunities on both the day-ahead and the intraday markets

Balancing and Restoration Services

- Balancing markets and slower frequency response services (e.g. mFRR and Replacement Reserve) ensure balance is maintained in the power system in each daily trading period
- Such services typically have higher and longer-lasting energy requirements
- Storage assets can take advantage of arbitrage opportunities and revenues from provision of such services

Frequency Response Services

- Maintain operational grid requirements and provide fast-acting power injection to arrest fast changes in system frequency, through sub-second to minutes long response
- Mostly procured on a capacity basis day ahead (e.g. FCR) or otherwise contracted in advance
- Storage assets can gain revenues from the provision of frequency services

Other ancillary services and benefits

- Additional trading markets exist to procure non-frequency ancillary services to maintain grid operability such as inertia and local congestion mitigation services, which creates additional revenue opportunities for batteries
- Grid charge credits or avoidance in specific countries could potentially provide additional benefits for batteries

Figure 7: Markets for energy storage (Böhmer et al., 2023).

However, while the ancillary services market is an important source of revenue for energy storage resources, it is also subject to constraints. The increasing availability of storage systems is leading to the saturation of some ancillary services markets, which tends to lower the price of these services (Oxford Institute for Energy Studies, 2024). Firms can also increase their competitiveness through vertical integration, which involves control over the entire production chain. This comprehensive approach includes the sourcing of raw materials, the execution of production processes, and the management of distribution networks, ensuring better control over costs, quality, and product availability (Jarbratt et al., 2023). Geographic expansion is another important strategic approach for incumbents seeking to enter new markets, particularly in regions with significant growth in demand for renewable energy and energy storage. In the global scenario, China, already a world leader in renewable energy expansion, is expected to account for more than half of all new renewable capacity installed by 2030. The country has already exceeded its 2030 targets for solar photovoltaic and wind capacity (International Energy Agency, 2024). The United States is experiencing rapid growth in energy storage, particularly in states such as Texas and California, driven by greater integration of renewables and supportive policies (Ramkumar, 2024). The EU is making significant investments in renewable energy and storage solutions to meet climate goals. Countries such as Germany, Italy, and Spain are leading the way in residential battery installations and large-scale storage projects (Kou, 2023). India is rapidly expanding its solar and wind capacity, requiring improved energy storage solutions to ensure grid stability (McKinsey & Company, 2024). In Latin America, countries such as Brazil and Chile are experiencing significant growth in renewable energy projects, particularly solar and wind, driving higher demand for energy storage systems (Jaeger, 2023).

A highly effective strategy for renewable energy producers is represented by co-location, which involves installing storage systems, such as batteries, near renewable energy generation facilities like solar and wind plants. This approach enables the integration of production and storage, making it possible to store excess energy generated during periods of low demand and use it when demand is higher or renewable generation is insufficient. This ensures greater stability in energy supply and optimizes the use of existing infrastructure, improving operational efficiency and managing intermittent energy sources (Oxford Insti-

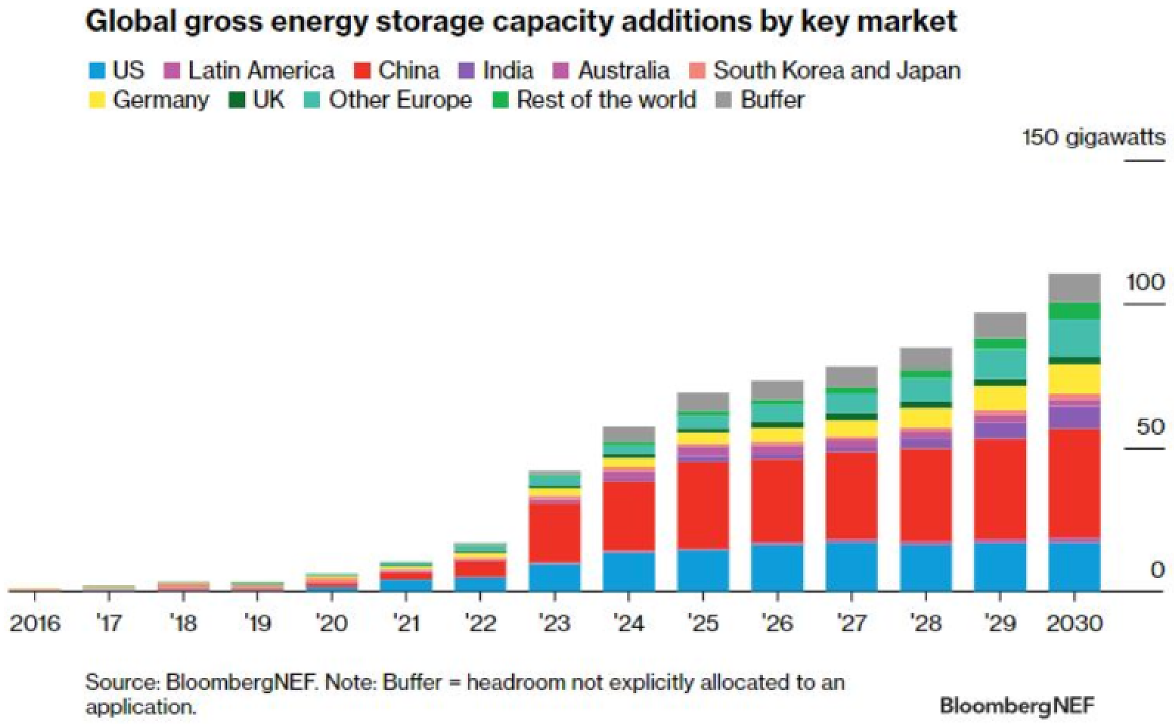


Figure 8: Global gross energy storage capacity additions by key market (Bloomberg, 2023).

tute for Energy Studies, 2024). Co-location also serves as a risk mitigation and revenue diversification strategy. For example, energy production from solar panels and energy stored in batteries have complementary operational cycles: solar panels primarily generate energy during midday hours when prices may be lower, while storage systems can be charged at low cost and discharged during periods of higher demand and prices, such as in the evening. This complementarity optimizes the use of grid connections without negatively affecting the operation of individual components. As a result, co-location supports a more stable energy supply and enables diversified revenue streams, increasing the economic resilience of the project and enhancing the operator's ability to manage market fluctuations (Oxford Institute for Energy Studies, 2024). However, the attractiveness of co-location depends on the investment costs in storage and the specifics of each market, such as renewable energy penetration, regulatory frameworks, and available markets (Oxford Institute for Energy Studies, 2024). In addition, this type of configuration allows for stable and predictable revenues through Power Purchase Agreements (PPAs). A PPA is a contract between an energy producer and a buyer that provides for the sale of energy at an agreed-upon price for an extended period of time. In co-location projects, PPAs can provide economic security to the producer, who benefits from a guaranteed revenue stream, and to the buyer, who secures energy at a stable and predictable price (Oxford Institute for Energy Studies, 2024).

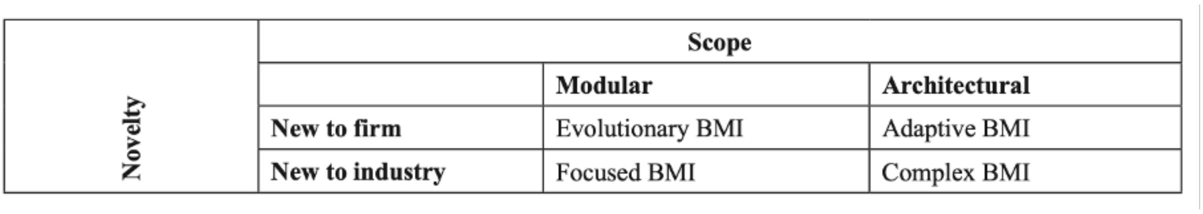
The subsequent chapter will present a literature review, examining theories related to Business Model Innovation (BMI) and introducing the concept of Cross Industry Innovation (CII). The third chapter will describe the methodology adopted for this research work, while the fourth chapter will present the main results obtained, highlighting the relationships and impacts resulting from the implementation of BMI in the energy storage sector. Finally, the fifth chapter will discuss these results in relation to the theoretical framework outlined, outlining the practical implications and possible directions for future research.

2 Literature review

2.1 Business Model Innovation

In the context of a rapidly evolving global economy, innovating the Business Model (BM) has increasingly emerged as a crucial source of value creation, positively influencing the performance of companies that implement it (Zott & Amit, 2007). Teece (2010) defines the BM as the *"design or architecture of the value creation, delivery, and capture mechanism"* of a company. Therefore, the BM must essentially be able to define who the customer is and what they want, how revenues can be generated in the relevant sector, and which economic strategy allows value to be delivered to customers while maintaining low costs (Magretta, 2002). The literature converges in recognizing the fundamental components that characterize a BM, such as: *"the firm's value proposition and market segments, the structure of the value chain required for realizing the value proposition, the mechanisms of value capture that the firm deploys, and how these elements are linked together in an architecture"* (Saebi, Lien & Foss, 2017). BMs are fundamentally important for companies, enabling them to transform new ideas into market opportunities and helping them to overcome the limitations associated with the introduction of specific technologies. A notable example of this is the invention of the first photocopier, whose production costs were so high that they hindered direct sales. The manufacturing company, Xerox, solved this problem by adopting a leasing model. This demonstrates that technologies do not possess inherent economic value, but gain value through the design of appropriate BMs that allow investments in research and development to be converted into tangible market value (Massa & Tucci, 2013). In fact, Chesbrough (2007) states that *"a better business model beats a better idea or technology"*, arguing that BM innovation can play a more strategic role than other types of innovation. Innovative BMs can therefore represent a disruptive element (Christensen, 1997), revolutionizing how entire industries operate and redefining their dynamics (Magretta, 2002). In this sense, BMs become effective tools through which companies can compete (Casadeus-Masanell & Ricart, 2007), even in mature industries (Zott & Amit, 2007). Since the early 2000s, corporate top management has begun to explore the sphere of Business Model Innovation (BMI), with a growing number of studies focusing on this concept. BMI can be interpreted as an evolutionary extension of the BM, as it introduces significant changes to its core components or their interactions to generate new value (Foss & Saebi, 2017). Foss & Saebi (2017) define BMI as *"designed, novel, and nontrivial changes to the key elements of a firm's BM and/or the architecture linking these elements"*. They also state that, considering the BM as a complex system (Fleming, 2001), any modification to its components – within a context where these elements are tightly interconnected – inevitably leads to a change in the overall architecture of the BM. In this regard, Porter and Rivkin (1998) further argue that a BMI integrating numerous highly interconnected elements is more likely to represent a source of sustainable competitive advantage compared to a BMI characterized by lower interconnection, as the level of causal ambiguity is significantly higher in the former case. However, the literature presents significant ambiguity regarding the interpretation of BMI. Indeed, Foss and Saebi (2017), through a literature analysis, pointed out that BMI is often considered both as a process (e.g., research, experimentation, transformation) and as a result, meaning the innovative BM itself. Moreover, the authors highlighted a disagreement on the nature of innovation: some perspectives focus on individual components of the BM, such as the value proposition or customer segments, while others emphasize the overall architecture and the relationships between its components.

Foss and Saebi (2017) classified different types of BMI based on two criteria: Scope, referring to the extent of the changes made – distinguishing between modular and architectural modifications – and the degree of Novelty, depending on whether the changes are new to the individual company or to the entire industry. This distinction allows for the identification of four specific types of BMI, as illustrated in the following figure.



Novelty	**Scope**		
		Modular	**Architectural**
	New to firm	Evolutionary BMI	Adaptive BMI
	New to industry	Focused BMI	Complex BMI

Figure 9: BMI Typologies (Foss & Saebi, 2017).

Evolutionary BMI represents a process of gradual improvement, characterized by voluntary or spontaneous changes to the BM's individual elements (Demil & Lecocq, 2010), while Adaptive BMI involves modifications to the entire architecture of a company's BM. According to Teece (2010), this type of innovation occurs when a company reorganizes the structure of its BM to adapt to changes in the external environment, such as competitive pressure arising from a new BM in the market. Focused BMI and Complex BMI, on the other hand, are characterized by modular or architectural changes to the BM, respectively, introducing innovative elements for the entire industry.

2.2 Antecedents of BMI

The reasons driving BMI can be numerous, heterogeneous in nature, and distributed across various internal and external levels of the firm (Foss & Saebi, 2017). The literature highlights that changes in BMs are often driven by transformations in the external environment, such as the evolving needs of stakeholders (Ferreira et al., 2013). Generally, in the early stages of a market, customers tend to demand products with innovative features and functionalities, pushing companies to compete primarily through product innovation. Once these needs are met, the focus shifts toward quality and reliability, turning innovation into a process-oriented factor. Subsequently, when these aspects reach satisfactory levels, customer value derives from convenience, personalization, and eventually cost reduction (Massa & Tucci, 2013). Johnson (2010) suggests that it is in this market maturity phase that managers should prioritize BMI. Among the antecedents of BMI are changes in the competitive environment (de Reuver et al., 2009), new opportunities generated by information and communication technologies (Pateli & Giaglis, 2005; Wirtz et al., 2010), as well as significant shifts in regulations and government policies (Massa & Tucci, 2013). Moreover, since BMI varies in terms of scope and degree of novelty, the antecedents driving evolutionary or adaptive innovation may differ from those fostering more complex and radical forms of innovation (Foss & Saebi, 2017).

2.3 Potential benefits of BMI on Firm Performance

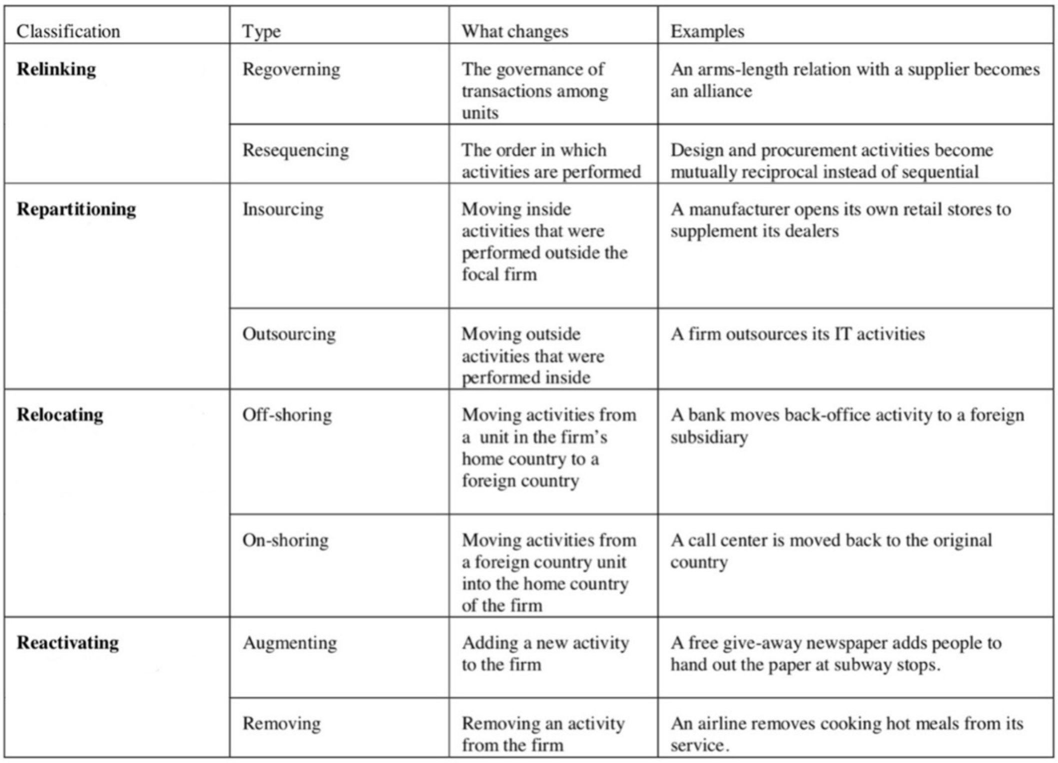
According to Porter's theory, a company's competitive advantage is based on structural industry factors such as entry barriers, rivalry among competitors, and mobility constraints. These factors, according to Porter (1985), determine a firm's strategic position and its ability to protect itself from competition, enabling it to achieve superior performance. This implies that, to improve its performance, a company should operate in advantageous industries characterized by high entry barriers and difficulties in imitation. The Resource-Based View (RBV) offers a different perspective, emphasizing a company's specific resources and capabilities as the primary source of competitive advantage. According to the RBV, these resources – also known as VRIO resources (Barney, 1997) – must be valuable, rare, inimitable, and non-substitutable to ensure superior results and a distinctive market position (Barney, 1997; Wernerfelt, 1984). Porter's theories and RBV are valid tools for analyzing competitive advantage. However, they do not prove sufficient to explain discrepancies in performance outcomes between similarly resourced firms operating in the same industry (Lanzolla & Markides, 2021). This theoretical limitation underscores the need to consider alternative perspectives that can interpret these dynamics. In this context, BMI emerges as a more effective approach to understand how firms can create and sustain competitive advantage through innovation of their BMs. This thesis will, therefore, focus on the analysis of BMI, leaving out a detailed exploration of the traditional theories mentioned above, which are referred to only to contextualize the relevance of this approach. Concrete examples of these dynamics can be observed in the case studies of Zara and H&M, as well as Canon compared to IBM and Kodak. Zara and H&M, for instance, both operate in the fast fashion sector, where "resources and capabilities such as workforce, location, and IT systems are widely available" (Lanzolla & Markides, 2021); however, they achieve different performance outcomes. The explanation lies in the fact that Zara developed a vertically integrated BM, whereas H&M relies on outsourcing and partnerships with third parties (Markides, 1997; Zott & Amit, 2010). In the photocopier market, Canon, IBM, and Kodak all adopted a second-mover strategy in response to pioneer Xerox, however only Canon emerged as a leader. Similarly, while IBM and Kodak replicated Xerox's model by targeting large companies, focusing on copy speed and direct sales, Canon chose to target small and medium-sized enterprises, emphasizing cost efficiency and quality while leveraging an existing network of dealers. In both cases, the winning factor was placing BM design at the core of the company's strategy (Markides, 1997; Markides & Geroski, 2005; Porter, 1985; Shankar et al., 1998). Supporting the BM's impact on corporate performance, a study conducted by Sohl, Vroom, and Fitza (2020) on a sample of 917 European retail companies, analysed over the period 2005–2016, quantified the influence of the BM on ROA's and market share's variance (5.1% and 7.9%, respectively). The results highlighted a significant correlation between the adopted BM and the company performance. This relationship, according to Lanzolla and Markides (2021), becomes stronger in contexts characterized by similar resources and capabilities and low barriers to imitation. BMI, as empirically demonstrated by Amit and Zott (2008), differs from simple product differentiation, and simultaneously interacts complementarily with product innovation, jointly enhancing business performance. Although improving processes and products often requires substantial resources, long timeframes, and significant investments – such as in R&D, specialized resources, new assets, or entire operational units – the economic returns from these efforts remain uncertain (Amit & Zott, 2010). Moreover, while it is relatively easy for competitors to imitate an innovative product or process, replicating an entire system of organizational activities is significantly more complex. According to the two researchers, this makes BMI a more sustainable strategy for achieving long-term competitive advantage. Indeed, managers can explore ways to maximize the value of already available resources and capabilities by innovating within existing markets and products through BMI. Despite involving costs related to organizational changes or new strategic partnerships, BMI can prove to be more cost-effective, especially during economic downturns when resources to fund significant R&D are limited (Amit & Zott, 2010). This is because it allows companies to leverage existing internal knowledge, thereby reducing the need to acquire new external competencies (Santos et al., 2009). The process of value creation through BMI can, in fact, be considered a form of " *"lean value creation"* (Santos et al., 2009). Amit and Zott (2010) also argue that in times of severe economic pressure, there is a greater willingness to challenge the status quo and embrace organizational change.

2.4 Type of strategies for BMI

After outlining the general meaning of BMI and its potential effects, this paragraph will describe the concrete actions that companies can take to innovate their BM. Through the analysis of practical examples and real-world cases, the strategies that can be adopted and the results they have generated in certain situations will be illustrated. Santos, Spector, and Van Der Heyden (2009) identified several strategies that enable BMI and grouped them into four main categories:

- Relinking: involves a transformation in the relationships and interactions between organizational units that perform specific activities;
- Repartitioning: is implemented by modifying the physical, cultural, or institutional boundaries that define the organizational units responsible for activities;
- Relocating: entails a change in the physical, cultural, or institutional distance between the organizational units performing the activities;
- Reactivating: involves an adaptation or transformation of the set of activities that make up the organization's current BM.

Figure 10 presents the four categories identified by the authors and highlights various actions that can be implemented for each. The theory proposed by Santos, Spector and Van Der Heyden (2009) has been supported by the analysis of several case studies. Some of the examples discussed by the authors are presented below to illustrate both the practical implications and the potential applications of the models addressed.



Classification	Type	What changes	Examples
Relinking	Regoverning	The governance of transactions among units	An arms-length relation with a supplier becomes an alliance
	Resequencing	The order in which activities are performed	Design and procurement activities become mutually reciprocal instead of sequential
Repartitioning	Insourcing	Moving inside activities that were performed outside the focal firm	A manufacturer opens its own retail stores to supplement its dealers
	Outsourcing	Moving outside activities that were performed inside	A firm outsources its IT activities
Relocating	Off-shoring	Moving activities from a unit in the firm's home country to a foreign country	A bank moves back-office activity to a foreign subsidiary
	On-shoring	Moving activities from a foreign country unit into the home country of the firm	A call center is moved back to the original country
Reactivating	Augmenting	Adding a new activity to the firm	A free give-away newspaper adds people to hand out the paper at subway stops.
	Removing	Removing an activity from the firm	An airline removes cooking hot meals from its service.

Figure 10: BMI Types (Santos, Spector & Van Der Heyden, 2009).

2.4.1 Relinking

Relinking, which involves reorganizing the relationships between business activities, can manifest in various ways, including regoverning, which redefines the governance of transactions between business units, and resequencing, which consists of altering the order in which activities are performed (Santos et al., 2009). A prime example of regoverning was observed at Lufthansa in the early 1990s when the company faced a severe crisis and the risk of privatization. The CEO Jürgen Weber led a significant transformation of the BM, transitioning the company from a strictly integrated model focused solely on air transportation to a group structure composed of five autonomous business units: Passenger Transportation (Lufthansa AG), Logistics (Lufthansa Cargo AG), Catering (SkyChefs AG), Systems (Lufthansa Systems AG), and Airline Maintenance (Lufthansa Technik AG). This reorganization redefined the governance of transactions between units, turning them into independent entities with specific goals and clear responsibilities. Thanks to this strategy, Lufthansa achieved extraordinary results in the following years, solidifying its position as one of the most profitable airlines in the world, with each business unit becoming a leader in its sector. Another relevant case is the one of Zara, the fashion brand which revolutionized the traditional BM of the fashion industry through resequencing. Traditionally, industry processes began with designers creating collections, followed by production and distribution to stores, with lead times that could exceed 12 months. Zara radically changed this sequence by making market analysis and customer preferences the starting point. By monitoring fashion trends through international events and collecting data from stores via store managers, Zara turned consumer demand into the foundation for design, production, and distribution decisions. This pull strategy allowed the company to respond rapidly to emerging trends, coordinating activities within a few weeks. The result was not only the disruption of the traditional industry model, but also the creation of the fast fashion concept, later adopted by companies like H&M, which made it a cornerstone of their strategy.

2.4.2 Repartitioning

Repartitioning involves redefining the boundaries of business activities. This can occur through insourcing, which brings previously outsourced activities in-house, or outsourcing, which involves delegating internal activities to third parties (Santos et al., 2009). Although both strategies can offer opportunities to improve efficiency and competitiveness depending on the context, they do not always lead to the desired outcomes. While BMI represents a powerful transformation tool, its results can vary based on the quality of planning and execution. To demonstrate this, two examples for each repartitioning strategy – one successful and one unsuccessful – will be analyzed. In the late 19th century, American entrepreneur Richard Sears adopted insourcing to transform his watch-selling business. Initially, he purchased fully assembled watches from external manufacturers, but he realized that profits could be increased by purchasing components and assembling the watches in-house. He hired A.C. Roebuck, an expert watchmaker, to manage this operation. Sears later internalized sales operations by eliminating independent agents, who represented a significant cost. These decisions allowed him to increase profitability and gain greater control over the entire process. An unsuccessful case of insourcing is represented by Joplin Clinic, a multi-specialty medical center in Missouri, which attempted to improve its competitiveness by insourcing two small family medicine practices located in affluent suburbs. The goal was to increase internal referrals to its specialists, thereby generating more revenue. However, the acquired physicians continued referring patients to external specialists, and internal referrals remained negligible. This failure highlights how insourcing, without effective integration and management, may not achieve the expected results. On the other hand, Embraer, a leading Brazilian aircraft manufacturer, revolutionized its BM in the commercial aircraft sector through strategic outsourcing. To reduce costs and improve efficiency, Embraer outsourced design and production activities to local and international suppliers, many of whom were former Embraer employees. Significant aircraft components, such as wings, were produced by foreign suppliers. This strategy allowed Embraer to focus on design and assembly while maintaining overall process control and leveraging external expertise. Thanks to this configuration, Embraer became the fourth-largest aircraft manufacturer in the world and the leader in regional jets. By contrast, Auratek, a data storage device manufacturer, decided to outsource its verification group to Bangalore, India, aiming to save about $2 million annually. However, this decision led to numerous issues. Cultural and language barriers between the Indian and American teams, combined with time zone differences, caused misunderstandings and delays. Poor communication resulted in product errors and increased defects, damaging the company's reputation. Internally, the decision negatively impacted employee morale. Of the original 33 engineers in the verification group, only six remained to coordinate with the external team. Many lacked the necessary skills or motivation for their new roles. Despite incentives like stock options and bonuses, four of them resigned, leaving only two engineers to manage an unsustainable workload. The consequences were disastrous: product launch delays and longer correction cycles led Auratek to lose its market leadership. Although outsourcing provided immediate cost savings, the overall costs – including those related to quality, internal cohesion, and customer trust – were significantly higher.

2.4.3 Relocating

Relocating involves moving business activities across different physical, cultural, or institutional locations. This can occur through offshoring, which transfers activities from the company's home country to another country, or onshoring, which brings activities from foreign countries back to the home country (Santos et al., 2009). Nissan, one of Japan's leading automotive manufacturers, faced a financial crisis during the 1980s and 1990s. Under the leadership of Carlos Ghosn, appointed COO following the alliance with Renault in 1999, the company implemented a comprehensive transformation plan known as the Nissan Revival Plan. This plan included relocating strategies through offshoring to restructure global operations and improve profitability. One key decision was reducing production capacity in Japan while increasing production in the United States. This shift aimed to bring manufacturing closer to target markets, lowering logistics costs and taking advantage of more favorable economic conditions in the U.S. This strategy allowed Nissan to optimize its global operations, enhance price competitiveness, and respond more quickly to local demand. The combination of this move with other strategic restructurings – such as redefining supplier relationships and outsourcing certain activities – led to an extraordinary recovery. Nissan returned to profitability within a single year, regained investor confidence, and solidified its position as a market leader.

2.4.4 Reactivating

Reactivating involves modifying the set of activities performed by a company, which can occur through augmenting – the addition of new activities – or removing – the elimination of existing activities (Santos et al., 2009). An example of augmenting is demonstrated by the well-known U.S. fast-food chain Taco Bell, which in the late 1980s introduced the *"K-Minus"* program – a strategy that redefined the role of kitchens within its restaurants. With this innovation, ingredient preparation was centralized at the company headquarters, where food was cooked, packaged, and shipped to outlets for reheating and assembly. This move added new activities to Taco Bell's BM, such as the delivery of pre-cooked food to restaurants and its reheating on-site, simplifying in-store operations. Thanks to this strategy, Taco Bell gained significant competitive advantages: efficiency and quality control improved due to centralization, and restaurant space was optimized to enhance customer service. The combination of BMI and production centralization enabled Taco Bell to lower operating costs, improve product quality, and increase profitability. A case of removing can be observed in Zara, which eliminated in-house design activities as part of its BM – a decision that significantly contributed to the creation of the fast fashion concept. Unlike the traditional fashion industry model, Zara chose not to engage in fixed collaborations with in-house designers, removing the direct creation of collections. Instead, the company focused on identifying and adapting emerging trends through a system that monitors major global fashion events. This strategic choice not only reduced design-related risks but also allowed Zara to dramatically speed up production times, integrating the previously described resequencing model. In doing so, Zara optimized its ability to respond quickly to consumer demands, solidifying its competitive advantage and setting new standards in the fashion industry.

2.5 BMI & Cross Industry Innovation

Access to external knowledge, often distant from a company's immediate context, is recognized as a key driver of innovation (Enkel & Gassmann, 2010; Santoro et al., 2020). This approach is a cornerstone of Open Innovation, which promotes the integration of external contributions in both the generation and dissemination of innovations (Chesbrough et al., 2014). An expression of this concept involves Cross-Industry Innovation (CII) (Obradović et al., 2021), defined as *"a particular type of open innovation characterized by a deliberate process consisting in the creative imitation, retranslation, or transfer of specific knowledge, established technologies, existing solutions, or business models from some (source) industries to solve problems, to innovate or meet the needs of organizations or end users in other (target) industries"* (Carmona-Lavado et al., 2023). There are several approaches through which CII is implemented, each reflecting a different process of open innovation:

- Inbound CII occurs when an organization adapts solutions developed in other (source) industries to address similar problems in its own (target) industry by integrating external knowledge;
- Outbound CII happens when an organization with an established solution in a (source) industry offers it to other (target) industries facing similar challenges;
- Coupled CII is based on collaboration between organizations from different sectors that combine resources and expertise to jointly develop new solutions or adapt existing ones.

CII is not limited to product or process innovation but also extends to BMI (Bader, 2013; Rhéaume & Tremblay, 2017). Although this approach seems typical of startups – one study found that about 60% of new firms base their BMs on existing models from other industries to create value in their own sector (Enkel & Mezger, 2013) – established companies also apply it. For example, Nestlé, in launching Nespresso, adapted BM elements from other industries: the revenue system was inspired by Gillette's *"razor and blade"* model, while the distribution strategy combined direct customer management with exclusive boutiques inspired by the luxury fashion industry (IMD, 2003). In the context of BMI, CII is particularly useful because companies often face significant limitations due to what Prahalad and Bettis (1986) define as *"dominant logic"* – the traditional, established way of thinking and operating within an industry – and what Spender (1989) calls *"industry recipes*, referring to the set of commonly accepted rules and practices. These mental and operational frameworks act as barriers to identifying radically innovative approaches (Chesbrough, 2010). In this scenario, studying how other industries have designed their BMs to seize market opportunities becomes a particularly promising strategy. Therefore, fully leveraging the potential of CII and integrating it into BMI processes is highly advantageous for companies (Enkel & Mezger, 2013). Research on CII has primarily focused on the early stages of product innovation, during which companies seek solutions to specific, well-defined problems (Brunswicker & Hutschek, 2010; Gassmann & Zeschky, 2008; Herstatt & Kalogerakis, 2005). In this context, Herstatt and Kalogerakis (2005) and Gassmann and Zeschky (2008) identified three main stages in cross-industry processes:

1. Abstraction: This stage involves simplifying the problem by reducing it to its basic structural elements (technical analysis) and the value it provides to customers (contextual analysis) (Gassmann & Zeschky, 2008). This approach broadens the range of solutions transferable from other industries by focusing on concepts that fulfill similar functions. A more abstract problem definition increases the chances of identifying structural similarities with other industries.
2. Analogy Identification: In this stage, solutions are identified by evaluating both superficial and structural similarities between the abstract problem in the target industry and existing solutions in a source industry. Structural similarities are essential for the effective transfer of solutions, while superficial ones can lead to strategic errors (Gavetti & Rivkin, 2005).
3. Adaptation: This stage assesses how a solution – such as a technology, strategy, or concept – can be transferred and implemented in the target industry. Necessary modifications, adjustments, or additional knowledge required for its application are identified (Gassmann & Zeschky, 2008; Gavetti & Rivkin, 2005). According to Herstatt and Kalogerakis (2005), four distinct levels of adaptation exist, each reflecting a different degree of complexity in CII: (i) direct transfer, (ii) structural transfer, (iii) transfer of functional principles, and (iv) using analogies as stimuli for new ideas.

At the simplest level, direct transfer involves applying a solution to a new industry with minimal or no modification. This approach is feasible when the source and target industries share similar operational contexts. However, when differences between industries arise, a more complex approach is required (Herstatt & Kalogerakis, 2005). With the structural transfer the original solution is retained, but specific elements are adapted to meet the unique requirements of the new environment. In more complex scenarios, adaptation requires going beyond structure to focus on the underlying mechanics of a solution. This is captured in the transfer of functional principles, where only the basic concepts are adopted, while the solution itself is redesigned to meet the needs of the target industry (Herstatt & Kalogerakis, 2005). Finally, the most abstract and creative form of adaptation is the use of analogy as a stimulus for new ideas. In this case, firms draw inspiration from concepts in unrelated industries to spark entirely new innovations, rather than directly transferring or modifying existing solutions (Herstatt & Kalogerakis, 2005). Enkel & Mezger (2013) analyzed the application of CII within BMI, highlighting how the stages of abstraction, analogy identification, and adaptation – originally proposed for transferring solutions between industries in product innovation – also apply to BMs. Abstraction plays a crucial role by reducing the problem to its core elements to identify latent customer needs and new starting points for innovation. The subsequent phases of analogy identification and adaptation enable the transfer and customization of solutions from other industries, tailoring them to the specific characteristics of the BM (Enkel & Mezger, 2013).

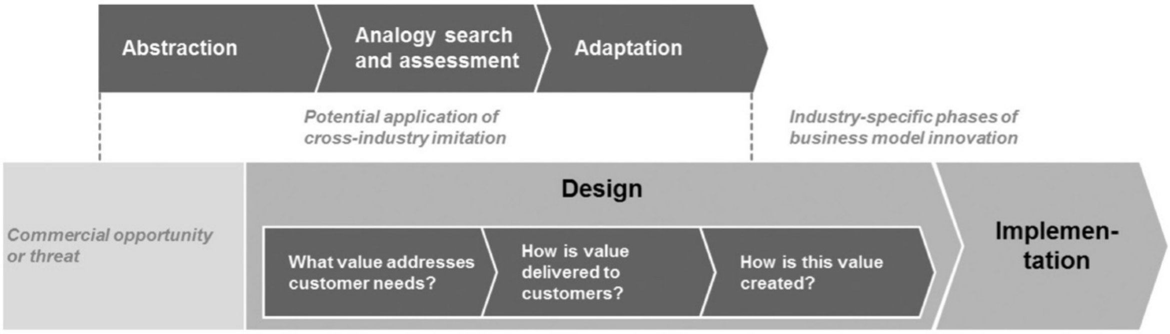


Figure 11: CII process next to business model innovation process (Enkel & Mezger, 2013).

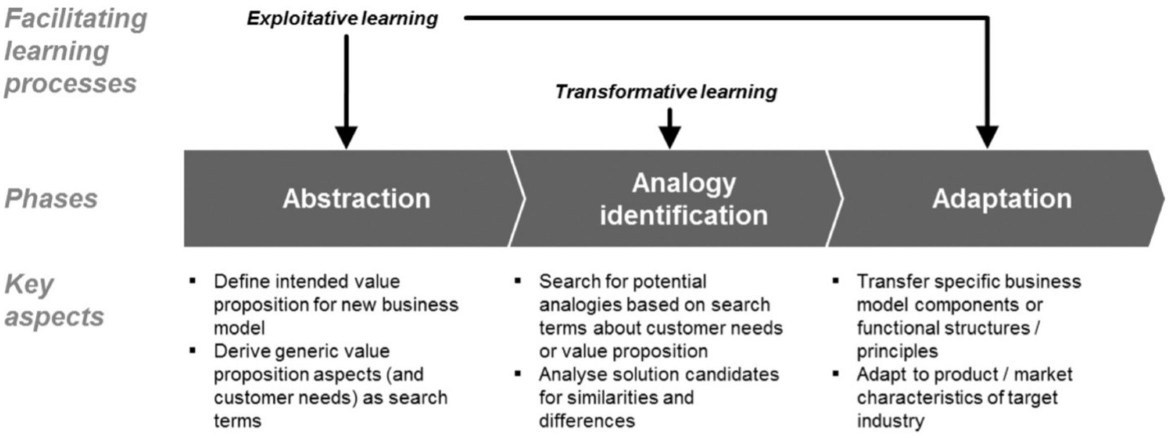


Figure 12: CII process for business model innovation (Enkel & Mezger, 2013).

2.6 Relevance of BMI and CII in Energy Storage

The global transition to renewable energy sources has intensified the need for efficient storage solutions capable of ensuring the stability and reliability of electrical grids (Wei et al., 2023). This necessity, recognized as an international priority, has prompted governments and institutions to introduce new regulations and policies favoring the adoption of energy storage systems (Sani et al., 2020). The integration of advanced technologies, such as artificial intelligence, enables the optimization of energy resources, improving grid management and reducing operational costs. These technological advancements, combined with innovative BMs, can transform energy storage companies into providers of intelligent energy solutions, fostering new models focused on grid flexibility and user empowerment (Ilieva & Rajasekharan, 2018). The described elements represent the main factors identified in the literature as determinants for the emergence of BMI, as discussed in paragraph 2.2. Another interesting aspect concerns the diverse background of many BESS manufacturers, who often originate from different sectors. This phenomenon highlights how cross-sectoral integration of skills and technologies can act as a catalyst for innovation. For instance, the automotive sector has played a crucial role due to the expertise acquired in developing batteries for electric vehicles, which has facilitated technological transfer and accelerated the introduction of innovative solutions in the energy storage field (Wang et al., 2024). This dynamic reflects the potential of CII to open new opportunities and drive a significant transformation of BMs. In conclusion, all these aspects underscore the importance of BMI and CII in the energy storage sector. These approaches not only address the challenges faced by the industry, but also serve as key tools for creating value, fostering innovation, and ensuring a sustainable competitive advantage in the long term.

2.7 Porter's Value Chain Model

In this paragraph, the Value Chain model as defined by Porter (1985) will be introduced. The value chain represents a set of activities that a company undertakes in order to provide valuable goods and services to an end customer. According to Porter's model (1985), the value chain encompasses the activities undertaken by companies and the margin, which is defined as the difference between the value generated and the total cost of these activities. Porter's classification of activities is into two types: primary and secondary. Primary activities are defined as those that directly contribute to the creation of the product, its sale, and the support provided by the company to the customer post-sale. In contrast, secondary activities support primary activities. According to Porter, primary activities fall into five main categories:

- Inbound Logistics: includes activities related to the sourcing, storage, and distribution of raw materials.
- Operations: encompasses all activities involved in transforming inputs into the final product, including processing, assembly, packaging, plant maintenance, and testing.
- Outbound Logistics: covers activities ranging from order planning and processing to the physical distribution of the product to the final consumer.
- Marketing and Sales: aimed at creating channels to promote and facilitate the sale of final products to customers.
- Service: contributes to maintaining or enhancing the product's value through activities such as installation, adjustment, assistance, and repair.

Secondary activities, by contrast, can be categorized into four distinct types:

- Procurement: refers to the function of purchasing inputs used in production processes, including raw materials, supplies, and other consumables, as well as assets such as machinery, equipment, and facilities. A procurement activity can support one or more specific value activities.

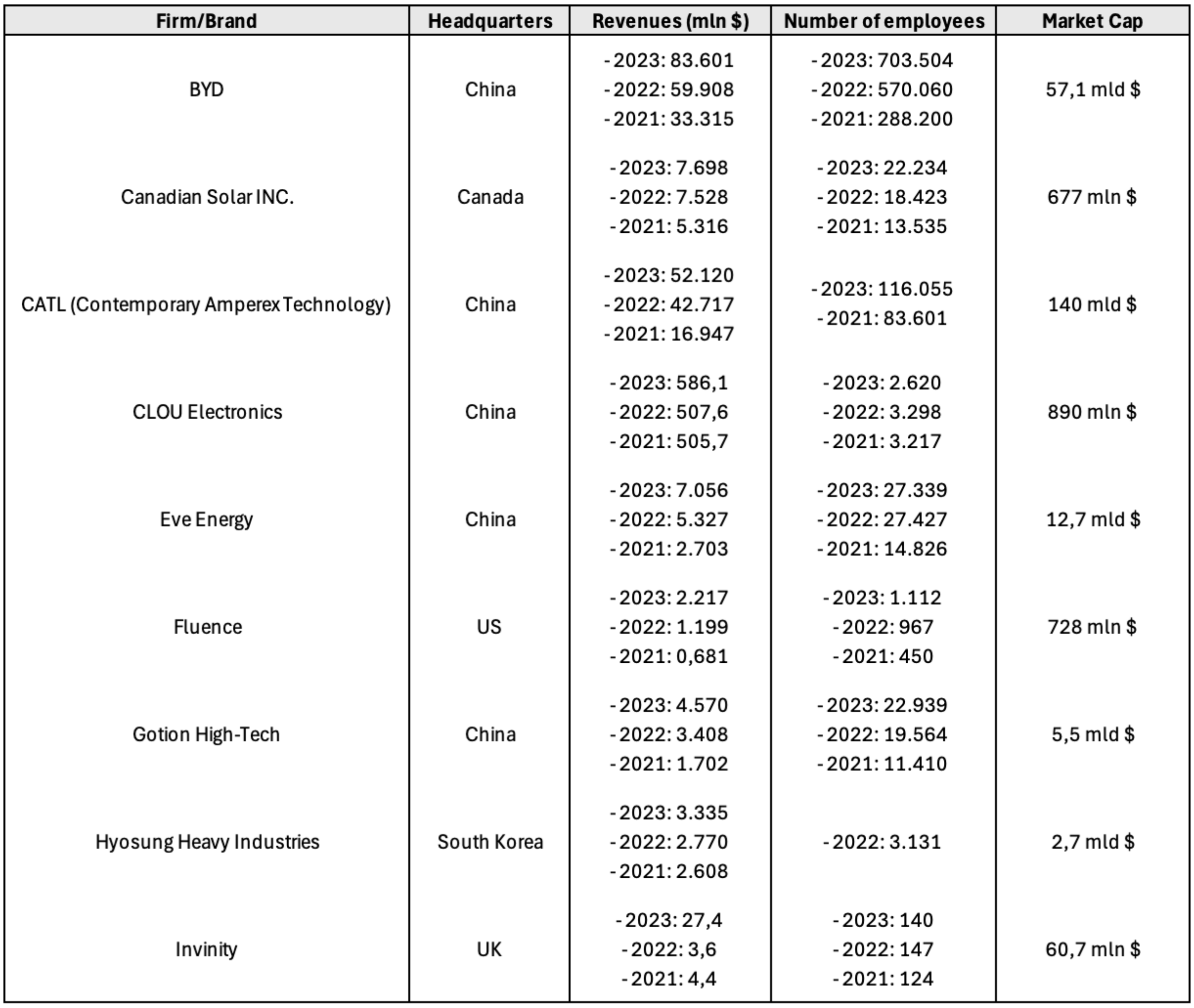
- Technology Development: encompasses any technology embedded in value activities, not only those directly related to the final product. Technology development supports the entire value chain when linked to the product but can also enhance specific primary activities.
- Human Resources: human resource management includes all activities related to recruitment, selection, training, development, and compensation of personnel of all types.
- Company Infrastructure: encompasses all activities related to overall business management, including planning, finance, accounting, legal affairs, government relations, and quality management. Unlike other support activities, infrastructure sustains the entire value chain rather than focusing on specific functions. Additionally, depending on the degree of business diversification, it can be self-managed or distributed between business units and the parent company.

3 Methodology

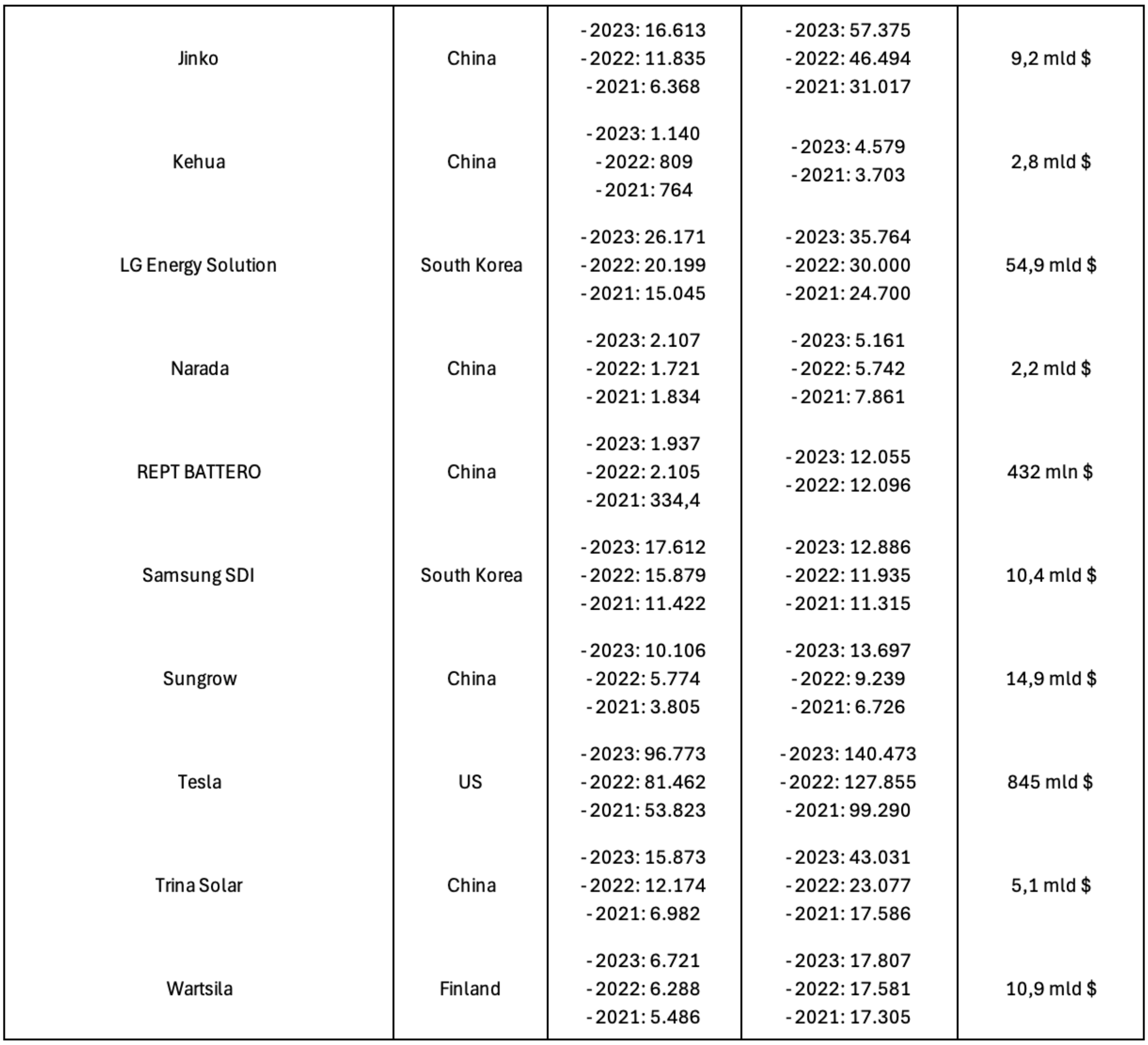
As part of this research, an investigation was conducted in the Energy Storage sector, with a particular focus on the production of BESS, in order to examine how the main manufacturers are innovating key components of their BMs. The following sections provide an overview of the case study (Section 3.1), describe the data collection process (Section 3.2), and outline the methodologies applied in the data analysis (Section 3.3).

3.1 Case selection and description

Energy storage technologies are embedded in the global energy transition, a transformation driven by the urgent need to identify sustainable alternatives to the use of fossil fuels (Sani et al., 2020). In this scenario, the storage of produced energy plays a crucial role in optimizing its use and ensuring production continuity, making it an essential element in the current energy landscape (Oxford Institute for Energy Studies, 2024). We believe that the market dynamics characterizing this rapidly expanding and transforming sector require companies operating within it to innovate their BMs to remain competitive. BESS stand out for their ability to be used across a wide range of applications and scales, from domestic to industrial levels, and even to support electricity grids (McKinsey & Company, 2023). Moreover, the diverse applications of batteries across multiple sectors (Olabi et al., 2023) suggest that the level of innovation could be further enhanced by technological and knowledge contributions from other industries. Finally, significant R&D efforts are concentrated on this specific type of energy storage (Wei et al., 2023), offering a valuable opportunity to examine how technological advancements in this sector influence the BMs of companies operating within it. The present study was conducted on a sample of companies included in the BNEF Energy Storage Tier 1 List, a classification that identifies the main manufacturers of stationary energy storage systems, taking into account developments over the past two years. The selection criteria for the companies included in this list involve the number of projects completed with a capacity exceeding 1 MW or 1 MWh – thresholds that, starting from the first quarter of 2025, will be raised to 10 MW or 10 MWh to reflect the growth of the energy storage market – and the requirement that such projects be developed or owned by third-party, independent customers, not affiliated with the storage system manufacturer. Furthermore, the projects must utilize the manufacturer's primary technology and cannot be implemented solely to adhere to regulatory requirements, such as systems for renewable energy integration (BloombergNEF, 2024). The analyzed sample includes all publicly listed companies from the list (19 out of 35), as illustrated in Figure 13. Due to regulatory obligations, publicly listed companies are required to regularly disclose detailed and verifiable information about their financial performance, business strategies and operations. This ensures greater availability of data, contributing to the reliability of the analysis results. The decision to include all publicly listed companies from Bloomberg's Tier 1 list is based on the objective of representing a diverse sample of players operating in the sector. This approach enables the consideration of companies from various geographical areas, with distinct business models and technological approaches, while also ensuring comparative validity through the availability of standardized metrics such as market capitalization, revenue, and size.



Firm/Brand	Headquarters	Revenues (mln $)	Number of employees	Market Cap
BYD	China	- 2023: 83.601 - 2022: 59.908 - 2021: 33.315	- 2023: 703.504 - 2022: 570.060 - 2021: 288.200	57,1 mld $
Canadian Solar INC.	Canada	- 2023: 7.698 - 2022: 7.528 - 2021: 5.316	- 2023: 22.234 - 2022: 18.423 - 2021: 13.535	677 mln $
CATL (Contemporary Amperex Technology)	China	- 2023: 52.120 - 2022: 42.717 - 2021: 16.947	- 2023: 116.055 - 2021: 83.601	140 mld $
CLOU Electronics	China	- 2023: 586,1 - 2022: 507,6 - 2021: 505,7	- 2023: 2.620 - 2022: 3.298 - 2021: 3.217	890 mln $
Eve Energy	China	- 2023: 7.056 - 2022: 5.327 - 2021: 2.703	- 2023: 27.339 - 2022: 27.427 - 2021: 14.826	12,7 mld $
Fluence	US	- 2023: 2.217 - 2022: 1.199 - 2021: 0,681	- 2023: 1.112 - 2022: 967 - 2021: 450	728 mln $
Gotion High-Tech	China	- 2023: 4.570 - 2022: 3.408 - 2021: 1.702	- 2023: 22.939 - 2022: 19.564 - 2021: 11.410	5,5 mld $
Hyosung Heavy Industries	South Korea	- 2023: 3.335 - 2022: 2.770 - 2021: 2.608	- 2022: 3.131	2,7 mld $
Invinity	UK	- 2023: 27,4 - 2022: 3,6 - 2021: 4,4	- 2023: 140 - 2022: 147 - 2021: 124	60,7 mln $



Jinko	China	-2023: 16.613 -2022: 11.835 -2021: 6.368	-2023: 57.375 -2022: 46.494 -2021: 31.017	9,2 mld $
Kehua	China	-2023: 1.140 -2022: 809 -2021: 764	-2023: 4.579 -2021: 3.703	2,8 mld $
LG Energy Solution	South Korea	-2023: 26.171 -2022: 20.199 -2021: 15.045	-2023: 35.764 -2022: 30.000 -2021: 24.700	54,9 mld $
Narada	China	-2023: 2.107 -2022: 1.721 -2021: 1.834	-2023: 5.161 -2022: 5.742 -2021: 7.861	2,2 mld $
REPT BATTERO	China	-2023: 1.937 -2022: 2.105 -2021: 334,4	-2023: 12.055 -2022: 12.096	432 mln $
Samsung SDI	South Korea	-2023: 17.612 -2022: 15.879 -2021: 11.422	-2023: 12.886 -2022: 11.935 -2021: 11.315	10,4 mld $
Sungrow	China	-2023: 10.106 -2022: 5.774 -2021: 3.805	-2023: 13.697 -2022: 9.239 -2021: 6.726	14,9 mld $
Tesla	US	-2023: 96.773 -2022: 81.462 -2021: 53.823	-2023: 140.473 -2022: 127.855 -2021: 99.290	845 mld $
Trina Solar	China	-2023: 15.873 -2022: 12.174 -2021: 6.982	-2023: 43.031 -2022: 23.077 -2021: 17.586	5,1 mld $
Wartsila	Finland	-2023: 6.721 -2022: 6.288 -2021: 5.486	-2023: 17.807 -2022: 17.581 -2021: 17.305	10,9 mld $

Figure 13: Public companies examined.

3.2 Data Collection

The data collection phase was carried out exclusively through publicly available information on the Internet, during the period from September 2024 to January 2025. The sources used to collect the information include:

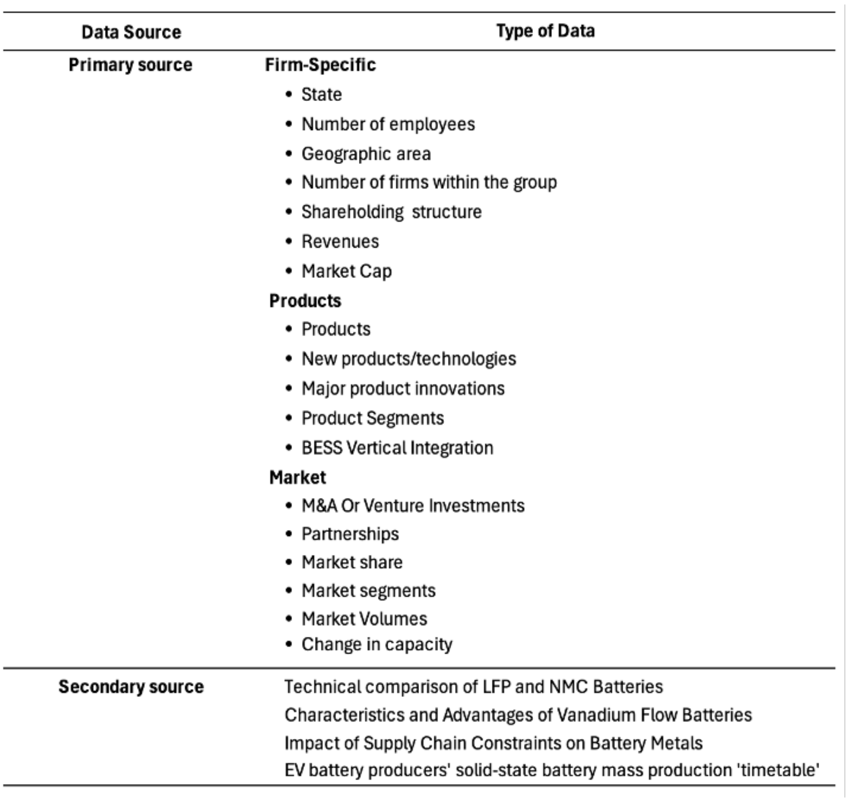
- Data sources such as Orbis, Yahoo Finance, MarketScreener, MergerMarket, Statista, Pitchbook, Bloomberg;
- Annual reports published by the companies;
- Official websites of the analyzed companies;
- Public information available on third party websites;

- Industry journals and publications that provided specific insights and analysis;
- Conferences and public statements useful for accessing strategic data and company communications.

The primary data collected were classified into three categories:

- Firm-specific information: This includes detailed information about the company, such as country of operation, number of employees, number of companies in the group, geographical areas in which the company has offices or controls other entities, market capitalization, corporate structure, total turnover and breakdown of turnover by business segment or geographical area. These data allow analysis of the size, organization and geographical presence of the company and provide a solid basis for comparing companies.
- Product-related information: This includes details of the company's products and technologies, with a focus on new launches and significant innovations. Data includes marketed BESS solutions, development of new products or technologies, major planned innovations, the different product segments in which the company operates, and the level of vertical integration related to BESS. These data are essential for analyzing the company's innovative capacity in the design and development of products and new technologies.
- Market-related information: This includes data relating to the company's market positioning and market activities. Data collected includes mergers and acquisitions or investments in other companies, strategic collaborations and partnerships, the company's market share, the market segments in which it operates, total installed volumes, and changes in its production or distribution capacity. These elements provide insight into the company's strategic operations, production capacity and strength of market presence.

The time span of the collected data varies depending on the type of information analyzed. For instance, revenues and number of employees were considered for the period between 2021 and 2023. Some categories, such as products, new technologies developed, information on vertical integration, M&A activities and partnerships, were not considered on the basis of a specific time period, but rather according to the relevance of the available information. Finally, other elements, such as market capitalization, company structure and market volume, were collected on the basis of the most recent data available at the time of the survey. Figure 14 summarizes the primary and secondary data sources.



Data Source	Type of Data
Primary source	**Firm-Specific** • State • Number of employees • Geographic area • Number of firms within the group • Shareholding structure • Revenues • Market Cap **Products** • Products • New products/technologies • Major product innovations • Product Segments • BESS Vertical Integration **Market** • M&A Or Venture Investments • Partnerships • Market share • Market segments • Market Volumes • Change in capacity
Secondary source	Technical comparison of LFP and NMC Batteries Characteristics and Advantages of Vanadium Flow Batteries Impact of Supply Chain Constraints on Battery Metals EV battery producers' solid-state battery mass production 'timetable'

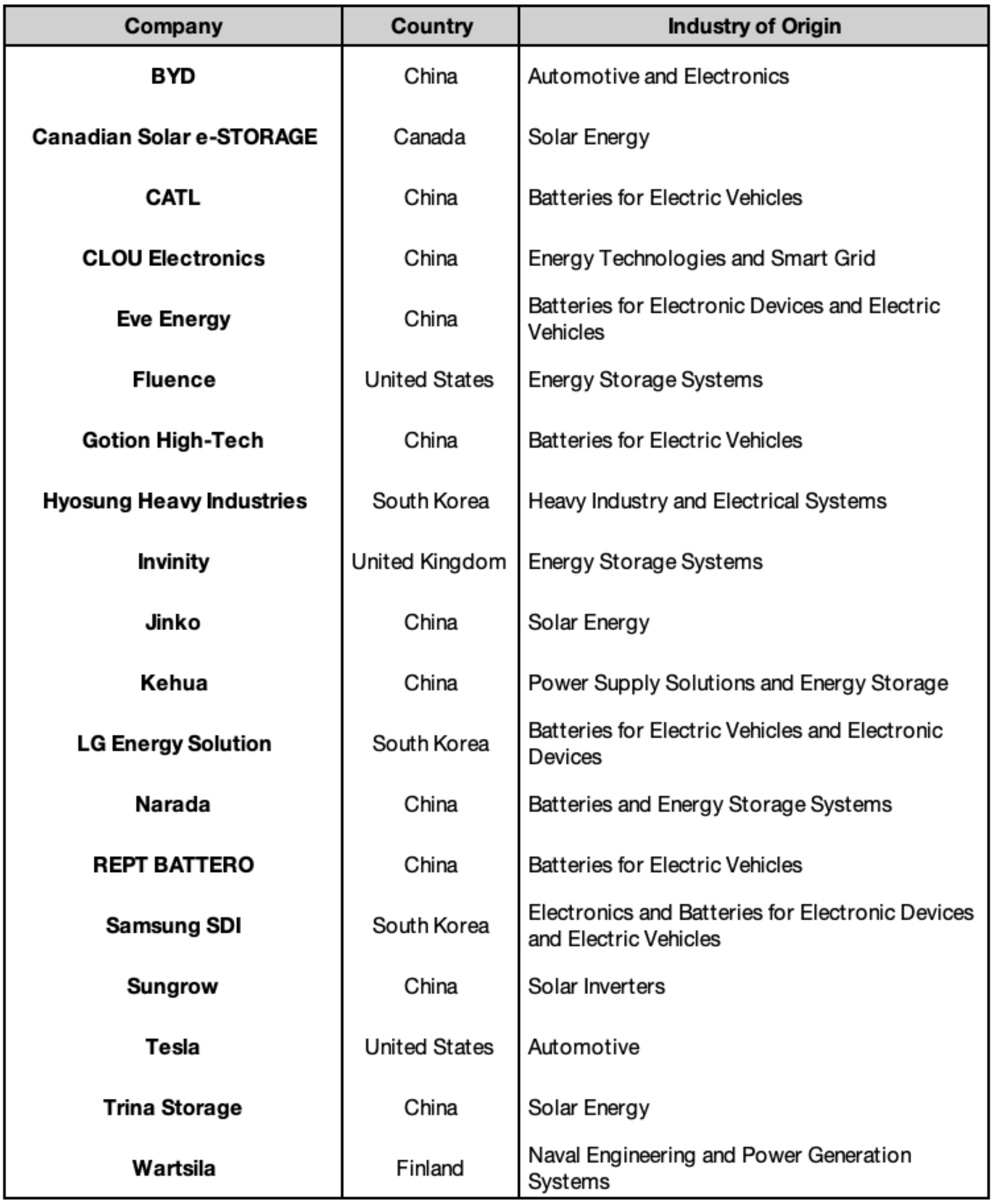
Figure 14: Data collection.

3.3 Data Analysis

Data analysis was conducted using a systematic and structured approach. The collected data were organized in an Excel file in matrix form, where the companies were arranged in the columns and the specific topic under investigation, among those mentioned in the Table, was listed in each row. This structure enabled a comprehensive view of each piece of information for all the companies analyzed, facilitating direct comparison among them. The process of analysis was carried out by considering one variable at a time, in order to examine specific information through a cross-sectional comparison between companies. In some cases, possible correlations between variables were investigated to explore potentially significant relationships. This enriched the analysis with additional perspectives and provided more detailed insights into company and sector dynamics. Certain pieces of information were analyzed by filtering columns based on relevant characteristics, facilitating a more accurate comparison among groups of companies. This approach allowed for the identification and analysis of specific patterns and differences related to particular factors. Furthermore, the analysis followed an iterative process, with multiple rounds of refinement and targeted investigations into specific information as new questions or research interests emerged. The subsequent section will present and analyze the results that emerged from the analysis, highlighting the innovations implemented by the companies and the main differences found in the various areas analyzed.

4 Findings

The analysis of the sample indicates that the predominant proportion of companies, 11 out of 19, are based in China, confirming the country's dominant role in the energy storage market. This is followed by three companies based in South Korea, two in the United States and one in Europe and Canada. Examining the industry of origin of the BESS companies is crucial to determine whether firms from specific sectors exhibit a higher propensity to enter this market. Figure 15 illustrates the industries of origin for the surveyed companies.



Company	Country	Industry of Origin
BYD	China	Automotive and Electronics
Canadian Solar e-STORAGE	Canada	Solar Energy
CATL	China	Batteries for Electric Vehicles
CLOU Electronics	China	Energy Technologies and Smart Grid
Eve Energy	China	Batteries for Electronic Devices and Electric Vehicles
Fluence	United States	Energy Storage Systems
Gotion High-Tech	China	Batteries for Electric Vehicles
Hyosung Heavy Industries	South Korea	Heavy Industry and Electrical Systems
Invinity	United Kingdom	Energy Storage Systems
Jinko	China	Solar Energy
Kehua	China	Power Supply Solutions and Energy Storage
LG Energy Solution	South Korea	Batteries for Electric Vehicles and Electronic Devices
Narada	China	Batteries and Energy Storage Systems
REPT BATTERO	China	Batteries for Electric Vehicles
Samsung SDI	South Korea	Electronics and Batteries for Electronic Devices and Electric Vehicles
Sungrow	China	Solar Inverters
Tesla	United States	Automotive
Trina Storage	China	Solar Energy
Wartsila	Finland	Naval Engineering and Power Generation Systems

Figure 15: Industries of Origin.

Interestingly, companies established with the explicit objective of developing and commercializing ESS represent a small minority. In the sample of the 19 listed companies selected by the Bloomberg Tier 1 List, only three fall into this category: Fluence, Invinity and Narada. The automotive sector related to the production of electric vehicles and batteries for them represents a major source industry among the players surveyed: two companies, Tesla and BYD, are properly car-makers, while CATL, Gotion High-Tech and REPT BATTERO are EV battery manufacturers. Eve Energy, LG Energy Solution and Samsung SDI are manufacturers of batteries for electronic devices as well as EVs. The high number of companies from battery R&D-related industries suggests that the competences acquired in these sectors are fully transferable to the design of energy storage system solutions. The already optimized production processes for battery manufacturing and the presence of synergies in R&D, procurement and automation processes enable carmakers and battery manufacturers to achieve economies of scale in the production of energy storage systems. Companies originally focused on battery production have transferred their know-how, consolidated in the development of technologies for EVs, to the design of energy storage systems. In this scenario, CII dynamics clearly emerge at the product level: the expertise acquired in their core business is reworked and integrated for the development of a new type of product.

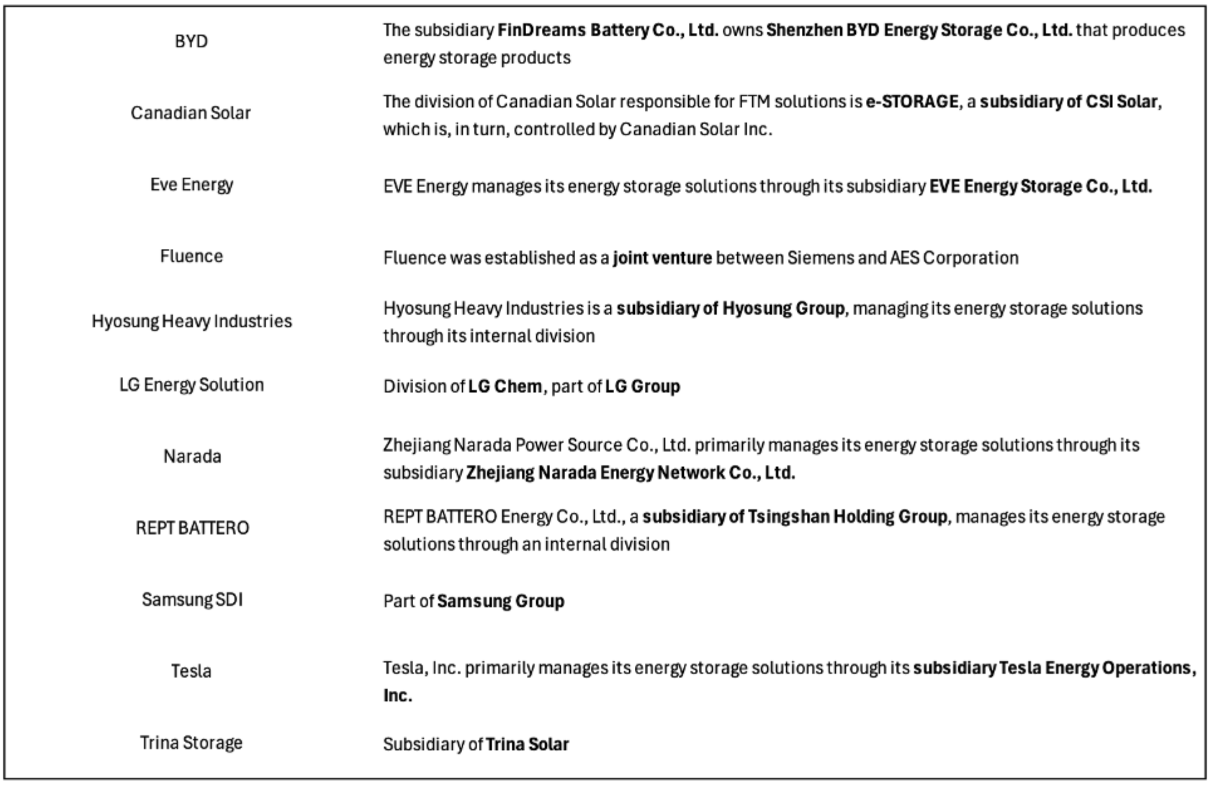
The results also revealed a strong interest among renewable energy companies in the production of BESS, with several industry leaders, such as Canadian Solar, Trina Solar, Sungrow, and Jinko, among those surveyed. The entry of these players represents an important strategic choice. Indeed, by integrating storage solutions with the technologies they already offer, such as photovoltaic modules and inverters, these companies are able to realize end-to-end systems that mitigate the intermittency of energy production and optimize consumption and overall energy management. The production of BESS allows these operators to expand their offerings, creating synergies that increase value for the end customer. Once more, we underline a cross-sectoral transfer of experience gained in the field of photovoltaic module production, such as the development and integration of inverters and control systems for photovoltaic panels.

Due to the possible integration with power generation, distribution and supply systems, utilities could theoretically expand their activities towards the production of BESS, similarly to what has been observed for companies in the renewable energy sector. However, the analysis does not reveal the presence of utilities in the examined sample, except for the case of Fluence. The latter is a joint venture, founded in 2018 by the collaboration between Siemens, a multinational technology company, and AES Corporation, an American utility active in the generation, distribution and supply of energy and involved in projects in the renewable energy and energy storage systems sectors. The absence of utilities and the case of Fluence suggest the difficulties they may face in the direct production of BESS. Utilities have historically had a BM oriented towards power generation, distribution and supply, and the shift to industrial production of high-tech components entails a non-trivial organizational and cultural transformation. While they have extensive infrastructure and expertise in power generation and distribution management, the lack of manufacturing experience appears to be one of the major obstacles for utilities wishing to expand into the production of these systems. These activities are not part of the core business of utilities, which are generally not directly involved in the design and construction of energy storage facilities, as they require advanced skills and competencies typical of companies with a proven track record in high-tech industrial manufacturing. Moreover, utilities typically also lack to develop and internalize technical competencies necessary for managing and integrating such systems. Indeed, the absence of these specialized skills prevents them from acting as system integrators, by integrating technologies and solutions developed by third parties. Consequently, utilities tend to rely on specialized operators for the design, construction, and management of infrastructure.

The entry into the storage sector by these players implies a substantial innovation of the company's BM, with implications on its entire architecture. The integration of new activities allows to expand the firm's value proposition, addressing new target customers and in some cases proposing more value for existing ones, but it also redefines the company's revenue stream and cost structure. An important finding concerns the fundamental role played by CI dynamics in this scenario. The results just presented suggest that the transfer of expertise acquired in one's core sector acts as a catalyst for expanding one's activities towards the production of storage systems.

The heterogeneity of the industries of origin motivated an in-depth analysis of how energy storage-related businesses are managed within the respective organizations. In particular, the analysis focused on whether the storage business was structured as a separate division, autonomous from the company's other activities, or whether it was instead integrated and managed directly by the parent company. From the data collected, it appears that all the companies surveyed own ad hoc subsidiaries to manage energy storage solutions. Most of the companies analyzed have a market capitalization of billions of dollars and exceed tens of thousands of employees and tens of billions of revenues (as holding companies), as shown in Figure 13. It stands to reason that for such large groups with multiple businesses, it is likely that the management of the businesses will be kept separate through stand-alone subsidiaries. However, almost the 60% of the analyzed companies have established a holding company for energy storage - as shown in Figure 16 - to which a number of other subsidiaries report. This organizational model allows sector-specific functions to be isolated from the group's core business, facilitating a more targeted and agile governance. By separating the energy storage business from its other activities, a company can develop a specific value proposition for this sector, ensuring greater operational flexibility and more efficient resource allocation. However, not all the analyzed firms adopt this type of organization. The remaining ones, including large groups in terms of size and turnover, prefer to keep the energy storage business integrated into the core business, presumably considering more advantageous to exploit existing synergies and share resources.

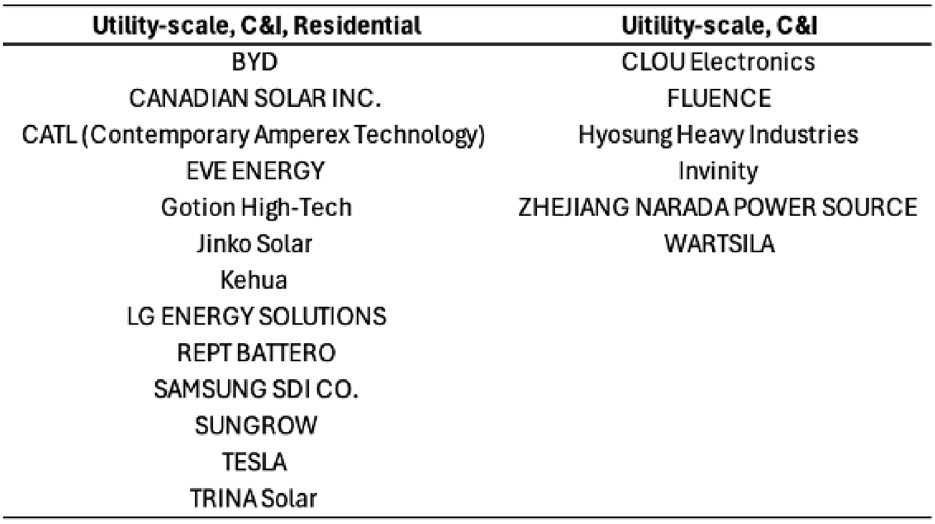
Based on the application and scale of energy storage solutions, it is possible to distinguish three main product segments in which companies in the industry operate, as described in section 1.2.5: utility-scale, commercial and industrial (C&I) and residential. All the 19 companies surveyed offer grid-integrated FTM solutions (utility-scale) and BTM C&I solutions. The first observation is that the utility-scale and C&I segments are present for all the companies, with no exclusive focus on one or the other. The technologies used in utility-scale and C&I systems are similar and often modular. For instance, lithium-ion batteries, EMS, and PCS can be adapted from utility-scale to C&I solutions. Additionally, some systems, such as EMS, are more complex than residential alternatives. The presence of all the analyzed companies suggests that larger systems allow lower production costs per KWh by leveraging economies of scale and can therefore bring higher margins. From this perspective, residential solutions may not be as cost-effective for some players.



BYD	The subsidiary **FinDreams Battery Co., Ltd.** owns **Shenzhen BYD Energy Storage Co., Ltd.** that produces energy storage products
Canadian Solar	The division of Canadian Solar responsible for FTM solutions is **e-STORAGE**, a **subsidiary of CSI Solar**, which is, in turn, controlled by Canadian Solar Inc.
Eve Energy	EVE Energy manages its energy storage solutions through its subsidiary **EVE Energy Storage Co., Ltd.**
Fluence	Fluence was established as a **joint venture** between Siemens and AES Corporation
Hyosung Heavy Industries	Hyosung Heavy Industries is a **subsidiary of Hyosung Group**, managing its energy storage solutions through its internal division
LG Energy Solution	Division of **LG Chem**, part of **LG Group**
Narada	Zhejiang Narada Power Source Co., Ltd. primarily manages its energy storage solutions through its subsidiary **Zhejiang Narada Energy Network Co., Ltd.**
REPT BATTERO	REPT BATTERO Energy Co., Ltd., a **subsidiary of Tsingshan Holding Group**, manages its energy storage solutions through an internal division
Samsung SDI	Part of **Samsung Group**
Tesla	Tesla, Inc. primarily manages its energy storage solutions through its **subsidiary Tesla Energy Operations, Inc.**
Trina Storage	Subsidiary of **Trina Solar**

Figure 16: Corporate Structures for Energy Storage Activities.

Moreover, as these are directly targeted at the end consumer, different channels and appropriate marketing strategies need to be identified to reach the desired target audience, which may be easier for companies that already operate under a B2C model in other sectors and can rely on an established distribution network. These considerations are supported by the fact that not all the companies are present in the field of the domestic solutions. In particular, 6 companies operate only in the C&I and utility-scale segments. It is no accident that none of these companies is an EV battery producer or a renewable company. All EV battery manufacturers offer residential solutions, suggesting possible correlations related to their technological and operational expertise. Indeed, these manufacturers have advanced skills in handling low-capacity batteries. They also have solid experience in optimizing energy efficiency in applications with limited space, a condition that is also found in residential BESS solutions. It is also worth noting that all the renewable energy companies offer home storage solutions. For these players, this type of system represents an opportunity to complement their home installations, such as photovoltaic panels. The strategies adopted by the renewable companies show an orientation towards the creation of a domestic energy ecosystem. In this way, they are able to offer end-to-end solutions that respond comprehensively to the customer needs, with the aim of achieving greater competitive advantage and optimal strategic positioning in the energy market. The Tesla case is particularly representative of this. Indeed, the Tesla's Powerwall residential system not only optimizes the home energy use, but also fits synergistically into the energy ecosystem designed by the company. Through integration with devices such as the Tesla Wall Connector, the system allows Tesla electric vehicles to be charged using energy stored in the Powerwall, which can be generated directly from Tesla's solar panels. The expansion of customer segments into the residential sector is an example of BMI, and the results set out how CI dynamics emerge in doing so. Battery manufacturers transfer their expertise in handling low-capacity, limited-size systems, while renewable energy companies exploit their established distribution channels to sell their domestic systems. Indeed, it has been observed that the authorized solar panel dealers of the before mentioned renewable companies tend to also offer their storage systems in their marketplaces.



Utility-scale, C&I, Residential	Uitility-scale, C&I
BYD	CLOU Electronics
CANADIAN SOLAR INC.	FLUENCE
CATL (Contemporary Amperex Technology)	Hyosung Heavy Industries
EVE ENERGY	Invinity
Gotion High-Tech	ZHEJIANG NARADA POWER SOURCE
Jinko Solar	WARTSILA
Kehua	
LG ENERGY SOLUTIONS	
REPT BATTERO	
SAMSUNG SDI CO.	
SUNGROW	
TESLA	
TRINA Solar	

Figure 17: Companies' Product Segments.

4.1 Residential Segment

Given this differentiation of applications, a first analysis was performed by comparing all the residential solutions offered by the 13 companies in Figure 17. First, it was found that 10 companies - representing the 77% - offer a single standardized product. This is partly due to the fact that the modular structure of a system makes it possible to achieve different capacity and voltage levels with a single module type. By connecting modules in parallel, the capacity of the system can be expanded to meet different needs. In addition it is possible to achieve high voltage solutions with the same capacity by connecting multiple modules in series. The 100% of the analyzed solutions have a modular architecture, and even compact systems such as Tesla's Powerwall 3 or the LG RESU 48V and RESU 16 H PRIME are modularly expandable - the latter, for example, allows a capacity of 32 kWh by connecting two 16 kWh modules in parallel. The predominant trend toward focused and standardized solutions in the residential segment can be attributed to the inherent uniformity of household requirements. This approach allows companies to focus their efforts on optimizing a single solution, taking advantage of economies of scale and simplifying interaction with the end consumer.

Regarding the technology employed for residential BESS batteries, we have detected an almost clear convergence towards the use of Lithium Iron Phosphate (LFP) batteries. All of the players use LFP technology, with the exception of LG Energy Solutions, which uses Nickel Manganese Cobalt (NMC) batteries for its RESU systems, a type of lithium-ion battery characterized by a cathode made of lithium nickel manganese cobalt oxide. The NMC batteries are known for their high energy density (higher than LFP), good power capacity and versatility, making them ideal for applications where a lot of energy needs to be stored in a small space. LFP batteries have emerged as the dominant technology due to their lower cost, higher safety and longer battery life. Some companies that used NMC technology for residential applications have switched to LFP technology over time - Tesla, for example, recently switched from the Powerwall 2, which used NMC batteries, to the Powerwall 3, which uses LFP batteries. Samsung SDI announced plans to begin mass production of lithium iron phosphate (LFP) batteries for energy storage systems in 2026, with the goal of providing cheaper and safer solutions. LG, which continues to utilize LFP batteries for RESU systems, introduced the LG enblock E system, a new LFP battery specifically designed for residential use, indicating that the company is aligning its strategy with that of its competitors. The companies that have most recently migrated to LFP technology, as mentioned above, have extensive knowledge of NMC batteries: for example, LG and Samsung use this type of application for EV batteries that they supply to some car-makers; similarly, Tesla uses NMC lithium batteries for some EV lines, such as for the high-performance Tesla Model Y and Tesla Model 3 models. Although the deep knowledge of this technology and economies of scale made the production of this type of battery affordable, all players seem to have now decided to adopt LFP technology for domestic BESS applications, due to the high cost of cobalt and nickel - also as a result of post-war restrictions on Russia, which was the largest supplier of Class 1 nickel with 20% of global supply - and the difficult availability of cobalt - 79% of cobalt comes from the Republic of Congo.

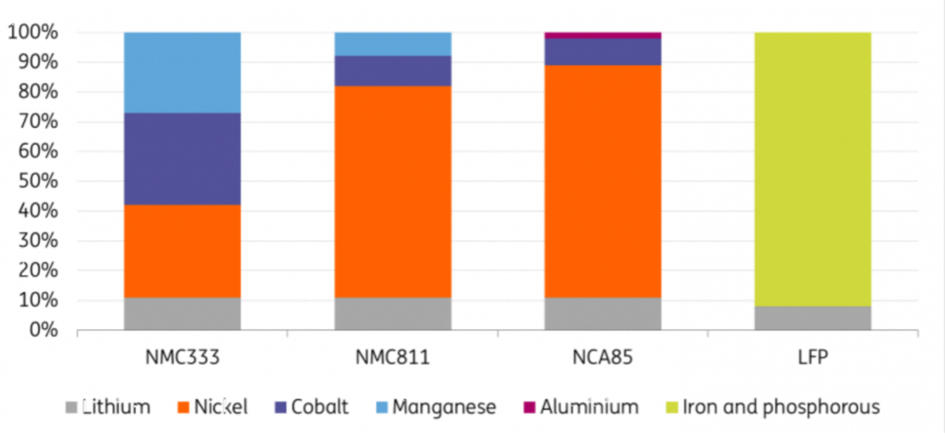


Figure 18: Approximate mineral composition of different battery cathodes (ING Group, 2023).

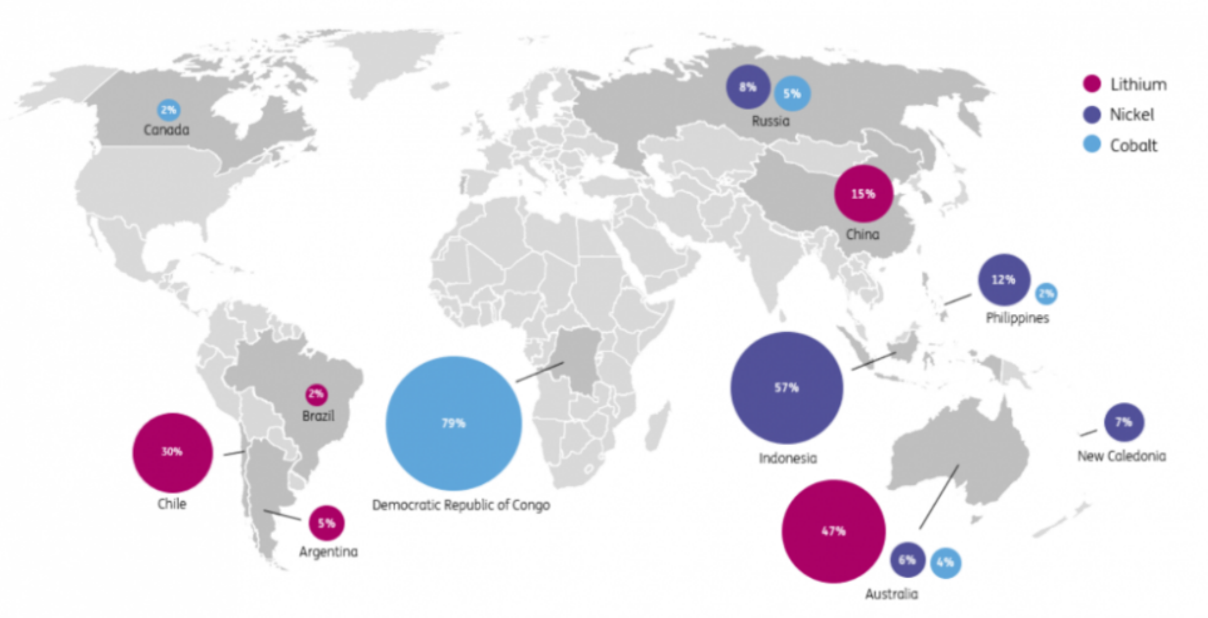


Figure 19: Top battery raw materials producing countries in 2022 (ING Group, 2023).

The shift to LFP technology for BESS battery production represents another case of BMI, as it entails changes in the company's value proposition by implementing safer and longer-lasting systems, while simultaneously altering its cost structure by eliminating reliance on expensive and critical materials. In this regard, it is worth noting that EV battery manufacturers could benefit in the future from the adoption of an innovative technology that is still under development: Solid-State Batteries (SSBs). Among the companies surveyed, almost all major EV battery manufacturers - CATL, Eve, Gotion High-Tech, BYD, LG Energy Solution and Samsung SDI - are involved in the development of this technology, with mass production targets not expected before 2030. SSBs offer significant potential advantages over conventional lithium-ion batteries, including higher energy density, improved safety through the elimination of flammable liquid electrolytes, and longer life cycle. In addition, the ability to operate at extreme temperatures and the reduced charging times could lead to a significant increase in operating efficiency in both electric vehicles and energy storage applications. From this perspective, SSB technology is not only a prospect for electric mobility, but also a potential solution for energy storage systems that require high reliability and consistent performance over the long term. However, studies suggest that even in the best-case scenario, mass production of SSBs at competitive costs may not be feasible before 2028, and in a less optimistic scenario not before 2032 (Alkhalidi et al., 2024). The development of such technology could therefore be critical to the production of BESS systems in the next decade. The analysis revealed not all the companies offer individual components like battery modules or inverters for residential applications, although this is the main trend. Only 5 companies - Jinko Solar, Kehua, Canadian Solar, Tesla, Trina Solar - propose all-in-one solutions, which are integrated systems that combine battery modules with other key components such as inverters, EMS and monitoring interfaces in a single platform. The advantages of this type of solution are many, starting with the ease of installation and the reduction of the risk of malfunction due to incompatibility between modules, as well as the simplicity of monitoring and control, which can be carried out through a single interface. In addition, being designed as single entities, energy losses due to conversion between inverter, battery and grid are minimized (all-in-one systems manage to achieve very high conversion rates, e.g. Tesla with its Powerwall manages to achieve a round-trip efficiency - energy recovered after a complete battery charge and discharge cycle - of around 89%). These companies have innovated their BMs by enhancing their value propositions and delivering greater customer value through complete, integrated systems. In doing so, some of these companies have expanded their offerings over time by internalizing the production of certain components. In the case of Tesla, for example, the first Powerwall (2015) consisted of a battery module that required an external inverter to convert the power, while Trina Solar only announced that it would start producing its own compatible inverters in 2021. Internalization enables companies to reduce dependency on external suppliers, lower production costs, and capture more value along the value chain. Furthermore, it increases their agility in responding to market demands and technological advancements, ensuring that their integrated solutions remain competitive and aligned with evolving customer needs. This shift represents a clear example of BMI, as it reconfigures key activities within the value chain, strengthening control over critical components and enhancing long-term competitiveness.

4.2 C&I and utility-scale segments

Subsequently, an analysis regarding C&I and FTM applications was conducted. First, it emerged that for this type of larger-scale application, certain companies – e.g. BYD or Fluence – offer a portfolio of solutions. This phenomenon is the result of market segmentation and the need to respond to specific operational requirements, such as energy needs, energy density, physical footprint, thermal management, and environmental conditions at the installation site. For instance, different configurations are optimized for applications where space is limited and high energy density is required, while others involve advanced cooling systems to ensure stable performance in extreme temperature environments, such as liquid cooling systems. This approach allows the most suitable solution to be chosen based on the type of application, whether it is peak shaving, load shifting, grid support, or integration with renewable energy. By contrast, it emerged that only about 30% of companies offer a standardized solution for each segment, adopting a more focused approach. Tesla is a peculiar case, because it offers a unified application, the Megapack, catering to both segments. A standardization strategy enables companies to prioritize the optimization of a single platform and fully exploit economies of scale, while a diversified portfolio fosters competitive differentiation by meeting specific market needs. Both approaches reflect distinct BMI strategies: standardization enhances efficiency and cost-effectiveness by streamlining operations, whereas diversification expands the value proposition by addressing a broader range of customer requirements. This scenario illustrates the strategic trade-off between customization and operational efficiency.

Regarding all-in-one systems, it emerged that all manufacturers offering integrated solutions in the residential segment do the same in the C&I and utility-scale. For these segments, the following companies have adopted a partnership approach for the provision of all-in-one systems. Sungrow and Samsung SDI, which do not manufacture domestic all-in-one systems, have collaborated to create an integrated solution optimized for the North American C&I market, leveraging Samsung's expertise in manufacturing battery modules and Sungrow's experience in inverter production. However, Sungrow has recently started the construction of its first production plant in China, making a significant step towards the internalization of battery production. A comparable instance is evident in CATL, which, in collaboration with KSTAR, has developed an all-in-one system for C&I applications, integrating CATL's LFP cell technology with KSTAR's proficiency in inverter and power management system design. This collaborative strategy underscores BMI dynamics by expanding the companies' value propositions through strategic alliances. By partnering, these firms compensate for gaps in individual expertise and pool their strengths, enabling them to offer complete, integrated solutions that enhance customer value through simplified installation, improved compatibility, and optimized performance.

Concerning the battery type used in storage systems, LFP technology is also confirmed to be dominant for large-scale applications. So far, however, not all companies in the analyzed sample have adopted LFP technology. In particular, only in one case the use of an alternative technology was found: Invinity, which uses vanadium batteries for its storage systems. Vanadium Redox Flow Batteries (VRFB) offer several advantages, including enhanced safety due to the non-flammable nature of the vanadium-based electrolyte, a significantly extended life cycle compared to lithium batteries, and a low degradation rate. These characteristics enable Invinity to achieve a more competitive energy cost level.

Invinity, a company founded in 2020 through the merger of two leading flow battery suppliers (redT energy and Avalon Battery), is a recent entrant in the energy storage sector that distinguishes itself with its innovative value proposition. The company has set itself the ambitious goal of revolutionizing the energy storage market through the introduction of new technology. In this regard, in an interview with PVTech in 2021, Invinity's Chief Commercial Officer Matt Harper stated that *"it is critical to battery*

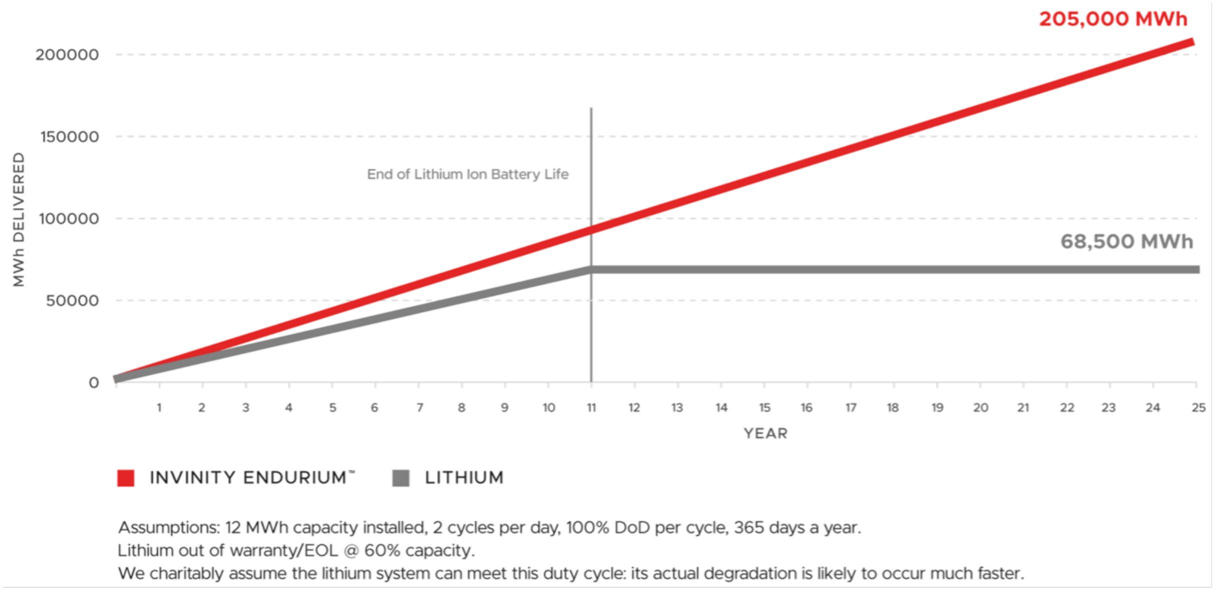


Figure 20: Comparison of Cumulative Energy Delivered Over Time – Invinity VRFB vs. Lithium Batteries (Invinity).

storage sector's development to dislodge the dominance of lithium-ion batteries in the industry's psyche" (Rai-Roche, 2021), as well as arguing that *"a standardized business model like that of the solar power purchase agreement"* (Rai-Roche, 2021) was needed.

The introduction of PPAs in the energy storage sector is a clear example of CII. In fact, these types of contracts are traditionally adopted in the renewables field to guarantee fixed tariffs and minimize the risk of price fluctuations. The integration of energy storage facilitates the negotiation of PPA contracts based on fixed or base load profiles, thereby enhancing predictability and reducing the variability in volume. This, in turn, enables the negotiation of higher prices compared to traditional "pay-as-produced" PPAs (Oxford Institute for Energy Studies, 2024). Integrating PPAs with energy storage constitutes a concrete case of BMI, as it reconfigures conventional revenue streams into a more stable, contract-based framework that minimizes fluctuations and supports long-term financial planning.

The case of Fluence was of particular interest, as it launched an innovative service model for large-scale energy storage systems, the Energy-Storage-as-a-System (ESaaS), as an alternative to 'business-as-usual' in Europe in collaboration with Siemens Smart Infrastructure, Siemens Financial Services and MW Storage. The ESaaS model offered by Fluence is based on the delivery of a turnkey service for energy storage, whereby the provider (Fluence) manages the entire lifecycle of the system, from its design to its operational management. In this scenario, MW Storage, a Swiss company specialized in the investment and management of energy storage-related projects, provides the initial financing, taking the majority share of the project. Meanwhile, Siemens Smart Infrastructure provides Engineering, Procurement and Construction (EPC) services for a period of ten years, guaranteeing the connection to the high-voltage grid and the control systems, as well as supplying the electronics and supporting components necessary for the overall operation of the facility. Concurrently, the bank-Siemens Financial Services-defines the regulatory, commercial, and financial framework, retaining the remaining share of the project. Fluence makes its storage technology available, and the customer, in exchange for the site concession and grid access, benefits from using the system to improve the efficiency and quality of energy in its facilities. This arrangement enables the customer to avoid significant investment costs, maintenance charges, and technical management expenses, paying solely for the stored energy in terms of kWh, as a service. A case study reported by Fluence, on behalf of a Finnish brewery, illustrates the generation of additional value through the sale of ancillary services, such as frequency regulation, to the Finnish national grid operator. This case is of particular interest as three of the four players involved are closely associated with the Siemens Group. Siemens SI and Siemens FS are both part of the Siemens Group, while Fluence is the result of a joint venture between Siemens and AES Corporation. This demonstrates how the Siemens Group, by exploiting the synergy between its units, is able to strategically expand its activities in the energy storage sector. The introduction of this innovative service model implies changes involving several elements of a BM's architecture, not only with regard to the value proposition, that focuses more on value generated over time and cost optimization, but also, for instance, in revenue streams, cost structure, customer relationships, and distribution channels. The adoption of the *"As-a-Service"* model in this sector represents the result of CII processes applied to BMs. In fact, this type of model, which originated primarily from the IT and cloud computing sector, has been adopted and continues to be used in a growing number of industries, transforming traditionally physical products into services.

As illustrated in the preceding case example, Fluence does not offer EPC services directly, but rather relies on specialized operators. The EPC services offered by BESS encompass engineering design, procurement of essential components, and construction/installation of the system, thereby ensuring safe and technical integration with the power grid. In the majority of cases, the companies analyzed do not offer EPC services, but rather collaborate with companies that specialize in system integration. However, there are notable exceptions to this trend, including Canadian Solar, Hyosung Heavy Industries, Trina Solar, and Wartsila. These findings suggest that companies engaged in large-scale plant construction are significantly more likely to undertake EPC projects in comparison to those that have historically emerged as battery manufacturers. This discrepancy can be attributed to the fact that companies engaged in large-scale operations have already developed established cross-functional skills in managing complex projects in areas such as marine engineering, heavy industry, or solar plant construction, where coordinating the entire project lifecycle is critical. In this instance, too, we identify CI dynamics that result in the expansion of the company's activities towards the provision of EPC services.

4.3 Partnerships, Acquisitions and Venture Investments

In order to understand the strategic dynamics aimed at strengthening competitive positioning and expanding business, the main partnerships established by the companies under study were analyzed. The main types that emerged from the analysis are described below, which are schematized in Figure 21, providing some examples for the mentioned cases.

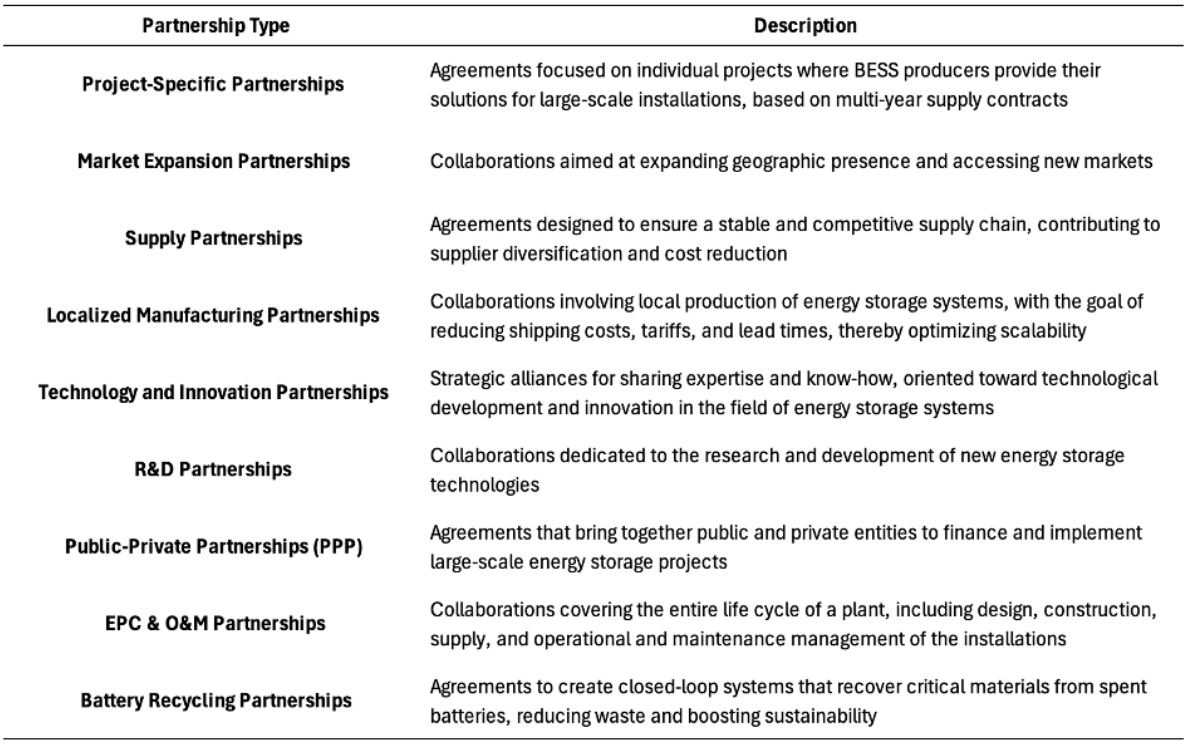
All of the companies establish project-specific collaborations, based on multi-year supply agreements through which BESS manufacturers deliver their solutions to implement large-scale projects. Among the most popular collaborations there are agreements with renewable energy companies, as, through the practice of co-location, solar modules and storage systems are integrated to provide comprehensive and sustainable solutions capable of enhancing renewable resources and ensuring a stable and reliable energy supply. Storage companies also enter into agreements with some energy utilities, integrating storage systems to ensure rapid response to changes in demand and contribute significantly to the stability and resilience of the electricity grid. These agreements, in addition to meeting the needs of intended applications, are often a strategic lever for expansion into new markets. For example, BYD expanded its relationship with Grenergy, a Spanish renewable energy company, to provide large-scale storage systems for Grenergy's projects in Chile, where MC Cube systems have been installed, contributing to a storage capacity of 3 GWh. Similarly, in December 2023, Narada partnered with NamPower, Namibia's national utility, and the Shandong Electrical Engineering & Equipment Group (SDEE) to develop the first grid-scale BESS in Namibia, with a 54 MW/54 MWh facility at the Omburu substation, representing an important entry opportunity into the African market.

These agreements allow companies to take advantage of opportunities in both established and emerging markets in the field of energy storage installations. In particular, the analysis revealed partnerships in India, South America, some countries in Africa, Australia, the United Kingdom and Germany. These nations, as represented in Figure 8, are projected to have the most substantial growth prospects in terms of GW of energy storage capacity, as per Bloomberg's estimations. The expansion strategy into foreign countries encompasses not only project-specific collaborations but also local manufacturing agreements and supply chain diversification strategies. For example, Invinity recently formalized a strategic agreement with its Taiwanese partner Everdura to start local production of its new vanadium flow battery product called *"Mistral"*. Through this agreement, Invinity will leverage Everdura's manufacturing capabilities and distribution network to penetrate the Taiwanese market and other Southeast Asian regions. Meanwhile, Tesla is expanding its energy storage business in China through a partnership with FinDreams, BYD's battery manufacturing unit. With the construction of the new Megafactory in Shanghai, dedicated exclusively to Megapack production, Tesla is relying on FinDreams to ensure a stable supply of LFP cells, thus diversifying its supply chain and obtaining more competitive prices.

It is evident that companies employ diverse strategies when expanding into new markets, and thus into new target client segments. Collaboration with specific partners has been identified as a significant catalyst for innovation in BMs in this regard. The case of Invinity offers an interesting example, illustrating a strategy that involves the outsourcing of production processes, leveraging the competencies and infrastructure already established by another company. A Localized Manufacturing Partnership facilitates market entry, reduces costs, shipping time, and logistical barriers, thereby impacting multiple facets of the BM. The example of Tesla also highlights the importance of diversifying its supply chain in order to reduce its dependence on suppliers. While the company has invested in the development of proprietary battery cells to meet global demand and ensure supply chain stability, it also relies on external suppliers, including some competitors identified in the sample of companies analyzed, such as CATL, BYD, and Eve Energy, which recently became the sixth battery supplier for the American company. Tesla is innovating its BM over time, diversifying its supply chain and redefining the balance with its key partners. The diversification of its suppliers allows the company to gain more bargaining power, with positive effects on its cost structure and profit margins. For example, CATL has been Tesla's primary supplier of energy storage cells until the entry of FinDreams, which secured more than 20% of Tesla's orders. Partnerships among BESS manufacturers that focus on technology and innovation development have been identified, as evidenced by the strategic cooperation agreement signed by Kehua and Eve Energy in the domain of energy storage. This collaboration involved the sharing of expertise and know-how between the two companies, with the objective of enhancing their respective offerings. Technology partnerships can also be aimed at integrating advanced automation, electrification, and digital technologies into their battery production facilities, as seen in the partnership between Gotion High-Tech and ABB (a multinational electrical engineering corporation). R&D partnerships have also been established to develop new storage technologies and test emerging BESS solutions, with the aim of improving battery efficiency, operational safety, and integration with next-generation power grids. These collaborations may be realized with private enterprises, as evidenced by the partnership between BYD and Zhongcheng Dayou Industrial Group in 2024, which focused on the research, development, and market promotion of new energy storage technologies, or with public entities, such as universities. A notable example of this is the joint founding of the Xiamen Institute of New Energy in 2021 by CATL and Xiamen University, with the aim of developing energy storage technologies.

Companies are not merely engaged in a competition for the production of BESS, but transform their operating model by sharing skills and resources. In particular, by integrating advanced technologies, automation and digitisation into their production activities, companies improve their value proposition, creating more complete and high-performance solutions for the market. Collaboration with partners also allows them to share the risk and costs associated with research and development, facilitating access to emerging technologies and accelerating time-to-market. Agreements with public entities involve not only universities but often also governments, which fund the development of large energy storage projects. As an example of Public-Private Partnership (PPP), Tesla partnered with the state government and the French company Neoen to construct the Hornsdale Power Reserve in South Australia, a 150 MW grid-connected energy storage system co-located with the Hornsdale Wind Farm. While public funding is often directed towards consolidated energy storage technologies, it can also be allocated to the development of new technologies. A noteworthy example of this is the partnership between the DOE and Invinity, which is based on funding and support for a government programme to demonstrate the effectiveness and scalability of large-scale energy storage systems. The DOE has allocated funding to install 84 MWh of Invinity's vanadium flow batteries at six sites in the United States. In this project, which also involves entities such as the Pacific Northwest National Laboratory (PNNL) and the National Renewables Cooperative Organization (NRCO), the DOE is acting as a catalyst, helping Invinity to demonstrate its technology on a national scale and encouraging the adoption of more innovative storage systems. Moreover, as previously mentioned, EPC partnerships have also emerged for companies offering these types of services. For example, Canadian Solar was selected as an EPC and O&M (Operation & Maintenance) partner by Copenhagen Infrastructure Partners to implement a battery energy storage project in South Australia.

Finally, among the various partnerships made by the companies, some are specifically oriented towards battery recycling. For instance, Tesla collaborates with Redwood Materials - a start-up founded by former Tesla CTO JB Straubel - with the aim of expanding large-scale recycling capacity and increasing the efficiency of precious metal recovery. Similarly, LG has entered into agreements with companies specializing in lithium-ion battery recycling, including Li-Cycle in North America, which enable the recovery of critical materials (such as lithium, nickel and cobalt) from exhausted batteries. To this end, some companies control subsidiaries specializing in end-of-life recycling, such as CATL with Brunp Recycling and Narada with Huabo Technology. The integration of recycling processes is strategic for BESS manufacturers, as the recovery of components from end-of-life batteries reduces dependence on external suppliers and significantly reduces the environmental impact of production, in line with sustainability requirements. This is also a clear case of BMI, as it affects some elements of BM such as the procurement of resources and the scaling of the relationship with suppliers, but also the cost structure of the company and the activities performed, if recycling processes are implemented internally, as in the case of CATL or Narada.



Partnership Type	Description
Project-Specific Partnerships	Agreements focused on individual projects where BESS producers provide their solutions for large-scale installations, based on multi-year supply contracts
Market Expansion Partnerships	Collaborations aimed at expanding geographic presence and accessing new markets
Supply Partnerships	Agreements designed to ensure a stable and competitive supply chain, contributing to supplier diversification and cost reduction
Localized Manufacturing Partnerships	Collaborations involving local production of energy storage systems, with the goal of reducing shipping costs, tariffs, and lead times, thereby optimizing scalability
Technology and Innovation Partnerships	Strategic alliances for sharing expertise and know-how, oriented toward technological development and innovation in the field of energy storage systems
R&D Partnerships	Collaborations dedicated to the research and development of new energy storage technologies
Public-Private Partnerships (PPP)	Agreements that bring together public and private entities to finance and implement large-scale energy storage projects
EPC & O&M Partnerships	Collaborations covering the entire life cycle of a plant, including design, construction, supply, and operational and maintenance management of the installations
Battery Recycling Partnerships	Agreements to create closed-loop systems that recover critical materials from spent batteries, reducing waste and boosting sustainability

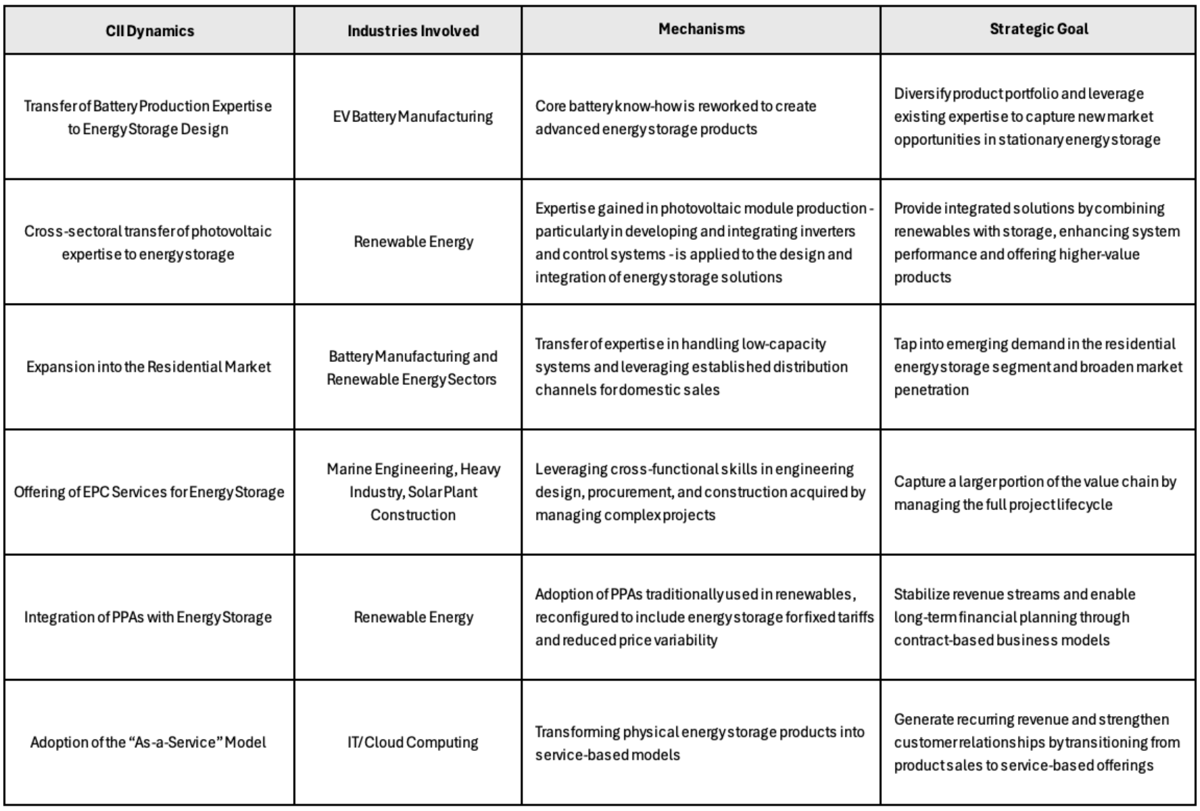
Figure 21: Partnership Types.

It was demonstrated that companies seek to establish alliances in order to innovate their BMs. In some cases, this is achieved through acquisitions and targeted investments, with the aim of vertically integrating their value chain and internalizing critical steps to gain greater control over production processes and reduce operating costs. To this end, the primary types of acquisitions and venture investments detected have been examined and will be illustrated below with some examples.

Vertical integration strategies start at the first stages of the value chain, namely the sourcing of raw materials, through investments and participations in mining companies. For instance, CATL has adopted a strategy of securing access to critical raw materials by acquiring stakes in mining companies, specifically targeting the extraction of resources such as cobalt, lithium and nickel. By expanding activities towards raw material extraction, the company transforms its traditional supply chain by integrating resource sourcing directly into the company's core operations. CATL through this BMI not only mitigates supply risks and reduces costs, but also strengthens its competitive position, paving the way for enhanced value creation and long-term operational resilience.

Some acquisitions could be directed towards integrating existing production capacities and expertise of other companies into their supply chain. A notable illustration of this is the 2019 acquisition of Maxwell, a company specializing in ultracapacitors, by Tesla, ostensibly for the purpose of integrating its energy storage systems. However, subsequent analysis suggests that the true objective of the acquisition was in fact different. Maxwell Technologies was a pioneer in the field of dry electrode technology, which facilitates the production of cells with higher energy density and reduced costs. Following the acquisition, Tesla introduced dry electrodes for the development of its 4680 cells. Once the technology and expertise had been acquired, the company was resold in 2021.

Among the strategic objectives of the acquisitions analyzed is also the internalization of system integration competencies, particularly in the area of EMSs. An emblematic example in this regard is the 2017 acquisition of Greensmith Energy Management Systems (GEMS) by Wärtsilä. This transaction allowed Wärtsilä to integrate the GEMS platform, an advanced software system for the management and optimization of energy storage systems, strengthening its ability to offer complete solutions. Fluence, compared to Wärtsilä, has taken a different approach to integrate software and artificial intelligence capabilities, focusing on direct acquisitions of software companies specializing in artificial intelligence and digital management, such as Advanced Microgrid Solutions (AMS). Although both cases are aimed at strengthening energy management capabilities, Fluence has chosen to develop in-house by acquiring advanced software rather than directly acquiring integration platforms already developed by third parties. The strategic objective of these acquisitions is to reduce dependence on third parties and ensure greater vertical integration, but the impact on the BMs is different. In Wärtsilä's case, the acquisition served to enrich its existing product offering without fundamentally changing its BM or operational framework. Greensmith operates as a business unit within Wärtsilä Energy Solutions, and the GEMS platform has been absorbed as a component of a broader solution portfolio. Conversely, Fluence's acquisition led to the full integration of AMS's technology into Fluence's digital platform, thereby substantially transforming the operating model and value proposition of the company. Finally, as seen in the partnerships analysis, acquisitions can also be aimed at integrating advanced automation capabilities into manufacturing processes. A significant example is Tesla's acquisition of Hibar Systems in 2019, a company specialized in the design and production of automated solutions for battery manufacturing processes that optimize efficiency and precision in the production of lithium-ion battery cells. This acquisition has enabled Tesla to enhance its automated production capacity, particularly for the production of 4680 cells, with a direct impact on the mass production of energy storage systems such as the Powerwall and Megapack.



CII Dynamics	Industries Involved	Mechanisms	Strategic Goal
Transfer of Battery Production Expertise to Energy Storage Design	EV Battery Manufacturing	Core battery know-how is reworked to create advanced energy storage products	Diversify product portfolio and leverage existing expertise to capture new market opportunities in stationary energy storage
Cross-sectoral transfer of photovoltaic expertise to energy storage	Renewable Energy	Expertise gained in photovoltaic module production - particularly in developing and integrating inverters and control systems - is applied to the design and integration of energy storage solutions	Provide integrated solutions by combining renewables with storage, enhancing system performance and offering higher-value products
Expansion into the Residential Market	Battery Manufacturing and Renewable Energy Sectors	Transfer of expertise in handling low-capacity systems and leveraging established distribution channels for domestic sales	Tap into emerging demand in the residential energy storage segment and broaden market penetration
Offering of EPC Services for Energy Storage	Marine Engineering, Heavy Industry, Solar Plant Construction	Leveraging cross-functional skills in engineering design, procurement, and construction acquired by managing complex projects	Capture a larger portion of the value chain by managing the full project lifecycle
Integration of PPAs with Energy Storage	Renewable Energy	Adoption of PPAs traditionally used in renewables, reconfigured to include energy storage for fixed tariffs and reduced price variability	Stabilize revenue streams and enable long-term financial planning through contract-based business models
Adoption of the "As-a-Service" Model	IT/Cloud Computing	Transforming physical energy storage products into service-based models	Generate recurring revenue and strengthen customer relationships by transitioning from product sales to service-based offerings

Figure 22: CIIs in Energy Storage.

5 Discussions

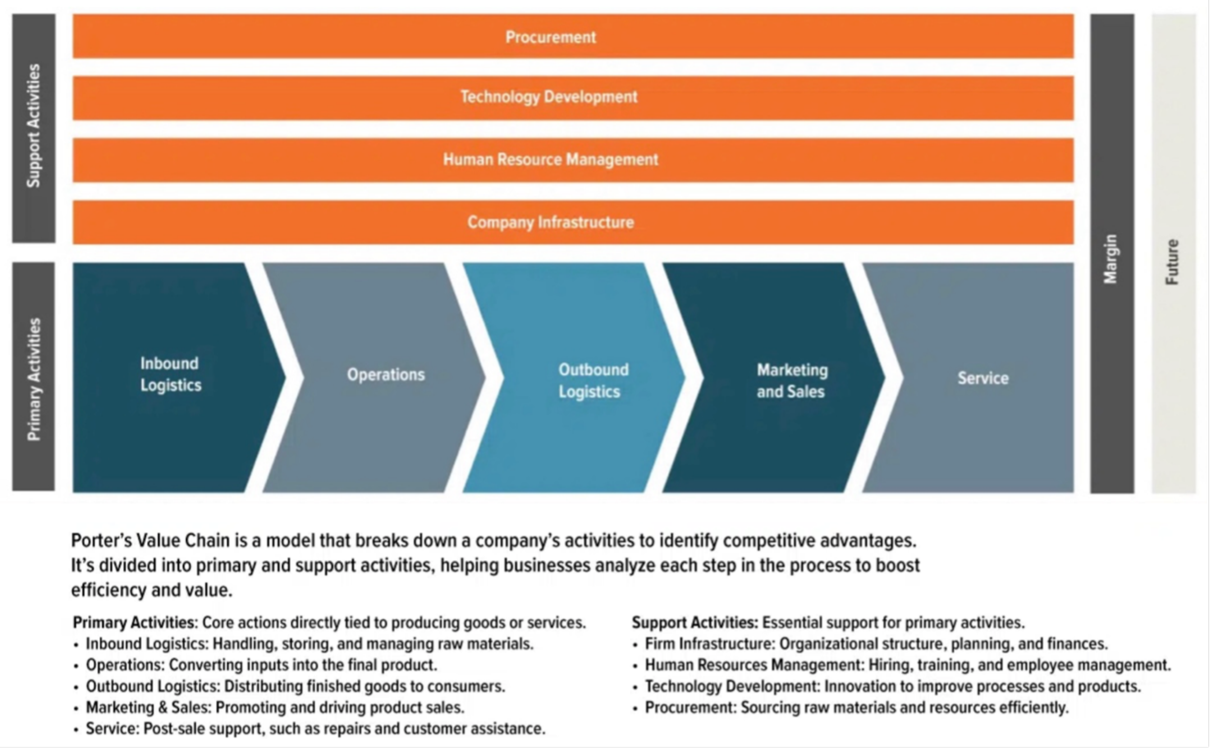
This chapter will discuss the findings of this study, placing them within the theoretical framework developed in the Literature Review. Discussions will particularly refer to the categorizations of BMI types proposed by Foss & Saebi (2017) and Santos, Spector and Van Der Heyden (2009), as well as on the application of CII theories in the context of BMI described by Enkel and Mezger (2013). This methodological approach will highlight points of convergence and possible discrepancies between the empirical data and the reference theories, offering a critical and articulate reflection on the significance of the results obtained.

An initial analysis of the industries of origin of the main players in the BESS market revealed a preponderance of companies from the battery manufacturing sectors, particularly for EVs, and companies from the renewables sector. The trend described fits firmly into the *Reactivating – Augmenting* paradigm illustrated by Santos, Spector, and Van Der Heyden (2009), according to which expansion into a new business entails a substantial change in overall activities through the addition of new functions and competencies. We expand on the theory presented by the mentioned authors, arguing that expansion into the energy storage sector from other industries presupposes the possession of previously acquired skills and expertise capable of being transferred cross-sectorally. The absence of utilities in the sample of companies examined suggests that synergies from common fields of application are not sufficient to guarantee a successful entry into this industry. Instead, an established background in the industrial production of high-tech components is required. In this scenario, *Outbound CII* dynamics clearly emerge. Furthermore, our study demonstrated that it is possible to bridge gaps in technical expertise by establishing collaborations with companies that possess robust technical know-how. The case of Fluence, for instance, showed that even a utility company can successfully enter the energy storage sector through strategic partnerships with a multinational technology firm.

The introduction of new business lines in the energy storage sector is indicative of a substantial change in all elements of the BM, and in this sense, the term '*Adaptive BMI*' can be employed, as proposed by Foss & Saebi (2017). Indeed, the findings demonstrate that the expansion into this sector involves multiple actors from the mentioned sectors.

Thus, this development is not unprecedented within the industries of origin. Concurrently, it does imply substantial changes to the entire BM architecture of the company.

With the aim of discussing the results obtained in relation to the reference theories described above, we will follow Porter's Value Chain model (1985). This approach will allow a systematic analysis of the different activities that contribute to value creation, examining how innovations in BMs are positioned along the entire value generation process.



Porter's Value Chain is a model that breaks down a company's activities to identify competitive advantages. It's divided into primary and support activities, helping businesses analyze each step in the process to boost efficiency and value.

Primary Activities: Core actions directly tied to producing goods or services.
- Inbound Logistics: Handling, storing, and managing raw materials.
- Operations: Converting inputs into the final product.
- Outbound Logistics: Distributing finished goods to consumers.
- Marketing & Sales: Promoting and driving product sales.
- Service: Post-sale support, such as repairs and customer assistance.

Support Activities: Essential support for primary activities.
- Firm Infrastructure: Organizational structure, planning, and finances.
- Human Resources Management: Hiring, training, and employee management.
- Technology Development: Innovation to improve processes and products.
- Procurement: Sourcing raw materials and resources efficiently.

Figure 23: Porter's Value Chain Model (Dr. Gary Fox).

This study contributes to the literature on BMI applied to the energy storage sector by highlighting how players involved in the production of BESS innovate their BM along all primary stages of the value chain. Our analysis showed the presence of BMI for all primary activities, as well as for 3 out of 4 secondary activities. The absence of BMI with regard to human resources management is not necessarily associated with a lack of BM innovation in this field, but our data did not provide useful information in this regard.

The entry of large corporate groups characterized by diversified business portfolios into the energy storage market has resulted in two divergent approaches to the redefining of *Company Infrastructure*. The first consists in opting for autonomous management of the business. This choice turns into the establishment of independent companies dedicated exclusively to the development and management of energy storage technologies. This strategy aligns with the model of *Relinking - Regoverning* proposed by Santos, Spector and Van Der Heyden (2009), which emphasizes the importance of redefining the governance of transactions between business units. However, our study showed that this is not the only approach taken. For companies in the renewable energy and EV battery manufacturing sectors, the decision to separate the energy storage business from the traditional core business is driven by the need to create specific governance structures to increase operational flexibility and efficiency in resource allocation. By contrast, maintaining the business's integration within the core business enables the exploitation of existing synergies and common resources. The choice between separation and integration reflects a strategic decision, motivated by the balance between the need for flexibility and specialization and the desire to capitalize on shared resources and synergies already present in the group.

With regard to *Inbound Logistics* and *Procurement*, the example of CATL has demonstrated how companies can innovate their business model from the very early stages of the value chain by acquiring stakes in mining companies to secure direct access to raw materials. This approach optimizes the acquisition of critical resources and strengthens competitive positioning through more efficient and flexible management of procurement processes with consequent cost reductions. The expansion of business activities aimed at vertical integration at an early stage of the value chain is a clear example of *Reactivating - Augmenting.* From this perspective, we underline the importance of the battery recycling processes. In fact, *"the value chain of a product or process encompasses the entire life cycle - from material sourcing to production, consumption and disposal/recycling"* (World Business Council for Sustainable Development, 2011). The integration of recycling processes is strategic for BESS manufacturers, as the recovery of components from end-of-life batteries reduces dependence on external suppliers and significantly reduces the environmental impact of production, in line with sustainability requirements. In this context, the analyzed partnerships have been established with companies specialized in battery recycling, transforming arm's length relationships into true partnerships, as outlined in the *Relinking – Regoverning* model by Santos, Spector and Van Der Heyden (2009). The CATL and Narada cases also showed how battery recycling processes can be integrated into business operations, for instance by controlling specialised ad-hoc subsidiaries, in line with the *Reactivating - Augmenting* paradigm.

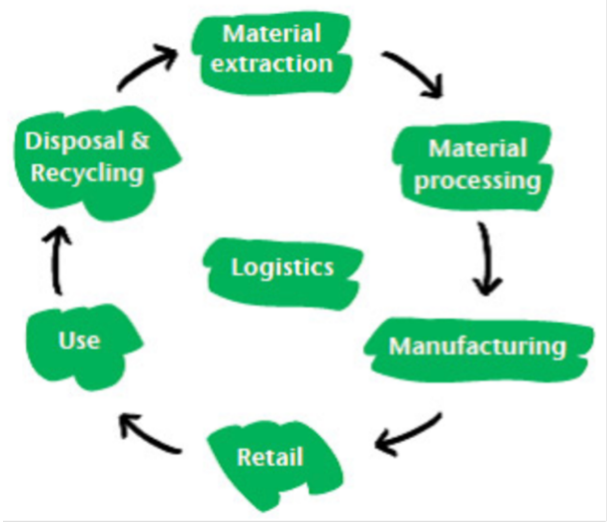


Figure 24: A standardized model of the sustainable value chain (World Business Council for Sustainable Development, 2011).

The main BMI strategies related to *Operations* and the *Final Solutions* offered to consumers in the market will be outlined below. Regarding the choice of segments to target, we derive that for battery manufacturers, the strategic decision to target the domestic market is driven by *Outbound CII* dynamics. These players have accumulated solid skills in optimising capacity- and size-limited batteries in the production of batteries for EVs and consumer electronics, which they can transfer to residential applications with similar requirements. Furthermore, the results revealed how renewable companies exploit already established B2C distribution channels for their PV solutions. We argue that the presence of these companies in the residential segment is the result of a strategy aimed at creating a domestic energy ecosystem, offering complete solutions ranging from generation to energy storage. This consolidates the companies' reputation in the energy sector and strengthens their strategic positioning, thus contributing to a more relevant competitive advantage. The strategy of expansion into the residential market, which we have identified as a form of BMI, also aligns with the *Reactivating - Augmenting* model proposed by Santos, Spector and Van Der Heyden (2009). The study also showed that two different types of strategies can be adopted depending on the target segment. We argue that for the residential BESS market, a focus strategy prevails, which is to propose a single standard solution. This is possible due to the lower requirements and types of application that residential systems require, as well as taking advantage of the modular battery architecture to expand the capacity or voltage of the system. For the C&I and utility-scale segments, on the other hand, companies tend to prefer diversified solutions to meet specific technical needs for different applications, although it is possible to adopt a focus approach in these segments as well, in order to concentrate on the development of a single system and exploit economies of scale. The choice between diversification and standardization is the result of a trade-off between customization of the solutions offered, aimed at increasing customer satisfaction, and the search for greater operational efficiency. In fact, we have shown how the 30% of the surveyed companies innovate their BM by focusing on a single type of solution even in the C&I and utility-scale segments, with impacts on the activities performed and the cost structure.

From our analysis, we deduce that the implementation of all-in-one systems offers a greater competitive advantage to companies. Integrated systems bring several advantages to the end customer, including greater efficiency, no compatibility problems between different modules, and easier installation and monitoring. In order to expand and enhance the proposed storage systems, one possible strategy involves the internalization of the production of components, such as inverters, battery modules. The approach just shown reflects the *Repartitioning - Insourcing* BMI strategy defined by Santos, Spector and Van Der Heyden (2009), whereby companies transfer internally some activities previously performed externally. Internalization can take some time, as demonstrated by the examples of Tesla and Trina Solar for the integration of in-house inverter production. We extend the theory of BMI through Insourcing in the field of energy storage, arguing that internalization can take place through the acquisition of specialized companies, as demonstrated for instance by the case of Wartsila and Fluence regarding the integration of EMS production, or by the case of Tesla with regard to dry electrode technology. However, it is also possible to realize all-in-one systems by outsourcing the production of certain components, following the *Repartitioning - Outsourcing* approach proposed by the same authors, as shown by the example of Tesla regarding battery production. In this instance, however, the company is exposed to an increased reliance on external suppliers. Tesla, for instance, has sought to mitigate this risk by establishing multiple supplier partnerships and redefining the balance of relationships with its suppliers and by starting the production of its own battery cells. We deduce that the most sustainable approach to offering complete solutions to the market consists in the internalization of the production of all components. However, the analysis also reveals how complete solutions can be realized by transforming simple supply agreements into true partnerships, aimed at offering all-in-one systems to the market, as shown by the example of the collaboration between Samsung SDI and Sungrow. This strategy aligns with the *Relinking - Regovering* paradigm articulated by Santos, Spector and Van Der Heyden (2009).

With regard to the production of storage systems, we have identified *Off-shoring* practices, which Santos, Spector, and Van Der Heyden (2009) identify as one of the Relocating strategies. As underlined in the findings section, a clear trend has emerged toward establishing production facilities abroad to reduce costs and logistical barriers while securing a presence in emerging markets. The case of Invinity provides new insights into off-shoring practices. In particular, it demonstrates that production can be relocated to foreign markets through localized manufacturing partnerships, whereby companies leverage a third party's established infrastructure and production capabilities to set up local manufacturing facilities. This approach enables companies to establish production in foreign markets without the need for significant upfront investments, facilitating agile market entry and efficient resource allocation while mitigating operational risks. In this regard, we affirm that players can also consolidate their presence in foreign markets through project-specific partnerships, both with private companies and utilities, but also with public entities and governments to implement large-scale projects. The types of BMI presented so far can be placed, according to the classification provided by Foss & Saebi (2017), in the field of *Evolutionary BMI.* They are in fact innovations that are new to companies but tend to have already been explored in the sector, aimed at restructuring some key elements to create new synergies and value, but which do not affect the entire architecture of the BM.

In terms of *Technological Developments* in battery manufacturing, there is an almost clear convergence towards the use of LFPs due to their lower cost, longer life and safety. Manufacturers specializing in NMC batteries are now also moving towards this technology. In addition, some operators are investing in the development of SSBs for EVs, with the prospect of transferring this innovation to storage systems once established. While the implementation of SSBs is not imminent, the intention to adapt this technology to storage systems is in line with the concept of *Outbound CII*. The analysis also shows that some companies cooperate with each other in order to share their accumulated know-how and expertise and to focus their efforts on new developments and innovations in the field of energy storage. In some cases, companies also form partnerships with research institutions such as universities. We further add that technological progress is not pursued solely at the product level, but also extends to the automation of industrial processes. In this regard, companies can optimize production through collaborations with specialized firms or through acquisitions, as demonstrated respectively by the cases of Gotion High-Tech and Tesla. With regard to technological innovation, the case of Invinity falls within the *Focused BMI* paradigm identified by Foss & Saebi (2017). The British company entered the energy storage industry with an innovative value proposition, aiming to revolutionize the storage industry as the first company to adopt VRFB technology. Indeed, the use of the latter enables the lowest Levelized Cost of Storage (LCOS) and higher revenues, differentiating itself in the energy storage market with a proposition that radically changes the cost/benefit ratio for consumers.

Finally, in the context of *sales models* and *services* offered by companies, an example of what Foss & Saebi (2017) define as *Complex BMI* can be seen with the case of Fluence, which has introduced an innovative sales approach to the storage market. Indeed, the ESaaS model allows the storage system to be offered as a service, as an alternative to the classic product sales model. This paradigm shift allows customers to take advantage of the technology without the burden of high upfront investment, while also transferring operational and maintenance risks to the provider, providing greater flexibility for the customer. We highlight the decisive role played by CII in the use of this type of model. The As-a-Service model, in fact, originates in the IT sector and tends to be adopted for services, although the adoption of 'aaS' models in product industries is becoming increasingly frequent. Among the four levels of adaptation identified by Herstatt and Kalogerakis (2005) we recognise the *transfer of functional principles*, as the basic concept of conceiving storage systems as a service is structured to meet the requirements of the target industry, as detailed in the findings section. This is in line with Enkel & Mezger's (2013) assertion that the most effective levels of adaptation for business models consist of the transfer of functional structures and principles. However, the analysis also revealed the application of *direct transfer*, in relation to the use of PPA contracts, due to the similar operational contexts linking the energy generation and storage industries.

6 Conclusions

In this study, the principal BMIs in the energy storage sector were analyzed by examining a sample of 19 listed companies selected from Bloomberg's Tier 1 List. The key findings emerged from the analysis are summarized below.

The entry of companies from other sectors, such as Battery Manufacturing and Renewable Energy, primarily represents a form of BMI, characterized by the transfer of knowledge acquired in the industry of origin. Companies that control several business units may decide to maintain separate and autonomous management of energy storage activities or to integrate them into their core business to exploit synergies and common resources. Innovation in the company's BM can take place from the earliest stages of the value chain, ensuring greater control over the supply of raw materials and integrating recycling processes for exhausted batteries to recover critical components and reduce dependence on external suppliers. Depending on the targeted market, companies define a strategy of either focusing or diversifying the solutions they offer on the market. The implementation of integrated systems is suggested to provide a competitive advantage to companies. In this respect, companies can evolve their BM from the production of single components to the proposal of complete solutions by internalizing the production of components, including through acquisitions or partnerships agreements. Companies can also outsource the production of certain modules, but this strategy exposes the players implementing it to greater dependence on suppliers. In the context of BESS production, it was observed that companies often establish new production facilities in regions experiencing growth in the energy storage sector. This strategy is driven by the desire to reduce costs and expand into new markets. The potential for starting production in new countries through partnerships was also noted, with the objective of leveraging the competencies and infrastructure already established by foreign companies. Furthermore, the expansion into new market segments is propelled by project-specific collaborations with private companies and public entities. BMIs implemented by companies also involve technological development. The analysis further illustrates how the introduction of new product technologies can be leveraged to enhance a company's value proposition, while also pointing out that technological progress also involves process automation. Finally, it was highlighted how innovation in the value capture structure can be achieved through the implementation of the 'aaS' sales model and the introduction of PPA contracts, both of which are expressions of CII dynamics.

The aim of this study was to investigate the implementation of BMI in the energy storage sector. The need for an energy transition towards sustainable sources and the increasing demand for energy have driven the adoption of energy storage systems. In this context, the energy storage sector is a dynamic and competitive environment, offering significant opportunities for new entrants and posing threats to incumbents. Innovation in BM represents therefore a key tool to respond effectively to market challenges and remain competitive. Our findings revealed that the major players in the energy storage sector are not only innovating their BM, but that the identified BMIs affect all primary value-creating activities (as defined by Porter, 1985) as well as supporting activities. Moreover, the study addresses the research question regarding the influence of CII dynamics on BMI implementation, demonstrating that these dynamics can play a decisive role. In particular, we found that CII manifests itself mainly through the transfer of skills and know-how acquired in other industries, such as electronics, automotive and renewable energy, prompting companies from these industries to enter the energy storage market. We also pointed out that the competences gained in the industry of origin play a role in the choice of market segments targeted by companies. Furthermore, it was found that CII dynamics are not only manifested through the transfer of know-how, but also through the adoption of innovative sales models and contract structures, as in the case of the 'aaS' model - from the IT sector - and PPA contracts - typical of the renewable energy sector. An important implication therefore concerns the crucial role that CII dynamics can play in BMI.

The study contributes to the existing literature by highlighting the relevance of BMI implementation in the energy storage sector through a multiple case study. In relation to the theoretical framework studied, the four BMI types identified by Santos, Spector and Van Der Heyden (2009) - Relinking, Repartitioning, Regovering and Reactivating - were observed, supporting the framework proposed by the authors. Furthermore, all four types of BMI proposed by Foss and Saebi (2017) - Evolutionary BMI, Adaptive BMI, Focused BMI and Complex BMI - emerged, highlighting how in the energy storage sector BMIs can represent both novelties for individual companies and radical innovations at the level of the entire sector, involving individual elements or the entire BM architecture. On a practical level, the study provides an insight into the different ways in which companies can innovate their BMs in the energy storage sector, by illustrating concrete examples drawn from the analysis of leading companies in the sector.

This research work contributes to the academic debate on BMI in the energy sector by offering new research perspectives on the correlation between the strategies adopted and their impact on companies. The analysis is in fact limited to defining what appear to be the main types of BMI adopted in the energy storage sector, and the collected data did not allow us to quantify the effects of these practices on company performance. Therefore, further studies could focus on an in-depth empirical analysis of the impact of the different types of BMI, adopting a quantitative approach to show precisely how the adoption of specific BMI strategies affects overall company performance. The present study is not without its limitations. Specifically, the analysis is based exclusively on listed companies, representing less than half of the major producers of storage systems identified by Bloomberg's Tier 1 List. Moreover, the information utilized in this study was obtained from public online sources. However, for certain fields, the available information was not exhaustive for some companies. Additionally, the breadth of the available sources may have led to the exclusion of certain information, despite its online availability, due to its non-inclusion in the selected sources. This may have resulted in a biased assessment of the dynamics analyzed, thus suggesting the need to supplement the currently available data with additional sources to obtain a more comprehensive and accurate picture. In order to surmount the limitations encountered and obtain a more complete view of the dynamics of BMI in the energy storage sector, it is suggested to expand the sample including unlisted companies, in order to capture a wider range of strategies adopted. Furthermore, the use of diverse and non-publicly available data sources could help to fill the information gaps that emerged from the data collection. A qualitative approach, through semi-structured interviews, focus groups and questionnaires, would also be useful in order to investigate aspects not emerging from the quantitative analysis alone. Finally, the application of longitudinal methodologies to single case studies would facilitate the observation of BMI strategies over time and permit a more accurate assessment of their impact on company performance.

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