



Techno-Economic Analysis and Sensitivity Assessment of Battery Energy Storage for Utility-Scale Solar Integration in the Indian Power Grid

¹Sanjeev Kumar, ²Dr. Samit Tiwari

¹Research scholar, Department of Physics, Dr. C.V. Raman University, Vaishali, Bihar

²Professor, Department of Physics, Dr. C.V. Raman University, Vaishali, Bihar

ABSTRACT :

As India rapidly expands its solar capacity, the value of energy storage becomes increasingly vital. This study analyzes a 100 MW utility-scale solar plant, coupled with a 50 MW/200 MWh LiFePO₄ battery energy storage system (BESS) within the Indian power system. The evaluation utilizes a variety of engineering and financial analysis techniques including annual energy balance, battery degradation, component replacement, net present value (NPV), internal rate of return, levelized cost of storage (LCOS), and benefit-cost ratio (BCR), alongside sensitivity analyses. The 100 MW solar plant, with a 22% capacity factor, produces 192.72 GWh of energy in annually. With the BESS integration, 59.40 GWh of energy is charged and discharged at 88% round-trip efficiency, resulting in a storage energy loss of 7.13 GWh. The BESS aids in storing excess solar energy and delivering up to 185.59 GWh of renewable energy, thus reducing baseline curtailment by 23.13 GWh and utilizing 96.3% of the gross solar generation. Financially, under base-case assumptions, total project cost is INR 620 crore, first year revenues are INR 97.50 crore, NPV is INR 142.00 crore, IRR is 11.9%, the BCR is 1.19, LCOS is INR 7.25/kWh. Ultimately, Senior debt acquisition and storage bankability depend on monetizing peak and balancing storage services as well as curtailment avoidance.

Keywords: Battery energy storage system (BESS), solar PV, Techno-economic analysis, LCOS, Sensitivity analysis, Indian power grid, Renewable energy integration

I. INTRODUCTION

India's energy transition is shifting from the challenge of expanding solar capacity to the complexities integrating into the grid projections within the Central Electricity Authority's (CEA) National Electricity Plan and the Ministry of New Renewable Energy's (MNRE) annual report highlight significant additions to India's solar capacity targeted for the 2026-27 in the 2025 and 2031-32 horizons, respectively. Because solar energy is an intermittent time-dependent resource with peak generation occurring at solar noon, its increased penetration presents substantial challenges for grid balancing and stability.

Deploying battery energy storage systems (BESS) effectively shifts electricity supply to align with peak demand periods. Due to their high efficiency and rapid response characteristics, Lithium-ion batteries are well suited for this task. Furthermore, modular construction and rapid cost reductions have led to the widespread adoption of Lithium ion phosphate (LFP) systems. The international energy agency (IEA) noted a 90% price decline for Lithium-ion batteries from 2010 to 2023, while the international Renewable Energy Agency (IRENA) reported that utility-scale battery costs dropped to USD 192/kWh in 2024. Parallel to these global trends, India is transitioning from pilot projects towards competitive bidding frameworks. The government's allocation of Viability-gap funding for a 4,000 MWh storage capacity, alongside gigawatt-scale storage trends issued by the Solar Energy Corporation of India (SECI), further demonstrates a strong commitment to integrating energy storage into the Indian grid.

The main focus of this research is to evaluate the lifecycle costs of storage (LCOS) within the Indian context. Specifically, this paper investigates whether the long-term economic value of energy storage outweighs its significant capital, financing, degradation, and replacement costs. This research addresses this question by developing a comprehensive techno-economic model of a 100 MW solar plant coupled with four hours of storage, and evaluates system performance and uncertainty through sensitivity analyses. A key element of this study is providing a detailed understanding of lifecycle cash flows, the resulting LCOS, and why operational flexibility is essential for investment decisions.

II. LITERATURE REVIEW

The primary objective of this research is to evaluate the lifecycle costs of energy storage within the Indian context. Specifically, this study investigates whether the revenue and systemic benefits of storage can offset its substantial capital, financing, degradation, and replacement costs. To address this

question, this research develops a comprehensive techno-economic model of a 100 MW solar plant integrated with a four-hour battery storage system, quantifying operational performance and uncertainty through sensitivity analyses. A key contribution of this work is lucidly demonstrating lifecycle cash flows, determining the levelized cost of storage (LCOS), and highlighting why operational and financial flexibility are vital for robust investment decisions.

Existing literature on the Indian power sector strongly supports the necessity of integrated system planning. Laha and Chakraborty (2021) demonstrated that declining capital costs for renewable energy and storage directly decrease overall system expenditure. However, Gangopadhyay et al. (2024) emphasized that demanding ultra-high grid reliability while exceeding localized capacity limits introduces severe techno-economic trade-offs. These findings collectively indicate that energy storage assets should not be evaluated in isolation, but rather optimized alongside alternative flexibility levers like planned curtailment and operational grid flexibility.

Battery physics directly influences economics. Kebede et al. (2021) report the lifecycle advantages of lithium-ion over lead-acid batteries for stationary applications. Furthermore, Shabani et al. (2022) showed that overly simplistic aging models can lead to sub-optimal battery sizing, while Lee and Kim (2022) integrated battery degradation costs into dispatch decisions. Additionally, Castillejo-Cuberos et al. (2023) found that nonlinear battery behavior can affect the levelized cost of electricity (LCOE). Finally, reviews by Yang et al. (2022) and Zhao et al. (2023) point toward the importance of state-of-health operations, advanced energy management and the integration of multiple services from batteries.

Value stacking continues to be a focal point in economic studies, as most combinations of grid services enhance the economic outlook of a battery energy storage system (BESS). For instance, Wassermann et al. (2020) analyzed the differences between single-purpose and multi-purpose batteries. In a different vein, Wrålsen and Faessler (2022) identified considerable scenario uncertainty in battery investments. To address economic viability, Mostafa et al. (2020) developed a framework for life-cycle storage cost metrics**, while** Gul et al. (2022) related the dispatch of batteries to the net present value (NPV) and levelized cost of electricity (LCOE) of a solar farm.

More recent studies on arbitrage have focused on degradation-aware optimization and a more realistic view of market value (Keske et al., 2024; Grimaldi et al., 2024; Bechlenberg et al., 2024). However, a key gap in the existing literature is the lack of a compact framework focused on India that integrates curtailment recovery, peak value, levelized cost of storage (LCOS), lifecycle replacement, and sensitivity analysis into a single, verifiable model.

III. MATERIALS AND METHODS

3.1 System Configuration

This work integrates an annual energy model with a discounted cash flow analysis and a 1,000-run Monte Carlo simulation. The project-level input parameters are scenario-based and are derived from engineering ranges documented in recent literature and Indian planning or procurement documents; consequently, they do not reflect the actual performance of operating assets. The base case study examines a 100 MW solar PV facility paired with a 50 MW / 200 MWh lithium iron phosphate (LFP) BESS. The system utilizes a controller integrated with an energy management system to charge from midday solar surplus and dispatch energy during peak value periods.

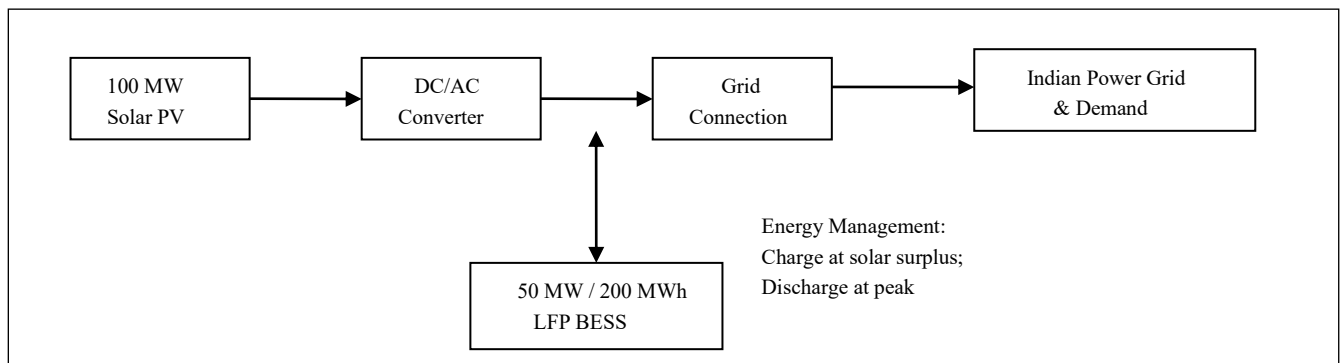


Figure 1. Solar PV-BESS grid-integration architecture and dispatch logic.

3.2 Dataset and Input Parameters

Table 1. Base-Case Technical Parameters of the Solar PV-BESS System

Parameter	Unit	Base value	Range
PV rated capacity	MW	100	80-150
Solar capacity factor	%	22	20-24
BESS power	MW	50	25-100
BESS energy	MWh	200	100-400

Storage duration	h	4	2-4
Chemistry	-	LFP	LFP
Depth of discharge	%	90	85-95
Round-trip efficiency	%	88	82-94
Equivalent cycles	cycles/year	330	280-350
Solar degradation	%/year	0.60	0.4-0.8
Battery throughput degradation	%/year	1.50	1.0-2.2
Project life	years	25	20-30

Table 2. Economic Input Parameters and Assumptions

Parameter	Unit	Base value
Solar CAPEX	INR crore	330
BESS CAPEX	INR crore	260
Interconnection/EPC balance	INR crore	30
Total CAPEX	INR crore	620
Annual fixed O&M	INR crore/year	10.46
Discount rate	%	9.00
Replacement year	year	12
Replacement cost	INR crore	117
Direct solar value	INR/kWh	3.00
Equivalent stacked BESS discharge value	INR/kWh	11.00
Baseline no-storage curtailment	%	12

3.3 Energy Modeling

The calculation of annual solar generation assumes a 22% capacity factor, utilizing the rated PV capacity and a conversion factor of 8,760 hours. Based on these assumptions, the gross generation equals 192.72 GWh. The rated storage capacity is multiplied by a 90% depth of discharge (DoD) to determine the usable storage per cycle. Assuming 330 equivalent cycles, the annual battery charging totals 59.40 GWh. Energy storage system (ESS) losses occur during both charging and discharging cycles; with an 88% round-trip efficiency (RTE), the total losses amount to 7.13 GWh. A no-storage curtailment benchmark of 12% equates to 23.13 GWh. Because the annual battery energy storage system (BESS) charging exceeds this benchmark, the full 23.13 GWh of curtailment is considered recoverable, while the remaining charging volume is allocated for peak shifting.

$$E_{solar} = P_{PV} \times CF \times 8760$$

$$E_{usable} = E_{rated} \times DoD$$

$$E_{discharge} = E_{charge} \times eta_{RTE}$$

Table 3. Annual Energy-Balance Results

Metric	Unit	Value
Gross solar generation	GWh/year	192.72
BESS charging energy	GWh/year	59.40
Direct solar delivery	GWh/year	133.32
BESS discharge	GWh/year	52.27
Storage losses	GWh/year	7.13
Grid-delivered renewable energy	GWh/year	185.59
Baseline curtailment recovered	GWh/year	23.13
Renewable utilization	%	96.30

3.4 Economic Model

The project evaluation horizon spans 25 years, with an initial capital expenditure (CAPEX) comprising INR 330 crore for solar, INR 260 crore for the BESS, and INR 30 crore for the balance-of-plant (BOP) and interconnection facilities. The annual fixed operations and maintenance (O&M) cost is INR 10.46 crore. Technically, solar output degrades at a rate of 0.6% per year, while battery throughput degrades at 1.5% per year. The battery throughput resets following a lifecycle replacement in Year 12, which is budgeted at 45% of the initial BESS CAPEX (INR 117 crore). Financial discounting is applied at a 9% discount rate, using a levelized cost of solar baseline of INR 3.0/kWh. Finally, the revenue from discharged BESS energy is set at INR 11.0/kWh, which holistically represents the combined value of peak energy, capacity, balancing, and curtailment avoidance services.

$$NPV = -I_0 + \sum (CF_t / (1+r)^t)$$

$$\text{LCOS} = \text{PV (BESS lifecycle costs)} / \text{PV (battery discharged energy)}$$

$$\text{BCR} = \text{PV (lifecycle revenue)} / \text{PV(lifecycle cost)}$$

3.5 Sensitivity and Statistical Analysis

The net present value (NPV) and internal rate of return (IRR) are computed using standard discounted cash flow techniques. The levelized cost of storage (LCOS) is calculated as the ratio of the present value of BESS capital expenditures (CAPEX), operations and maintenance (O&M) costs, and lifecycle replacement costs to the present value of the total discharged energy. Similarly, the benefit-cost ratio (BCR) is defined as the present value of discounted revenues divided by the present value of discounted costs. To evaluate risk, one-way sensitivity analyses are performed for key parameters, including BESS CAPEX, the discount rate, the value of stacked energy, round-trip efficiency, throughput degradation, the solar capacity factor, replacement costs, and the project lifespan. Finally, a Monte Carlo simulation utilizes physically plausible ranges of these identical variables to compute descriptive statistics and evaluate their statistical correlation with both NPV and LCOS.

Table 4. One-Way Sensitivity of NPV and LCOS

Variable	NPV at low	Base NPV	NPV at high	LCOS at low	LCOS at high
BESS CAPEX	232.48	142.00	51.52	5.36	9.13
Discount rate	333.72	142.00	8.10	6.20	8.36
Peak/stacked energy value	-16.32	142.00	300.32	7.24	7.24
Round-trip efficiency	89.23	142.00	194.77	8.05	6.59
Battery degradation	149.43	142.00	134.77	7.10	7.39
Solar capacity factor	60.67	142.00	223.32	7.24	7.24
Replacement cost	154.48	142.00	129.52	6.98	7.50
Project lifetime	90.33	142.00	173.78	7.68	7.01

IV. RESULTS

The base case energy balance demonstrates that a 100 MW solar plant coupled with a 50 MW / 200 MWh (four-hour) BESS significantly increases renewable energy utilization. The annual gross PV generation of the solar facility is estimated at 192.72 GWh. Of this total, 59.40 GWh is routed to the BESS for storage, while the remaining 133.32 GWh is injected directly into the grid. Accounting for system efficiencies, the BESS discharges 52.27 GWh of energy back to the grid. Consequently, total annual energy delivery to the grid reaches 185.59 GWh, achieving a 96.3% utilization rate of the available renewable resource. The framework assumes the BESS operates for 330 equivalent full cycles during its first year of operation.

From a financial perspective, the total initial project cost is INR 620 crore. In the first year of operation, the system is expected to generate INR 97.50 crore in gross revenue**, yielding** INR 87.04 crore in net revenue after accounting for operating costs and debt service. Under the base-case scenario, the Net Present Value (NPV) is estimated at INR 142.00 crore with an Internal Rate of Return (IRR) of 11.9%. The simple and discounted payback periods are determined to be 7.37 years and 14.72 years, respectively, while the benefit-cost ratio (BCR) stands at 1.19. Furthermore, the Levelized Cost of Storage (LCOS) for the BESS is estimated at INR 7.25/kWh, compared to a levelized cost of energy (LCOE) or discounted total project cost of INR 4.39/kWh. Over the project lifecycle, the battery is projected to deliver approximately 1.20 TWh of electricity to the grid. While this cumulative discharge is constrained by gradual battery degradation, system capacity can be periodically restored through scheduled cell replacements.

The scenario analysis reveals a distinct asymmetrical risk-return profile. In the optimistic case—characterized by lower battery costs, higher solar generation, a 92% efficiency rating, a 7% discount rate, and enhanced value-stacking opportunities—the project yields an NPV of INR 518.30 crore, an IRR of 16.3%, and an LCOS of INR 5.17/kWh. Conversely, under the pessimistic case, the financial metrics deteriorate to an NPV of negative INR 184.27 crore, an IRR of 6.7%, and an LCOS of INR 10.15/kWh. Consequently, this stark variance demonstrates that technical feasibility alone does not guarantee financial viability.

A Monte Carlo uncertainty analysis utilizing a 1,000-run simulation estimates the mean NPV at INR 144.21 crore, with a standard deviation of INR 114.41 crore and values ranging from negative INR 140.24 crore to INR 576.21 crore. The mean LCOS is projected at INR 7.28/kWh, with a standard deviation of INR 1.02/kWh. In terms of parameter sensitivities, the negative association between the discount rate and NPV constitutes the strongest correlation, followed closely by a positive association between stacked discharge value and NPV. Conversely, LCOS is positively associated with BESS CAPEX and negatively associated with round-trip efficiency. Furthermore, a one-way sensitivity analysis reveals that the primary bankability drivers for the project are commercial value capture, the cost of capital, and equipment pricing.

Table 5. Base-Case Techno-Economic Performance

Metric	Unit	Value
Total project CAPEX	INR crore	620
First-year gross value	INR crore	97.50

NPV	INR crore	142.00
IRR	%	11.90
Simple payback	years	7.37
Discounted payback	years	14.72
Benefit-cost ratio	ratio	1.19
BESS LCOS	INR/kWh	7.24
Combined discounted cost	INR/kWh	4.39
Lifecycle BESS discharge	GWh	1199.64

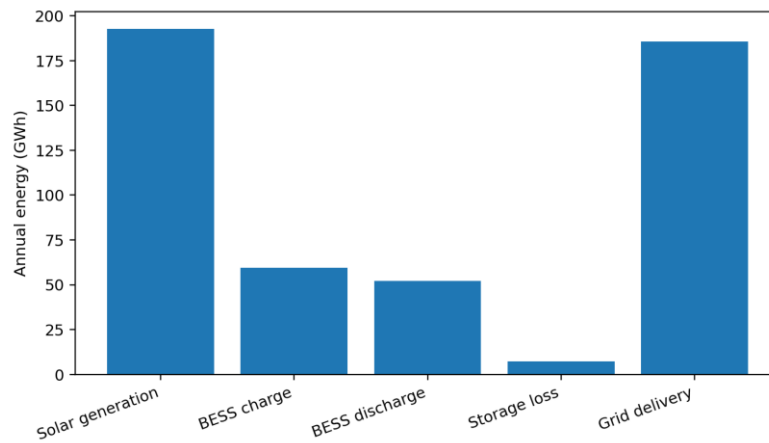


Fig. 2 - Annual solar generation, battery energy flows, storage losses, and grid delivery.

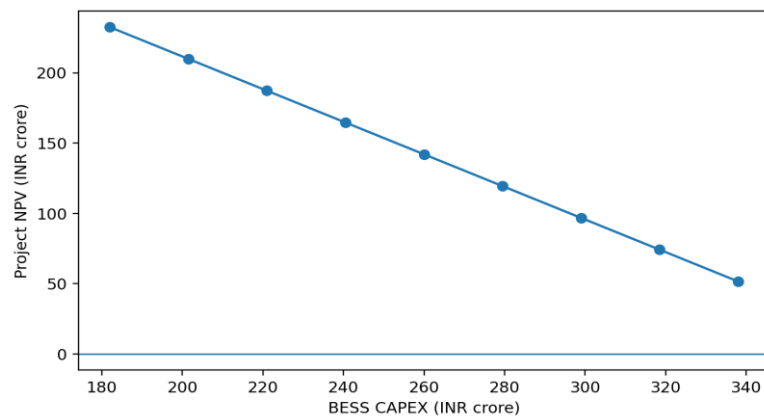


Fig. 3 - Sensitivity of project NPV to BESS capital expenditure.

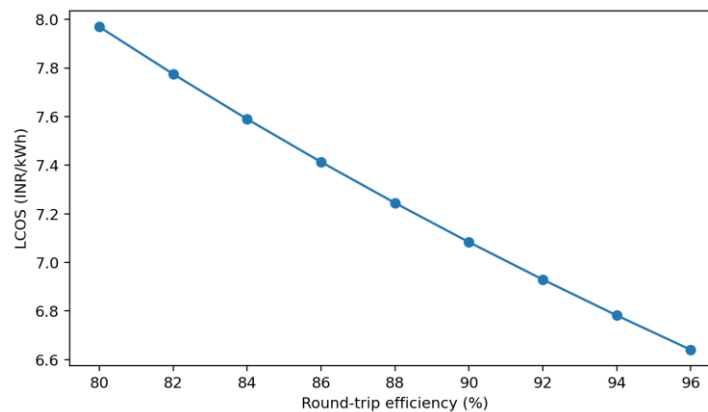


Fig. 4 - Sensitivity of BESS LCOS to round-trip efficiency.

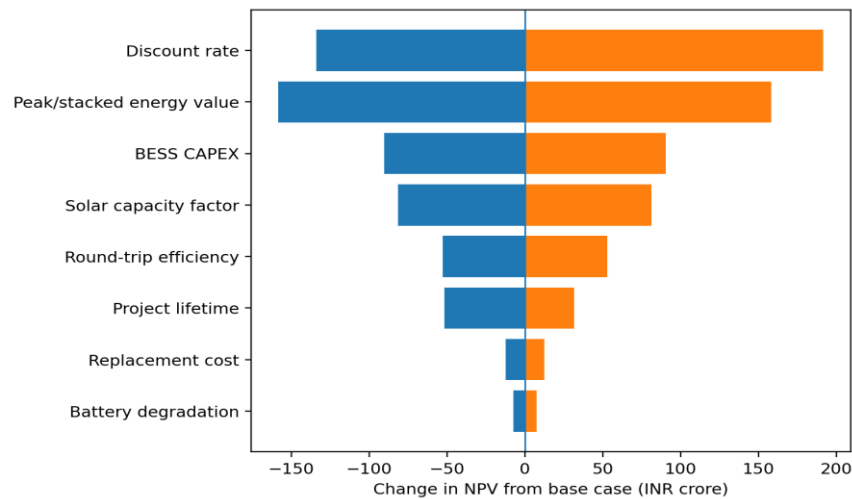


Fig. 5 - Tornado sensitivity of major variables affecting base-case NPV.

Table 6. Optimistic, Base-Case and Conservative Scenario Comparison

Scenario	NPV (INR cr)	IRR (%)	LCOS (INR/kWh)	Payback (yr)	BCR
Optimistic	518.30	16.31	5.17	5.74	1.70
Base case	142.00	11.90	7.24	7.37	1.19
Conservative	-184.26	6.70	10.15	10.64	0.77

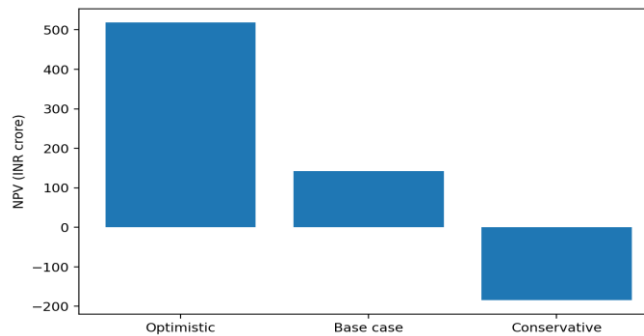


Fig. 6 - Net present value under optimistic, base-case, and conservative scenarios.

Table 7. Pearson Correlation of Major Drivers with NPV and LCOS

Input variable	r with NPV	r with LCOS
BESS CAPEX	-0.35	0.82
Discount rate	-0.57	0.43
Stacked discharge value	0.65	-0.05
Round-trip efficiency	0.17	-0.26
Battery degradation	0.00	0.06
Solar capacity factor	0.22	0.08
Replacement cost fraction	-0.03	0.05
Project life	0.20	-0.16

V. DISCUSSION

Battery storage systems straddle two distinct positions. From a technical perspective, the core system curbs a significant amount of midday energy that would otherwise be curtailed or have low-value. From a literature perspective, battery systems enable peak shifting, and help facilitate other grid services such as reserves and ramping (Zhao et al., 2023; Yamujala et al., 2022). Similar findings have been outlined in CEA planning which also forecasts a need for battery energy storage systems (BESS) as solar and wind capacity increases (CEA, 2023).

From an economic perspective, the outcomes reveal battery systems are not always economically viable from a revenue perspective. LCOS of INR 7.25/kWh is greater than solar energy tariffs. Similar findings are supported by Lopez-Lorente et al. (2021), who argue that if technical benefits of battery systems are to be realized, appropriate financial value should also be considered. Likewise, Grimaldi et al. (2024) outline that arbitrage opportunities for battery systems relies on physical and chemical parameters of the battery system. Market design should allow for storage systems to monetize capacity, balancing, ancillary services, and other grid services.

Sensitivity results also highlight the role of finance conditions. Reducing the discount rate boosts NPV while keeping physical performance constant, suggesting that policy mechanisms reducing revenue uncertainty or cost of capital can be as important as incremental efficiency. BESS CAPEX is the largest driver of LCOS. This correlates with the cost decline reported by IRENA and suggests that further procurement at scale and supply-chain maturity can improve economics. As reported by IRENA, costs may not materially improve beyond 2025. In the tested ranges, price and financing conditions are more important than efficiency improvements.

Battery degradation is a key factor deserving more analysis. If not for degradation, expected lifetime discharge and revenue would be less, and replacement would be more. Shabani et al. (2022), Lee and Kim (2022), Castillejo-Cuberos et al. (2023), and Keske et al. (2024) support this analysis. Depending on the project, warranty structures, thermal management, depth of discharge, state of charge windows and dispatch, should all be considered in project valuation.

The model has several gaps. First, annualized energy accounting does not consider hourly nodal congestion, forecast errors, state-of-charge history, non-linear battery degradation, taxes, debt sculpting, and detailed ancillary services and settlement. Stacked discharge value is an analytical equivalent and should be replaced with site-specific contracted and market revenues during project evaluation. Similar to stacked discharge value, assumed curtailment recovery requires adequate charging ability at the times when surplus energy occurs. Future research should integrate chronological dispatch, network constraints, probabilistic solar forecasts, battery degradation, and warrant limits in conjunction with Indian market prices and power to energy ratio and contractual structure. There are implications on storage contract design and operational governance. Compared to conventional procurement, energy-only storage contracts open up several performance dimensions that remain covered. The contractual documents should define the guaranteed energy at delivery point, round-trip efficiency, response time, throughput, permitted DoD, Augmentation, and EoL capacity, among others. These factors influence how long a bid remains competitive over a period of 20 or more years. There are also implications from contract design and controls. A battery reserved for solar shifting may be devalued due to conflict in state of charge for energy and capacity for frequency response. This also affects location. A battery located in a constrained renewable energy corridor may avoid curtailment and provide ancillary services, while an identical battery at a more liberalized node may only provide energy arbitrage.

As mentioned above, BESS viability assessments depend on location-specific peak shapes, transmission charges, and renewable energy profiles. For these reasons, nodal or regional modeling is often done prior to procurement. Standardized reporting of BESS lifecycle events and service revenues would enable ex-post performance comparisons. Such reporting would enable a reduction in uncertainty around key storage system parameters, improve the confidence of storage system investors, and facilitate estimations of probabilistic distributions rather than wide, upper and lower bound, engineering ranges in future studies. Transparent, standardized lifecycle reporting is essential for the rapid deployment and scale-up of storage systems.

VI. CONCLUSION

India has a lot of potential for utility-scale solar with storage. After adding storage to existing solar projects, new solar projects could benefit from adding storage. In this case study, a 100 MW solar project coupled with a 50 MW/200 MWh Lithium Ferro-phosphate (LFP) battery project showed numerous positive results. For the project assumptions, solar generation was estimated at 192.72 GWh per year. BESS discharge was estimated at 52.27 GWh, grid-delivered renewable energy was at 185.59 GWh and the project recovered 23.13 GWh of baseline curtailment. The project showed a Net Present Value of INR 142.00 crore, an Internal Rate of Return of 11.9%, Benefit Cost Ratio of 1.19 and a BESS LCOS of INR 7.25/kWh.

The sensitivity assessment shows that a project's outcomes are largely influenced by commercial considerations of storage energy value, discount rate, and BESS CAPEX. Improvements in storage costs and financing costs enhance viability, and higher efficiency and solar capacity factor provide incremental benefits. Higher CAPEX and financing costs, coupled with lower value capture, make the project uneconomic despite its technical usefulness.

For Indian utility-scale solar, this means that in the deployment of BESS, there must be clear revenue stacking and system considerations rather than storage capacity alone. Flexibility in power systems can be monetized using competitive procurement, long-term contracts, and access to ancillary services, especially if countered by a degradation-aware operating strategy. While modeling is useful to define system requirements, the next step prior to investing should be to develop the infrastructure and construction of the network.

REFERENCES

1. Ministry of New and Renewable Energy (MNRE). (2025). Renewable Energy Statistics 2024-25. Government of India.
2. Central Electricity Authority (CEA). (2023). National Electricity Plan 2022-32, Volume I. Ministry of Power, Government of India.

3. Ministry of Power. (2023). Viability Gap Funding scheme for development of Battery Energy Storage Systems: Rajya Sabha Unstarred Question No. 300, 5 December 2023. Government of India.
4. Solar Energy Corporation of India (SECI). (2024a). RfS for 1000 MW/2000 MWh Standalone Battery Energy Storage Systems in India (ESS-II), Tender SEC1000145.
5. Solar Energy Corporation of India (SECI). (2024b). RfS for 2000 MW ISTS-connected Solar PV with 1000 MW/4000 MWh Energy Storage Systems (ISTS-XVII), Tender SEC1000162.
6. International Energy Agency (IEA). (2024). Batteries and Secure Energy Transitions. Paris: IEA.
7. International Renewable Energy Agency (IRENA). (2025). Renewable Power Generation Costs in 2024. Abu Dhabi: IRENA.
8. Hunter, C. A., Penev, M. M., Reznicek, E. P., Eichman, J., Rustagi, N., & Baldwin, S. F. (2021). Techno-economic analysis of long-duration energy storage and flexible power generation technologies to support high-variable renewable energy grids. *Joule*, 5(8), 2077-2101. <https://doi.org/10.1016/j.joule.2021.06.018>
9. Edoo, N., & Ah King, R. T. F. (2021). Techno-Economic Analysis of Utility-Scale Solar Photovoltaic Plus Battery Power Plant. *Energies*, 14(23), 8145. <https://doi.org/10.3390/en14238145>
10. Lopez-Lorente, J., Liu, X. A., Best, R. J., Makrides, G., & Morrow, D. J. (2021). Techno-Economic Assessment of Grid-Level Battery Energy Storage Supporting Distributed Photovoltaic Power. *IEEE Access*, 9, 146256-146280. <https://doi.org/10.1109/ACCESS.2021.3119436>
11. Laha, P., & Chakraborty, B. (2021). Cost optimal combinations of storage technologies for maximizing renewable integration in Indian power system by 2040: Multi-region approach. *Renewable Energy*, 179, 233-247. <https://doi.org/10.1016/j.renene.2021.07.027>
12. Kebede, A. A., Coosemans, T., Messagie, M., Jemal, T., Behabtu, H. A., Van Mierlo, J., & Berecibar, M. (2021). Techno-economic analysis of lithium-ion and lead-acid batteries in stationary energy storage application. *Journal of Energy Storage*, 40, 102748. <https://doi.org/10.1016/j.est.2021.102748>
13. Shabani, M., Wallin, F., Dahlquist, E., & Yan, J. (2022). Techno-economic assessment of battery storage integrated into a grid-connected and solar-powered residential building under different battery ageing models. *Applied Energy*, 318, 119166. <https://doi.org/10.1016/j.apenergy.2022.119166>
14. Yamujala, S., Jain, A., Bhakar, R., & Mathur, J. (2022). Multi-service based economic valuation of grid-connected battery energy storage systems. *Journal of Energy Storage*, 52, 104657. <https://doi.org/10.1016/j.est.2022.104657>
15. Lee, J.-O., & Kim, Y.-S. (2022). Novel battery degradation cost formulation for optimal scheduling of battery energy storage systems. *International Journal of Electrical Power & Energy Systems*, 137, 107795. <https://doi.org/10.1016/j.ijepes.2021.107795>
16. Yang, Y., Bremner, S., Menictas, C., & Kay, M. (2022). Modelling and optimal energy management for battery energy storage systems in renewable energy systems: A review. *Renewable and Sustainable Energy Reviews*, 167, 112671. <https://doi.org/10.1016/j.rser.2022.112671>
17. Gul, E., Baldinelli, G., Bartocci, P., Bianchi, F., Domenghini, P., Cotana, F., & Wang, J. (2022). A techno-economic analysis of a solar PV and DC battery storage system for a community energy sharing. *Energy*, 244, 123191. <https://doi.org/10.1016/j.energy.2022.123191>
18. Zhao, C., Andersen, P. B., Traeholt, C., & Hashemi, S. (2023). Grid-connected battery energy storage system: A review on application and integration. *Renewable and Sustainable Energy Reviews*, 182, 113400. <https://doi.org/10.1016/j.rser.2023.113400>
19. Castillejo-Cuberos, A., Cardemil, J. M., & Escobar, R. (2023). Techno-economic assessment of photovoltaic plants considering high temporal resolution and non-linear dynamics of battery storage. *Applied Energy*, 334, 120712. <https://doi.org/10.1016/j.apenergy.2023.120712>
20. Wrålsen, B., & Faessler, B. (2022). Multiple Scenario Analysis of Battery Energy Storage System Investment: Measuring Economic and Circular Viability. *Batteries*, 8(2), 7. <https://doi.org/10.3390/batteries8020007>
21. Mostafa, M. H., Abdel Aleem, S. H. E., Ali, S. G., Ali, Z. M., & Abdelaziz, A. Y. (2020). Techno-economic assessment of energy storage systems using annualized life cycle cost of storage and levelized cost of energy metrics. *Journal of Energy Storage*, 29, 101345. <https://doi.org/10.1016/j.est.2020.101345>
22. Wessellmann, M., Wilkening, L., & Kern, T. A. (2020). Techno-Economic evaluation of single and multi-purpose grid-scale battery systems. *Journal of Energy Storage*, 32, 101790. <https://doi.org/10.1016/j.est.2020.101790>
23. Keske, C., Srinivasan, A., Sansavini, G., & Gabrielli, P. (2024). Optimal economic and environmental arbitrage of grid-scale batteries with a degradation-aware model. *Energy Conversion and Management: X*, 22, 100554. <https://doi.org/10.1016/j.ecmx.2024.100554>
24. Grimaldi, A., Minuto, F. D., Brouwer, J., & Lanzini, A. (2024). Profitability of energy arbitrage net profit for grid-scale battery energy storage considering dynamic efficiency and degradation. *Journal of Energy Storage*, 95, 112380. <https://doi.org/10.1016/j.est.2024.112380>

-
25. Gangopadhyay, A., Seshadri, A. K., & Balachandra, P. (2024). Wind-solar-storage trade-offs in a decarbonizing electricity system. *Applied Energy*, 353, 121994. <https://doi.org/10.1016/j.apenergy.2023.121994>
 26. Bechlenberg, A., Luning, E. A., Saltik, M. B., Szirbik, N. B., Jayawardhana, B., & Vakis, A. I. (2024). Renewable energy system sizing with power generation and storage functions accounting for its optimized activity on multiple electricity markets. *Applied Energy*, 360, 122742. <https://doi.org/10.1016/j.apenergy.2024.122742>