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Battery Storage for Industrial Solar in Vietnam: ESG Impact, Regulatory Barriers, and Investment Model

Nguyen Lam Phat[1] Nguyen Manh Ha[2]

[1]Olympia High School, Ha Noi, Viet Nam Email: nguyenlamhat08@gmail.com
[2]Truong Thanh Group, Ha Noi, Viet Nam Email: ha.nm1589@gmail.com

Abstract: *This study discusses the economic and investment viability of integrating battery energy storage systems (BESS) with rooftop solar photovoltaics (PV) in Vietnamese industrial zones, in the context that the development of renewable energy is progressing faster than supportive policies and regulatory frameworks for energy storage. There was a mixed-method research design with both expert interviews and in-depth techno-economic simulations for the Northern, Central, and Southern provinces, with particular case study on the Southern region's viability of the use of green finance such as International Renewable Energy Certificates (I-RECs), ESG loans, and other such mechanisms. The simulation results indicate that BESS adoption can increase solar self-consumption from approximately 60% to over 85%, reduce electricity costs by 5–15%, and generate internal rates of return above 11% under high-irradiance conditions. Under low irradiation conditions, BESS enhances operational resilience and energy surety. This is the first Vietnamese research that tries to provide a realistic assessment of BESS installation in the industrial sector combine technical performance indicators, ESG investment trends, inter-regional strategy, and policy geography. The findings offer strategic advice to energy planners, policymakers, and investors who aim to decarbonize industrialized economies. The research offers a model reference for financing Vietnam's transition towards low-carbon industrialization through the transfer of solar PV installations into storage and green finance mechanisms.*

Key words: Battery Energy Storage Systems (BESS); Rooftop Solar Photovoltaics (PV); ESG Investment; Green Finance and Carbon Credits; Industrial Decarbonization.

1. Introduction

In Vietnam's industrial parks, the adoption of photovoltaic (PV) systems has accelerated greatly in recent years. This development is driven by heightened energy requirements, favorable policies, and the potential of solar energy. In addition, industrial factories face rapidly growing electricity prices coupled with greater scrutiny on Environmental, Social and Governance (ESG) practices from both regional and interregional markets. Energy optimization and reduction in the cost of production have become a strategic necessity for business firms, especially those engaged in energy-intensive manufacturing activities.

Despite the growth of solar PV installations, there is a major limitation: the intermittency of solar energy hinders its reliability for industrial applications in processes requiring a constant and stable power supply. The failure to implement adequate energy storage technology systems translates to loss of economic value in investment towards renewable energy sources; this is especially true during peak hours of electricity generation.

The industrial zones in Vietnam are arguably one of the first places BESS technology should be deployed. Cost effective BESS systems would be able to serve as a solution for many of the current economic challenges faced in that region. Companies lack the capacity to store surplus electricity, and in the absence of support mechanisms or regulating policies, most company have little knowledge of the economic benefits of BESS application. Context-specific research evaluating the economic feasibility of BESS application in Vietnamese industrial contexts is also limited.

This study aims to provide an overall assessment of the economic–environmental benefits and financial performance of integrating BESS into renewable energy production in industrial zones. Specifically, this study explores how BESS can optimize operational efficiency, energy consumption, and help businesses tap into green financial tools and carbon credit mechanisms. Furthermore, the study aims to propose viable models of BESS investment, operation, and financing according to different geographic locations and industrial profiles.

The study is guided by the following research questions:

- How can Battery energy storage system help industrial firms reduce electricity costs and improve the efficiency of solar PV utilization?
- What are the economic factors influencing companies' investments in BESS in industrial zones?
- How can the integration of BESS unlock opportunities for carbon credits, green finance, or other financial incentives?

2. Literature Review

The Economic Role of Battery energy storage system (BESS)

Battery energy storage system (BESS), particularly battery-based systems, have emerged as a fundamental enabler of energy transition and industrial cost savings. A few of the key applications of BESS include peak shaving—reduction in demand charge through release of stored energy at peak times; load shifting—transfer of energy consumption from high-cost to low-cost time intervals; and energy arbitrage—taking advantage of price spread in time-of-use tariff structures (Luo et al., 2015). Taken together,

all these applications mitigate costs in industrial sectors, allow for improved productivity, and enhance system robustness and stability.

Once again, the impact of BESS integration on the energy cost architecture in some manufacturing sectors like textiles, food processing, and electronics that are classified as energy intensive is more pronounced. With BESS, firms have increased energy autonomy from the grid which lowers energy expenditures and enhances competitiveness. As noted by IRENA (2020), this enables a greater self-consumption rate of solar PV, while reducing dependency on grid electricity.

International Models Demonstrating Economic Efficiency

Across the world, several countries have adopted BESS models with favorable economic outcomes. In China, BESS is increasingly being applied in industrial parks as a way of reducing the cost of production and helping meet national decarbonization targets. BESS combined with rooftop PV helps enterprises to keep energy costs in check and attain green production specifications, which is critical for export enterprises (Zhang et al., 2021).

Leasing models BESS have gained traction in both Germany and the United States, as businesses are now able to avoid upfront capital expenditures unexchanged for periodic operational payments. With the addition of subsidies, tax incentives, or participation in carbon markets, these models can achieve internal rates of return (IRRs) surpassing 10% (Denholm et al., 2019). Such findings demonstrate that BESS remains financially viable in deregulated power systems, even when market electricity prices are relatively lower.

Vietnam's Context and Institutional Challenges

Vietnam had a solar PV boom, particularly in the industrial parks, but integration with BESS is not extensive. The current regulatory environment does not include a particular policy or incentive program for BESS installation. Internal PPAs are permitted in industrial parks, but there is no preferential tariff or funding scheme for BESS (Vietnam Ministry of Industry and Trade, 2022).

Adoption hinderances are the battery cost at an initial investment, uncertainty over long-term return on investment, and absence of standard guidelines for depreciation, maintenance, and tax treatment. Furthermore, green finance for BESS remains underdeveloped, partially due to the absence of standardized assessment measures and bankable project pipelines.

Geographical and Sectoral Variations in BESS Economic Viability

The economic performance of BESS also depends on geospatial and industrial conditions. Locations with higher solar irradiance, such as central and southern Vietnam, have more favorable conditions for integrating BESS–PV. Northern regions with less stable weather conditions can use BESS to a larger degree for grid backup or load stabilization (Pham et al., 2023).

Sector-wise, sectors with chronic or heavy-load electricity demands—such as seafood processing, textile manufacturing, and electronics assembly—benefit most from BESS adoption. These sectors stand to maximize energy cost saving and improve ESG performance concurrently, thereby increasing access to green value chains and sustainable finance options.

3. Methodology

This study uses a mixed-methods approach where qualitative and quantitative methods are combined to assess the techno-economic viability of the use of battery energy storage system (BESS) in industrial parks across Vietnam. The study design is such that it seeks to leverage expert view as well as actual performance figures to allow for a comprehensive assessment of financial feasibility, investment effectiveness, and suitability at the regional level.

Qualitative Methods

To gather contextual and institutional data, semi-structured interviews were conducted among a targeted group of stakeholders. They included energy finance experts, infrastructure investors, and industrial zone managers. The interview guide focused on key issues such as the understanding of investment risk, regulatory constraints, financing options for BESS, and clean energy solution demand in export sectors. Interview responses were coded and thematic analysis conducted in order to identify patterns and inform the construction of the quantitative modeling stage.

Quantitative Methods

The quantitative component involved simulation of hybrid PV–BESS systems under various industrial conditions. The simulations indicated energy flows, demand profiles, and cost savings for 20–25 year project lifetimes for different levels of investments. The following principal indicators were calculated:

- Capital expenditure (CAPEX): Installation, inverter, and battery costs.
- Performance indicators of the economy are:

1. Payback Period (PBP): In the context of PBP, the recuperation of any initial investment will denote the duration which is required for investment recovery.
2. Internal Rate of Return (IRR): Profitability of an investment is measured by IRR.
3. Net Present Value (NPV). NPV emerges as one of the results achieved from performing discounted costs and benefits analysis.

- Accessibility of climate finance instruments: The evaluation also considered prospective revenue from carbon credits through I-REC, in addition to green loans from developmental banking institutions and ESG investors.

The model applied the actual technical parameters and cost benchmarks of solar storage systems from Vietnam and other Southeast Asian countries.

Geographical Comparison Framework

Keeping in view the enormous variability of solar irradiance, price of electricity, and industrial load of electricity by region, the study included regional comparison among three representative clusters:

- Northern Vietnam (e.g., Hanoi, Hai Duong, Thai Binh): With moderate irradiance, seasonal climate, and spot grid curtailment.
- Central Vietnam (e.g., Da Nang, Khanh Hoa): High solar resource with growing industry bases and logistics infrastructure.
- Southern Vietnam (i.e., Binh Duong, Long An, Can Tho): High irradiance, stable power demand, and heavy export manufacturing concentration.

This scheme enabled determination of region-specific strengths, investment risk, and suggested business models for BESS deployment.

4. Findings & Discussion

4.1. Technical Performance

The integration of solar PV systems with roof tops and battery-based battery energy storage system (BESS) has a major impact on technical performance in industrial applications. Simulation results indicate that solar self-consumption can improve from an average of 60% to 85–90% when BESS is implemented. This innovation is a result of the ability of batteries to store surplus solar electricity generated during off-peak times (i.e., during noon hours) and release it during off-peak evening peaks when solar generation is zero but factory operations could still be in progress.

This significantly enhances the matching of production and consumption, which is vital for:

- Reducing curtailment of solar electricity,
- Supplying stable voltage and frequency at the plant level, and
- Decreasing reliance on peak demand or grid instability imports from the grid.

Besides, by reducing peak load withdrawals from the national grid, BESS indirectly removes pressure from Vietnam's increasingly congested transmission network. This is particularly helpful in industrial parks remote from generation hubs.

4.2. Economic Performance

Important Financial Benefits of ESS Integration

ESS combined with rooftop solar delivers four important economic advantages:

- Lower electricity bills (5–15%): ESS enables energy arbitrage by storing surplus daytime solar energy to offset during more costly evening hours or peak grid tariff time.
- Enhanced energy security: ESS minimizes production loss due to grid volatility, a vital concern in industrial regions.
- New revenue streams: Assets are eligible for carbon credit income (I-REC) and ESG lending, adding to financial returns.
- Long-term cost savings: With a 20–25-year lifetime, conventional systems yield total savings of VND 20–80 billion (≈ USD 800k–3.2M per MWp), depending on solar insolation and load profile.

Model simulations for Southern and Central Vietnam—where PV yield and grid tariff are best—show IRRs over 11 %, confirming commercial viability.

Table 1: Detailed Offer Analysis from Leading Funds (Devloper)

Developer	Investment Model	Battery Use Case	Key Value Drivers
Singapore Dev	PPA/OPEX, no capex for host	ESS for load-shifting, IREC	No upfront cost + carbon credit + ESG
France Dev	EPCC + project loan	Scalable ESS to optimize rooftop PV	Cost-saving turnkey + simplified licensing
Local Dev	Zero-cost investment + leasing	ESS enables arbitrage, net-zero PPAs	Carbon savings + load alignment
Malaysia Dev	EPCC + financing	ESS viable with low battery costs	Financing scale + carbon stacking
Indonesia Dev	BaaS + premium PPA	Centralized ESS, carbon monetization	ESG premium + energy security

In Vietnam's solar rooftop and energy storage (ESS) investment market, several global and regional funds are already providing structured financing along with sophisticated deployment models for industrial customers. Despite the differences in ownership structure, regional focus, and technical integration of these players, there exist a number of converging trends that are of immediate relevance to factory owners and energy-intensive tenants.

Most of these funds provide PPAs or lease-based contracts on OPEX terms eliminating upfront capital investment by the industrial user. From an economic standpoint, this is beneficial to most producers, particularly SMEs, as asset ownership risks and financial hurdle rates are eliminated allowing them to earn immediate return from electricity savings. Within these frameworks, the Service Company takes on the full responsibility for the system installation and operation, reputed PV panels, inverters, and optionally the ESS. The factory pays a fixed or reduced tariff for the duration of the contract which typically spans 15 to 25 years.

The integration of battery storage into these offers—either as a bundled package or as add-ons at a later stage—enhances the economic advantages further. Along with solar self-consumption, BESS enables factories to self-consume 85-90% of solar energy and reduces grid dependence. This leads to a reduction of 5-15 percent in electricity expenditures relative to consumption patterns

as well as local solar irradiance. Moreover, the undelivered indirect operating cost, power quality issues and the risks of unplanned outages as seen in powered storage systems improve due to the demand charge removal and load fluctuation leveling.

Considering general investments, the Internal Rate of Return (IRR) for BESS-integrated projects ranges from 8% to 12%. Southern and Central provinces tend to perform better due to stronger solar irradiance and higher-priced grid electricity, thus widening the margins. Accompanied by green revenues, these figures increase, such as I-REC which pays for every generated and consumed MWh of clean energy. Carbon reporting services also add value, allowing clients to achieve ESG goals which enhance exposure to export markets and green finance.

The uniformity and scalability of products is another benefit of market comparison. For most investors, there is a turnkey technique: investment funds begin with site evaluation and lead all the way to engineering, construction, and operations & maintenance (O&M). This enables manufacturers to benefit from expert risk management and technical optimization outside of house-owned energy teams. Furthermore, large funds are able to provide more favorable financing terms and volume procurement discounts, which reduces the tenants' levelized cost of electricity (LCOE) relative to self-owned or small-scale systems.

To summarize, self-owned BESS, along with the currently offered investment funds, present an economically advantageous alternative for industrial clients in Vietnam. By externalizing CAPEX, the claims offer lower energy expenses while granting enhanced reliability, issuance of green financial instruments, and opportunity for monetizing carbon returns. This transforms the energy transition into value creation instead of cost burdening. This is particularly enticing for export sector producers where ESG compliance along with energy resilience shifts to a competitive need.

4.3. Regional Comparison: Geographic Factors Influencing Investment Returns

Geographical differentials in Vietnam impact the economic efficiency, as well as the technological effectiveness, of integrating BESS with photovoltaics for industrial applications. Factors such as solar irradiance, grid reliability, energy costs, and industrial demand not only differ by region, but also influence the scope of BESS integration that yields the best ROI.

In northern Vietnam: Hanoi, Bac Ninh, and Hai Phong. These locations receive solar resources in a much moreless predictable manner due to greater prevalence of cloudiness and rain generated weather seasons, particularly during winters. Moreover, the annual yield associated with rooftop solar systems falls significantly along with their intermittency issues. Notwithstanding these challenges, energy storage systems in such regions boost resilience tremendously. This is particularly salient for power hungry manufacturers operating 24/7 especially in the electronics, textile and food processing sectors. By providing reliable backup during grid fluctuations and diminishing photovoltaic intermittency, BESS turns into a critical resource. While the internal rate of return for standalone PV systems in Northern Vietnam remains lower than other regions, the value of non-quantifiable benefits such as energy security and uninterrupted production supports the BESS investment rationale, particularly in thinly connected grid regions or in export-oriented plants subject to CBAM or ESG regulations.

Greater Central and Southern Vietnam (Da Nang, Khanh Hoa, Binh Duong, Long An, Can Tho, etc.) are more and steadier in solar irradiance levels. Such areas have longer sunshine durations and lower seasonal variability, generating higher solar generation output and hence a more solid economic case for the installation of PV + BESS. In this scenario, battery storage gains maximum benefits of solar self-consumption as well as arbitrage, because it optimizes minimal use from the national grid and escapes maximum exposure to increasing electricity tariffs. Industrial facilities operating double or triple shifts in these areas are particularly benefited by load-shifting methods, where excess solar energy stored in the daytime is used during other production hours. IRR in such areas usually is more than 11–12%, and overall lifetime savings are increased by the synergy of high PV output with the possibility of avoiding demand charges on high evening loads.

Overall, technical motivation for BESS varies—Northern resistance, economic savings in the South and Central—but economic justification remains firm across regions when solar performance and regional energy needs are considered.

4.4. Barriers and Policy Recommendations

Even though there exists a clear technological and financial opportunity for integrating battery energy storage systems (BESS) in industrial applications, in Vietnam there still exist some structural and policy issues that require attention. A lack suitable legal and financial structures remain one of the most critical barriers.

Unlike rooftop solar, which has benefited from feed-in-tariffs and net metering in earlier phases, BESS currently exists in a policy vacuum. There are no standard guidelines on asset classification, depreciation, or grid integration protocols. More significantly, there is no investment cost recovery mechanism or tax incentive exclusively applicable to storage assets. Absence of such financial incentives—like accelerated depreciation, import duty exemptions, or value-added tax (VAT) exemptions—reduces the bankability of ESS projects and discourages private sector involvement.

In addition, the current electricity tariff frameworks in Vietnam do not properly reflect time-of-use price differentials or demand charges in a way that would make storage investments economically attractive. Consequently, the business case for BESS remains weak unless bolstered by ESG or carbon revenue streams since the economic value derived from peak shaving and load shifting is not optimally captured.

There are gaps that would need to be closed through a combination of policy and market interventions. Short and foremost, fiscal stimulus in the form of income tax credits, accelerated depreciation, or subsidies has a goal of enhancing ROI through lowering capital spending on total capital.

Additionally, time-of-use tariffs and internal PPA arrangements in industrial parks must be revised to capture the complete value-added role of storage in load shifting and peak demand management.

One highly promising approach is the encouragement of shared or centralized BESS adoption in industrial parks. Under this framework, one or more energy service providers invest in and operate a centralized battery facility with the capability of delivering service to multiple tenants via internal distribution systems. This not only achieves economies of scale and higher asset use, but also reduces the initial investment burden on individual factories, especially SMEs. Collective storage systems can also enable collective accession to I-REC schemes and ESG reporting, thereby improving access to green finance for all stakeholders in the park.

Overall, unleashing the complete economic opportunity of BESS in Vietnam involves regulatory reform as well as market design innovation, along with targeted intervention to support those industrial clusters for which energy cost, ESG compliance, and power reliability are business-critical.

5. Policy and Business Model Proposals

To foster the development and deployment of Battery Energy Storage Systems (BESS) in industrial parks, an enabling policy framework coupled with innovative funding avenues will need to be deployed. Drawing upon stakeholder consultations and empirical data, this section presents five strategic proposals aimed at resolving both economic and institutional bottlenecks within the BESS market in Vietnam.

5.1. Leasing/OPEX Model with Financial-Operational Integration

For industrial users, one of the most practical approaches is the Leasing or OPEX model in which a PV–ESS system is financed, installed, and operated by a third-party investor (usually an energy services company or infrastructure fund). The industrial tenant enters a long-term energy service agreement (15–25 years) and pays either a fixed monthly fee or a discounted rate per kilowatt-hour.

Key strengths:

- Weakens adoption barriers, particularly to SMEs; there is no upfront capital expenditure required by the end user.
- Allows firms to secure benefits of lower energy costs for extended periods, which aids in budgetary predictability and shields firms from electricity price volatility.
- Operational risks (investment and performance risk) associated with maintenance, battery degradation, and regulatory issues are offloaded to the asset owner, significantly lowering operational complexity for manufacturers.
- Enabled BESS development with measurable environmental impact, thus attracting international climate funds and ESG investors.

5.2. Integrating BESS into ESG Parameters for Priority Green Financing

In order to enhance financial viability, it is imperative for BESS to be integrated into national and sectoral ESG frameworks enabling projects to utilize preferential green finance instruments. Most impact investors, development banks, and ESG credit lines (e.g., ADB, GCPF) look for bankable projects that involve emissions reduction, resilience improvement, and are aligned with sustainable development goals.

Key strengths:

- Translates investment on BESS further than optimizational operational efficiencies to improve corporate environmental impact and compliance with TIER regulations on supply chain sustainability.
- Grants access to affordability in financing from green bonds, climate funds, and sustainability-linked loans.
- Under the CBAM framework, enhances attractiveness for export manufacturing consumers which indirectly monetizes the self-bearing decarbonization value of clean energy.

These benefits would be further bolstered and access to ESG capital would be enhanced if BESS was recognized as ‘green’ infrastructure within the national taxonomy.

5.3. Centralized Battery Storage Farms in Industrial Park Situations

The most promising development is the construction of centralized BESS plants—"Battery Farms"—covering whole industrial parks. Instead of numerous small individual batteries per tenant, a third-party company (e.g., utility affiliate, private SPV, or public-private JV) owns and manages a common system.

Advantages:

- The independent systems’ storage cost per kWh is reduced due to the economies of scale.
- Helps in balancing the load across different tenants which optimizes storage dispatch to the aggregated consumption trends.
- Greater participation in carbon credit programs (I-REC, VCM) is possible which makes cleaner revenue easier and more impactful.
- Lays the foundation for future uses of virtual power plants (VPPs), where flexible load and stored energy can be blended to provide grid services.

The model is best suited for export hubs with high-density electricity demand and high ESG regulatory standards.

5.4. Pilot Projects in Priority Provinces with High Rooftop Solar Penetration

In order to encourage replication, the government must encourage pilot projects in high solar potential and industrial cluster concentration provinces such as Bình Dương, Đồng Nai, Khánh Hòa, and Long An. These provinces have:

- High PV rooftop deployment,
- Strong industrial infrastructure, and
- Established investor interest in clean energy.

Benefits:

- Provides evidence of successful policies and business models.
- Empowers local governance with skills in monitoring, permitting, and regulation.
- Provides local exemplars and benchmarks which help offset perceived regulatory and technological risks for further adopters.

Publicly funded climate financial institutions featuring cross-sector partnerships are best positioned to enable transparent funding with rapid implementation.

5.5. Investment Recovery Mechanisms and Climate-Linked Subsidies

Lastly, the nation-specific enabling policies for cost recovery and capital subsidy programs for BESS investment should be formulated. This includes:

- Accelerated depreciation schedules for taxation.
- Partial finance grants/VGF for early adopters.
- Carbon savings monetization on domestic or foreign credit markets.

Key benefits:

- Enhanced attractiveness to investors and consumers, especially during the market's initial phases when battery prices are high.
- Improved bankability and loan-to-value ratios, expanding credit access for many businesses.
- Public climate aligned objectives using private sector investment with climate funds (GCF, JCM, ADB managed trust funds).

Proposed action requires coordinated inter-ministerial collaboration (MOIT, MOF, MPI) along with legal clarity on the BESS asset treatment framework.

In total, these five proposals provide a comprehensive approach to the adoption of battery storage in Vietnam's industrial parks. Capturing the economic and environmental advantages of ESS as an anchor for industrial decarbonization and a resilient energy enabler will require climate finance and regulatory shifts alongside financial creativity.

6. Conclusion and Future Research Directions

The present research has examined the techno-economic potential of incorporating Battery Energy Storage Systems (BESS) into rooftop solar power generation in industrial parks in Vietnam. The findings confirm that BESS is not only a complementary technology to solar PV, but also a key driver of industrial energy revolution, with potential cost savings, energy resilience, and environmental sustainability. When used through suitably designed financing structures—namely leasing and collaborative storage schemes—BESS is able to unlock strong value for manufacturers, especially those seeking long-term competitiveness in ESG-conscious markets globally.

The returns on investment of PV + BESS systems are already lucrative in Southern and Central markets, with IRRs of over 11%, and are even stronger combined with carbon credit programs and green finance products. At Northern latitudes where solar generation is less reliable, ESS value proposition focuses on the reliability of production and insurance of power quality. Comparative analysis of policy barriers and investment capital highlights the importance of institutional support, regulatory certainty, and new business models in enabling large-scale take-off.

There are several knowledge and implementation gaps that need to be filled. Future studies must be aligned with the following areas:

- Sophisticated financial instruments such as green bonds, pay-for-performance contracts, and asset securitization for BESS installations. These funds can access institutional capital and tie incentives with operational efficiency and ecological value.
- Battery system lifecycle analysis, including degradation rates, second-life applications, and end-of-life recycling or disposal costs. A full-cost accounting system will be required to achieve the full sustainability and long-term economic viability of BESS for industrial purposes.
- Analysis of BESS's export competitiveness effect, highlighting emerging carbon regulatory systems such as the EU Carbon Border Adjustment Mechanism (CBAM). There needs to be follow-up research quantifying the degree to which BESS use leads to cleaner output, better supplier ESG track records, and broader market access for Vietnamese manufacturers.

In total, BESS is not just a technological fix but an economic strategy instrument for Vietnam's manufacturing. Its linkage with rooftop solar energy should be seen as the foundation of a comprehensive shift to a low-carbon, stronger, and more internationally competitive manufacturing economy.

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