

Sustainable Economic Growth through Battery Innovation: The Impact of Industry Expansion and Testing Capacities in Hungary

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In an era where sustainability has become a pivotal concern, the battery industry emerges as a beacon of hope for innovation and economic transformation. Batteries are a cornerstone of sustainable development. They provide an essential energy storage function, facilitating the transition to renewable energy sources and decarbonization. Batteries enable efficient storage and distribution of renewable energy and reduce dependence on fossil fuels. This results in mitigating environmental pollution and contributing to a more sustainable energy landscape. Batteries are, therefore, a fundamental driver of both energy and environmental sustainability.

The integration of testing capacities in battery factories and third-party locations is crucial for ensuring product reliability, safety, and performance. In turn, this reinforces market confidence and consumer adoption of the new sustainable applications batteries support. By investing in advanced testing facilities, the industry adheres to stringent quality standards and promotes technological advancements and R&D. This contributes to the economic and sustainable growth of the sector. This approach demonstrates a commitment to continuous innovation, product excellence, and a multitude of sustainability factors, highlighting the essential role of testing in the burgeoning battery industry.

In summary, the battery industry is at the intersection of sustainability and economic growth. Our publication shows how the strategic infrastructure development of the innovation-focused battery sector can offer a new perspective on achieving sustainable and economic growth and how it can play a key role in this global transformation.

1. Introduction

The battery industry has experienced rapid growth worldwide, especially in the fields of electric vehicles (EVs) and energy storage systems (ESS). In Europe, the development of the industry is strategic to achieving sustainability goals, while the continent is still heavily dependent on Asian battery manufacturers. This is particularly important for Hungary, which has set itself the goal of becoming one of Europe's battery manufacturing hubs, which can contribute to economic growth and industrial innovation. However, in addition to increasing investment, there are still several challenges to be faced, such as the development of independent R&D capacities and the integration of the entire battery supply chain.

This research explores how the rapid development of the Hungarian battery industry contributes to sustainable economic growth. Particular attention will be paid to the integration of battery testing capacities for manufacturing processes and their impact on battery reliability, safety, and performance. We will also examine the extent to which these developments enhance market confidence, stimulate consumer acceptance and industrial innovation, and, in turn, support both economic and environmental sustainability (Figure 1.).

The generic battery market emerged at the same time as the development of portable electronic devices such as calculators and torches, spurred on by the performance limitations of earlier batteries. The search for higher energy density has focused on lithium-ion batteries (LIBs), exploiting the properties of lithium and the potential of organic electrolytes, which led from rechargeable lithium metal batteries in the early 20th century to modern LIBs (Li et al., 2018).

One of the reasons for the recent success and uptake of electric vehicles is the use of advanced lithium-ion batteries, which offer better performance, durability, and lower costs. Recent advances in the technology include improved energy and power performance, longer life, operating temperature range, and lower costs. These improvements mean that EVs offer a longer electric range and better acceleration at a lower cost premium. (Muratori et al., 2021).

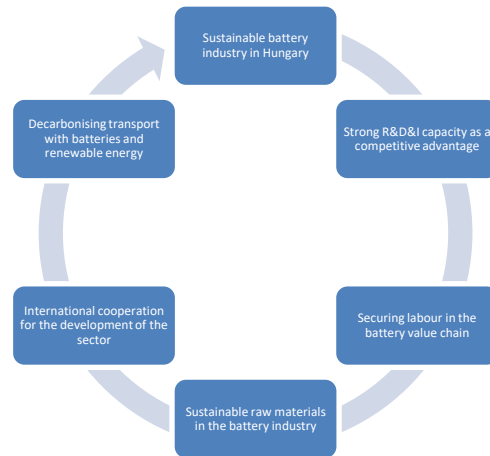


Figure 1: Hungary has 6 objectives to become a center for the European battery industry (Kormany, 2022)

1.1 Areas of application for electric vehicles (EVs)

EVs are mainly used in passenger and freight transport, contributing to sustainable mobility and reducing carbon emissions. EVs are also increasingly used in urban public transport, such as buses and trucks, reducing air and noise pollution. Developments in battery technology, especially lithium-ion batteries and fast charging solutions, are increasing the efficiency and practicality of EVs.

EVs could become widespread soon through advances in battery design and control techniques. Successful EVs will need to address challenges such as cost, durability, safety, reliability, sustainability, and performance. The development of nanotechnology, new battery materials, and more advanced fast-charging systems can contribute to increasing the performance and popularity of EVs. (Sharma et al., 2020)

1.2 Battery sustainability of electric vehicles

EVs are key to climate sustainability through decarbonization by fighting climate change and air pollution. Lithium-ion batteries are at the heart of these vehicles' electric power trains. Battery cells are packed together in module frames or rigid cell casings, storing the required energy and reducing and replacing ICE fossil fuel systems. (Vlad and Lungu, 2022)

Other sources also highlight that the expansion of the EV market and the interoperability of battery technology are key to reducing carbon emissions and ensuring the sustainability goals of the sector and beyond. Market trends and new technologies (e.g., low-cobalt or cobalt-free batteries) can influence EV market share and manufacturing strategies. Changes in battery technology and carbon pricing can have a significant positive effect on the environment and the competitiveness of the battery sector itself and other sectors using the technology. In the future, supply chain re-design and strategic decisions on 'ally-shoring' could be fundamental to improving the sustainability of EV batteries and reducing greenhouse gas emissions (Lal and You, 2023).

1.3 Production of EVs in Europe

The production of electric vehicles and their batteries is a strategic sector for the global market economy. Currently, the European market is less developed in this sector than it needs to be. Asian manufacturers, particularly Chinese, Japanese, and Korean companies, are steadily developing. European Union (EU) policymakers and industry leaders have set themselves the goal of improving the situation in battery production, but this takes time and must be done in a clear and concisely planned manner. The strategic action plan developed by the European Commission and the cooperation with industry and academia are important steps in this direction. The EU must create an environment that supports collaboration and innovation in battery research and production while creating an attractive European market for EVs (Beuse et al., 2018).

1.4 Battery testing capacities in Europe

European battery test centers play a key role in the development and production of electric vehicles and energy storage systems (ESS). These facilities test batteries for aspects including performance, safety, durability, and environmental impact. They also support R&D activities by testing new innovative battery technologies, including new materials and designs that can improve battery performance and safety.

At these centers, researchers are targeting the further development of lithium-ion batteries and research into new types of batteries, such as sodium-ion, lithium-sulfur, solid-state batteries, and post-lithium-ion chemistries. They work with regulators and industry organizations to continuously develop testing standards and regulations. This ensures that batteries meet international and local regulations and are safe to use. Several test centers also offer education and training programs to train industry professionals in battery technologies and testing methods, helping to ensure that the latest research findings and technologies are quickly incorporated into industry practice. This applies both on a technician-vocational and engineer-research level. The current state of battery testing centers in Europe is evolving dynamically as demand for electric EVs and ESS grows. However, for the Central Eastern European region (CEE), the number of established test facilities is still low. Significant global battery manufacturers – mostly Asian - are building their European factories here now, if not planned within the next few years.

1.5 Effects of EU battery regulation

EU battery legislation aims to boost domestic industries, protect the environment, and promote the sustainability of the circular economy. However, uncoordinated regional regulations make its effects unpredictable. Poor coordination can disrupt EU and global battery supply chains, affecting producers and recyclers. If not addressed in time, it could hamper the production of electric vehicles, which will be needed as many EU countries ban the sale of internal combustion engine vehicles from 2030.

Globally coordinated efforts could make regulation more efficient and predictable. They also come with risks. If EU battery regulations become the de facto norm for global recycling, circularity and battery data sharing standards, then EU companies could benefit and be ensured a level playing field. Although there are challenges, the EU's significant market share provides an opportunity to influence global standards. Regulation will put the EU at the forefront of the battery market in terms of environmental and sustainability performance, but potential unintended consequences must also be considered. (Melin et al., 2021)

1.6 Importance of battery testing

Battery test centers ensure reliability, safety, and long-term performance, contributing to the safe introduction of batteries to the market. As the Hungarian battery industry develops, testing capacity will also expand, benefiting the economy and the environment by reducing dependence on fossil fuels and pollution. The expansion of electric vehicles and energy storage will create new industries and jobs while testing facilities will support technological development and sustainable economic growth. The growth of test centers stimulates innovation, enabling faster development and testing, which increases the competitiveness of local firms while also contributing to sustainable economic impacts.

Figure 2. illustrates the importance of battery testing, highlighting its role in ensuring reliability, safety, and long-term performance. It also highlights the sustainability impacts on the environment, economic growth, technological development, and diversification of the local economy, ultimately contributing to a stronger international trading position.

1.7 Novelty justification

The novelty of the research lies in the fact that it examines the rapid development of the Hungarian battery industry and its contribution to sustainable economic growth. While previous studies have already addressed the role of batteries in EVs and ESS, little attention has been paid to the situation in Central and Eastern Europe, especially in Hungary. The research places particular emphasis on the development of battery testing capacities, which are underdeveloped in this region but play a key role in improving reliability, safety, and performance.

The study also looks at how these technological developments can help both economic growth and environmental sustainability, especially in light of Hungary's strategic ambition to become a European battery manufacturing hub.

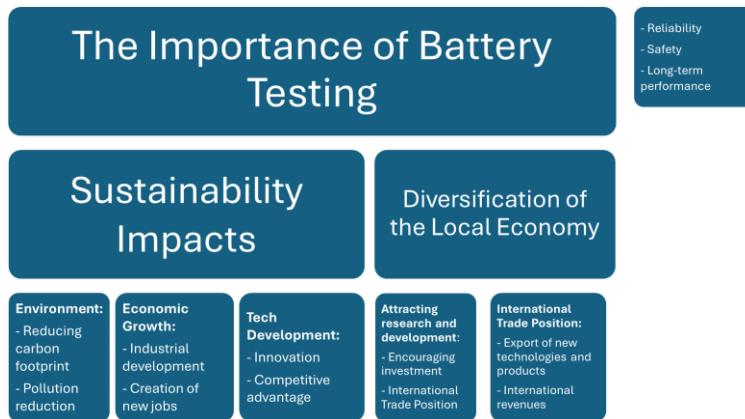


Figure 2: The importance of battery testing

2. Methodology

The aim of the research is to explore how the rapid development of the Hungarian battery industry contributes to sustainable economic growth, with a special focus on the integration of battery testing capacities into the manufacturing process. The fundamental problem is that the battery value chain in the region, especially in Hungary, is not yet fully integrated and lacks independent R&D capacities. Increasing battery testing capacity is essential to foster sustainability and innovation in the industry, but the independence of manufacturing processes is limited as the sector is dominated by Asian investors.

The research is based on a qualitative analysis of the current state of the battery industry in Hungary and Europe. As part of the methodology, case studies are used to illustrate the impact of FDI (Foreign Direct Investment) on the development of the industry. In addition, the research will pay particular attention to the role of battery testing capacities and competence centers, particularly in terms of sustainability and industrial innovation, which are key to increasing the competitiveness of the region.

3. Results and discussion

The shift to renewable energy sources is key to decarbonization and environmental sustainability. It is also a key pillar of the EU's long-term economic competitiveness. This shift will increase the importance of energy infrastructure transitions, including the continued proliferation of batteries. In turn, battery testing and verification will help optimize manufacturing processes and product development and ultimately “value” all across the supply chain and economy. Concurrently, Hungarian automotive firms are embracing electromobility, with traditional powertrain sectors still pivotal for employment stability in the coming decade (Czifrusz, 2023). This atmosphere creates an opportunity for sustainable economic growth, supporting battery competence centers focused on Testing, R&D, and Training.

3.1 Foreign investments by Asian manufacturers in Hungary

Recently, ICE vehicle development has been shifted to electromobility. Traditional manufacturers and component suppliers are opening up to opportunities from the developing EV supply chain. In Hungary, significant and notable investments in EVs have appeared; for example, BYD opened an electric bus factory in Komárom. Another example is the joint venture between Ikarus and CRRC to assemble electric buses in Székesfehérvár. In addition to commercial vehicles, Asian investors are also developing production capacity for the automotive industry, not only in the area of vehicle assembly but also in electric powertrains, including battery cells, packs, eDMs, and various components. Asian investors, who also produce batteries for electric vehicles, have channeled significant funds into battery production, creating a considerable number of jobs (Szabo et al., 2023). Asian investors landed on a consensus that Hungary is an excellent destination for investment. Reasons for this preference are due to several factors like location, skilled workforce, competitive costs, support from Hungarian government industry policy, strong legacy automotive presence, and newly developed infrastructure projects that support the industry, such as the ZalaZONE Science Park and Proving Ground.

Major investments in the near future with battery production projects are expected from CATL, SK Innovation, and EVE Power, while BYD has committed to building an electric car factory in Szeged, as seen in recent press releases. Highlighting CATL, one of the world's largest battery manufacturers, has decided to invest in Eastern Hungary and have started to build a 100Gwh Giga Factory with a budget of €7.3 billion. This is one of the largest of its kind in Europe compared to the average existing or planned European cell production sites to date. Once

completed, the plant will produce batteries for Mercedes, BMW and Volkswagen. Mercedes has already confirmed the cooperation between the two companies and has indicated that it will be the first and largest customer to receive CO₂-neutral battery cells for the new generation of electric vehicles (Moldicz, 2022).

3.2 Challenges

The Hungarian public has a strong distanced attitude towards battery factories, partly due to industrial tragedies of the past and partly due to a lack of information. A large proportion of respondents are concerned about the consequences of industrialization, but few are informed by professional sources, creating a discrepancy between public opinion and the facts. This situation could be remedied through education and clarification of labor market objectives and sustainability requirements. At the same time, a significant proportion of respondents support the phasing out of battery production and oppose the establishment of new factories, reflecting environmental concerns. (Remsei et al., 2023)

These concerns cannot be divorced from the economic and environmental importance of battery production, as billions are being invested in the development of batteries and related technologies in Europe. These investments are in the interests of sustainability and decarbonization. However, the battery industry faces several challenges, such as high costs, low energy density, long charging times, and limited range for electric vehicles. In addition, infrastructure, particularly the lack of fast charging stations, is hampering the uptake of EVs, and battery safety risks are also a concern. Addressing these is key to increasing the economic efficiency of the industry. (Irmiya et al., 2020) Battery competence centers can play an important role in addressing these challenges by acting as a hub for industry research, innovation, and training. They can also facilitate the spread of best practices and support safety, technology, and infrastructure development.

3.3 The build-up and sustainability impact of battery investments in Hungary

Battery investments in Hungary are structured on several levels. Basic economic and political support provides a favorable environment for investment. This includes government incentives that support the initial capex on infrastructure. The development of production and manufacturing capacity, as these facilities will ensure efficient mass production of batteries. The key to the previous two points is the establishment of battery test centers or, in more specific words, "battery competence centers" that encompass slightly more activities. Here, fundamental activities carried out and supported are:

1. Testing for performance, safety, reliability, durability, and environmental impact.
2. Research & Development (R&D) for fostering innovation in new battery chemistries, battery pack / eDM solutions - applications, and related infrastructure.
3. Training and re-training initiatives to support the growth of an educated workforce focusing on industry professionals, both vocational and academic.
4. Cooperation and coordination with regulators to develop testing standards, as well as their communication and education.

Through this combined investment structure, high-tech innovation and development will ensure long-term competitiveness and economic sustainability by creating new industries and jobs in Hungary over its complete supply chain.

4. Conclusions

The rise of lithium-ion batteries has played a fundamental role in the development of the battery market. Without the current lithium-ion chemistry, the development of portable electronics, electric vehicles (EVs), and energy storage systems (ESS), as well as the balancing of household and electrical grids, would not have reached the current level. In the case of electric vehicles, the integration of lithium-ion-based electric drive trains (eDM) has led to significant improvements in performance, cost-efficiency, and sustainability, making electromobility more attractive to consumers and essential in the fight against climate change and air pollution. These all contribute to climate stability and to environmental sustainability.

Hungary has emerged as a key player in the European battery industry, attracting significant investment from Asia due to its strategic location and cost advantages. These investments have provided opportunities to launch domestic battery manufacturing projects, resulting in overall job creation and economic growth. Nevertheless, the sector continues to face challenges such as high costs of battery raw materials, high rates of manufacturing scrap, energy density constraints and safety issues, which have received negative media coverage. These factors have all contributed to the industry not reaching its full potential so far.

Tackling these challenges through technological developments and strategic industry partnerships is essential to achieve further growth and the desired economic and environmental sustainability impacts. Tackling these challenges is particularly important in view of the EU's 2030 target dates when many Member States will ban the marketing of internal combustion engine vehicles.

Quantitative analysis shows that Hungary's current battery production capacity is already having a significant impact on the EU battery market. For example, the 100 GWh capacity plant to be built by CATL will be among the largest in Europe and is expected to significantly increase Hungary's international competitiveness in the battery market. Increased innovation opportunities and testing capacity in the industry could create a multiplier effect that could significantly accelerate the market uptake of sustainable technologies and help achieve both economic and environmental sustainability goals.

These centers of excellence will not only stimulate technological development but also promote economic diversification by creating new industries and jobs. The export of locally produced technologies and products can strengthen Hungary's international trade position, contributing to long-term economic growth and sustainability.

Based on the above, Hungary can become a key player in the global battery transition, contributing to innovation and sustainability goals and strengthening its position in the industry transformation.

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