Hybrid Gas–Battery Power Plants in the United States: Operational Flexibility, Market Participation, and Grid Reliability

Samuel Nimaful[1]

[1]Eastern Illinois University

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Abstract: The integration of battery energy storage systems (BESS) with natural gas–fired power plants is gaining attention as a viable approach for improving operational flexibility, response speed, and the economic competitiveness of gas generation within the U.S. electricity system. This paper examines the integration of lithium-ion battery storage with both open-cycle and combined-cycle natural gas plants, with emphasis on operational performance, market participation, emissions implications, and regulatory context. Hybrid gas-battery configurations combine the rapid response capability of batteries with the sustained energy delivery of gas turbines, thereby improving start-up performance, ramping capability, reserve provision, and load-following operations. Drawing on case evidence and market developments in regions such as the California Independent System Operator (CAISO), PJM Interconnection, and the Midcontinent Independent System Operator (MISO), this study evaluates how hybridization can improve the dispatchability and economic competitiveness of gas-fired assets. The findings indicate that hybrid systems can reduce inefficient part-load operation, lower start frequency, expand participation in ancillary service markets, and improve operational readiness during periods of renewable variability. Project-level evidence also suggests that hybrid retrofits can reduce emissions and operating costs for peaking units when batteries are actively dispatched as intended. In addition, evolving market rules and federal policy developments, including FERC Order No. 841 and ISO-specific hybrid participation models, are creating a more supportive environment for hybrid resource deployment. Overall, natural gas-battery hybrids represent a transitional grid solution that can enhance reliability and flexibility while supporting decarbonization objectives. The paper concludes by identifying market, policy, and research priorities needed to expand hybrid deployment in the U.S. power sector.

Keywords: *Battery Energy Storage; Natural Gas Power Plants; Hybrid Power Plants; Ancillary Services; Grid Flexibility; Peaker Plants; Energy Storage.*

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I. INTRODUCTION

The U.S. electric power sector is undergoing a structural transition driven by the rapid growth of variable renewable generation, the retirement of aging thermal assets, and increasing pressure to maintain reliability while reducing emissions. As wind and solar penetration rises, system operators need resources that can respond quickly to sudden changes in supply and demand. Natural gas plants, especially simple-cycle peaking units, have historically provided this flexibility because they can start faster than coal or nuclear units and can be dispatched during periods of scarcity. Yet standalone gas turbines remain constrained by start-up times, minimum load requirements, cycling costs, and emissions associated with standby operation and repeated starts. These limitations have become more salient as renewable generation deepens intraday price swings and increases the operational value of fast, precise response (FERC, 2018; CAISO Department of Market Monitoring, 2025).

Battery energy storage systems offer a complementary capability. Batteries respond almost instantaneously to dispatch signals, provide accurate power output control, and can supply short-duration balancing services that conventional gas turbines cannot deliver as efficiently. When integrated with a gas-fired plant, battery storage can cover the first seconds or minutes of a response event while the turbine starts or ramps, thereby creating a hybrid resource that is both fast and durable. In this configuration, the battery contributes speed and precision, while the gas turbine provides sustained output over longer durations. Hybridization thus converts a conventional plant from a purely thermal asset into a multi-technology resource designed around operational coordination.

Interest in natural gas-battery hybrids has expanded because the concept addresses three overlapping needs. First, it enhances operational flexibility by reducing start-up delays, improving ramping performance, and allowing gas units to avoid inefficient standby operation. Second, it creates additional revenue opportunities by enabling participation in ancillary service markets such as spinning reserve, regulation, and fast-response products. Third, it offers an emissions-reduction pathway for gas assets by reducing unnecessary run hours and limiting cycling-related inefficiencies. These advantages have made hybridization attractive both as a retrofit strategy for existing peaker plants and as a design feature in new-build flexible capacity projects (Gorman et al., 2020; Ericson et al., 2017).

Early U.S. projects provide practical evidence that the concept is more than a theoretical proposition. In California, Southern California Edison’s Hybrid Enhanced Gas Turbine projects and the Stanton Energy Reliability Center demonstrated that a battery paired with an aeroderivative gas turbine can provide spinning reserve and rapid-response services with lower fuel consumption and greater operational accuracy than a conventional peaker alone (Patel, 2017; Larson, 2021). At the same time, broader research on hybrid plants suggests that co-location can reduce soft costs, better utilize existing interconnection rights, and create additional operational value when market rules permit coordinated dispatch (Seel et al., 2022). These developments indicate that natural gas-battery systems may play an important transitional role in maintaining resource adequacy and supporting renewable integration in organized electricity markets.

This paper evaluates the technical, economic, and regulatory dimensions of hybridizing natural gas power plants with battery storage in the United States. Specifically, it addresses three questions. First, how does battery integration alter the operational behavior of gas-fired plants? Second, what market value can hybrid plants capture in energy, capacity, and ancillary-service markets? Third, how do current policy and market rules shape the deployment of hybrid resources? By combining case evidence, market context, and prior research, the paper contributes to the growing literature on flexible hybrid generation as an emerging component of the modern U.S. power system.

II. OPERATIONAL RATIONALE FOR GAS-BATTERY HYBRIDIZATION

The core logic of hybridization is rooted in the mismatch between the capabilities of conventional gas plants and the increasingly dynamic needs of the grid. A battery can respond within fractions of a second, whereas even a highly flexible gas turbine requires several minutes to reach full output from a cold or warm condition. Similarly, a battery can follow a rapidly changing automatic generation control signal with very high accuracy, whereas a gas turbine’s response is governed by combustion dynamics, ramp-rate limits, emissions controls, and thermal stress constraints. The hybrid plant resolves this mismatch by assigning short-duration, high-speed services to the battery and longer-duration energy provision to the gas unit.

This operational division of labor has several implications. One is improved start-up performance. If a grid operator needs immediate power because of a generation contingency or a sudden drop in solar output, the battery can inject power immediately while the gas turbine starts in the background. Another is improved load following. Rather than forcing a gas unit to chase every short-term fluctuation, the battery can absorb the short-cycle volatility while the turbine moves more smoothly toward a new dispatch point. A third implication is reduced minimum-load operation. Conventional peakers frequently remain online at minimum stable generation in order to provide spinning reserve or maintain readiness. In a hybrid configuration, the turbine can often remain offline while the battery maintains immediate responsiveness, reducing fuel burn and standby emissions.

Hybridization also matters from the standpoint of asset strategy. Many gas plants that were originally designed as peakers are increasingly being used in ways that expose their economic weaknesses. More renewable penetration often means deeper midday price troughs, steeper evening ramps, and shorter but more intense net-load scarcity periods. These conditions reward flexibility rather than simple thermal capacity. A battery can increase the value of a gas asset by shifting its role toward higher-value moments and away from inefficient low-value operation. In effect, the battery helps the gas turbine operate less often, but at more economically and operationally advantageous times.

The argument is not that a battery makes the gas turbine obsolete. Rather, the two technologies occupy complementary duration domains. A battery excels at sub-hour and hour-scale balancing, depending on its size and state of charge, but cannot economically provide indefinite energy output. A gas turbine can provide longer-duration capacity so long as fuel is available, but is slower and less efficient in rapid-cycling or low-load applications. Hybridization therefore reflects a design philosophy in which fast-response and endurance are jointly valued. This makes particular sense in systems that still

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rely on thermal reliability but increasingly need storage-like behavior from their dispatchable resources.

III. LITERATURE REVIEW AND INDUSTRY BACKGROUND

Research on hybrid power plants initially focused on renewable-plus-storage combinations, especially solar-plus-battery systems. However, the broader literature on hybrid generator-plus-battery projects provides a useful foundation for understanding gas-battery combinations as well. Gorman et al. (2020) describe hybrid generator-plus-battery projects as a growing segment of the bulk power system, driven by the opportunity to share infrastructure, capture multiple value streams, and improve operational flexibility. Their analysis is especially important because it moves beyond technology-specific narratives and frames hybridization as a system-design and market-participation problem. The value of a hybrid plant depends not only on physical co-location but also on whether the market can recognize and compensate the resource's combined attributes.

Berkeley Lab's later synthesis of hybrid power plant research reinforces this point. Seel et al. (2022) show that hybrid projects have grown rapidly in the United States and that the combination of generation and storage is increasingly being pursued as a way to address interconnection constraints, improve resource adequacy contributions, and respond to volatile market conditions. Although most active projects remain renewable-storage hybrids, the analytical insights extend to thermal-storage configurations as well. In particular, the ability to share transmission access and exploit complementary operating profiles is directly relevant to retrofitting or redesigning gas plants as hybrid facilities.

Analytical work on gas- and storage-specific coordination is less abundant but highly informative. Ericson et al. (2017) assessed storage hybrids from a market perspective and found that batteries can create incremental value when paired with generators because they can provide services that are hard or costly for thermal assets to deliver on their own. The report emphasizes that hybridization can reduce total system costs in some cases and help projects meet market and regulatory requirements more effectively than standalone storage or standalone generation. This framing is useful for gas-battery combinations because it places battery value not merely in arbitrage, but in a wider portfolio of operational services.

Nian et al. (2019) provide one of the more targeted studies relevant to gas-battery integration. Using a feasibility analysis for combining large-scale battery storage with combined-cycle gas generation, they conclude that coordinated operation can lower the levelized cost of electricity and reduce life-cycle carbon emissions under certain conditions. Their study is not U.S.-specific, but it is conceptually important because it demonstrates that the value of pairing storage with gas generation extends beyond peaking applications. In a combined-cycle context, the battery can smooth load changes, support more efficient dispatch, and potentially reduce the need for additional peaking capacity elsewhere in the system.

Industry case studies complement the academic literature by providing plant-level evidence. Patel's account of Southern California Edison's Hybrid Enhanced Gas Turbine projects describes how adding a 10 MW battery to peaker plants in California materially altered their operating profile. The battery remained synchronized to the grid and enabled immediate response, reducing the need to keep turbines spinning at low load while waiting for dispatch. Larson's description of the Stanton Energy Reliability Center similarly highlights how hybrid design can expand the operating envelope of a peaker plant to include a practical minimum output of zero while preserving rapid availability. These examples are not peer-reviewed studies, but they are among the most widely cited public accounts of actual gas-battery integration in the United States and therefore remain useful when interpreted cautiously and paired with official market documentation.

A final strand of the literature concerns regulation and market design. FERC's technical and regulatory work on storage participation, along with ISO initiatives related to hybrid and co-located resources, has become central to the hybridization debate because market design determines whether the operational advantages of a hybrid plant can be monetized. CAISO's issue papers and participation options for hybrid resources illustrate how a market operator can gradually build dispatch and settlement models for multi-technology resources. PJM and MISO have likewise been developing structures for hybrid and co-located participation, although their approaches have differed in important respects. The literature therefore suggests that hybridization is not merely a technological development; it is equally a regulatory and institutional evolution.

IV. U.S. REGULATORY AND MARKET CONTEXT

The U.S. market context for gas-battery hybrids is shaped by three interacting developments: the formal inclusion of storage in wholesale markets, the rise of ISO-specific hybrid participation models, and the increasing strategic importance of flexible capacity under high-renewables conditions.

The first major national milestone was FERC Order No. 841, issued in 2018. The order required regional transmission organizations and independent system operators to remove barriers to the participation of electric storage resources in wholesale markets and to establish participation models that recognize storage resources' physical and operational characteristics (FERC, 2018). Although Order No. 841 did not create a dedicated hybrid-resource framework, it was foundational for hybridization because it normalized battery participation in energy, capacity, and ancillary-service markets. Once storage could compete on more equal footing, developers and plant owners had a stronger incentive to explore co-located and integrated resource configurations.

The second development has been the emergence of market rules specific to hybrid and co-located resources. CAISO has been the most visible leader in this area. Its hybrid-resource issue paper and subsequent participation options laid out ways for multiple technologies behind a single point of interconnection to participate either as a single resource or through coordinated co-located configurations (CAISO, 2019; CAISO, 2022). This matters greatly for gas-battery hybrids because point-of-interconnection limitations often constrain how a battery and a generator can be dispatched together. If the market cannot model the plant's true combined capabilities or properly account for state of charge, the hybrid may be forced into suboptimal bidding and settlement arrangements. CAISO's work shows that the benefits of hybridization are partly contingent on market software and tariff design.

PJM and MISO have moved in the same general direction, though with different procedural emphasis. PJM's manuals now recognize hybrid resources and co-located resources as part of market participation and capacity accreditation processes (PJM, 2025). MISO has pursued a hybrid-resource participation model focused on clarifying how hybrid and co-located resources share interconnection service and participate in energy and operating reserve markets (MISO, 2025). While these frameworks remain more commonly associated with solar-storage configurations, their implications extend to gas-battery hybrids because the same questions arise: should the plant bid as one resource or multiple resources, how should interconnection limits be applied, and how should the system value the storage component relative to the thermal unit?

The third contextual driver is the changing economics of flexibility. In high-solar systems such as California, midday oversupply and steep evening ramps have increased the value of resources that can charge, discharge, and ramp quickly. In more diversified systems such as PJM and MISO, the growth of storage is still reshaping assumptions about reserve provision, capacity accreditation, and energy arbitrage. CAISO's market-monitoring reports document how battery storage has grown from a niche service provider to a major operational category with increasing influence on energy demand patterns and ancillary-service provision (CAISO Department of Market Monitoring, 2024, 2025). Although not all of this capacity is paired with thermal generation, the trend reveals a broader system reality: storage is no longer peripheral, and gas plants that remain economically relevant will increasingly need to coexist or integrate with storage logic.

This regulatory and market context is critical because hybridization does not produce value automatically. A battery paired with a gas plant is only as useful as the surrounding rules allow it to be. If the market cannot dispatch the battery efficiently, cannot compensate it for rapid-response services, or cannot recognize the hybrid's reliability contribution, the project's economics deteriorate. Conversely, where market rules are flexible and scarcity pricing is meaningful, hybrid plants can unlock value far beyond simple energy sales. The result is that hybridization should be understood as both a plant-design choice and a market-design challenge.

V. METHODOLOGY

This paper uses a qualitative case-synthesis methodology supported by market and policy analysis. The objective is not to estimate an original engineering model or to optimize a dispatch algorithm, but to produce a rigorous, publication-style assessment of the system-level implications of hybridizing natural gas power plants with battery storage in the United States. The approach combines evidence from operating projects, official market documents, peer-reviewed research, and technical reports.

The case-study element centers on three categories of evidence. The first consists of retrofitted peaker projects, particularly Southern California Edison's Hybrid Enhanced Gas Turbine installations. These cases are useful because they show how batteries can materially alter the performance of existing gas units without requiring full plant replacement. The second consists of purpose-built hybrid plants, especially the Stanton Energy Reliability Center, which provides a clearer view of what hybridization looks like when it is embedded in the design rather than bolted onto an existing unit. The third category includes emerging utility planning examples, such as Ameren Missouri's Big Hollow Energy Center, which indicate how large utilities increasingly view gas-plus-storage combinations as a reliability strategy in high-transition power systems.

The market-analysis component relies on official documents from FERC, CAISO, PJM, and MISO. These sources are used to assess how hybrid-resource participation is evolving, how storage is being integrated into wholesale markets, and how batteries are changing operating patterns in organized power systems. CAISO's market-monitoring reports are especially valuable because California remains the leading U.S. region for battery deployment and hybrid-resource experimentation. Those reports provide evidence on battery capacity growth, ancillary-service participation, and the shifting role of storage as both supply and demand on the grid.

The literature-review component draws from peer-reviewed articles and technical reports. The academic literature is used primarily to frame the conceptual and economic logic of hybridization, while technical reports are used to support claims about market value, infrastructure-

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sharing benefits, and deployment trends. The paper deliberately distinguishes among these source types. Peer-reviewed articles anchor the broader analytical claims; official market documents support regulatory and operational observations; and trade publications are used more narrowly for project-specific descriptions where other public documentation is limited.

A comparative framework is then applied across the evidence base. Four dimensions are emphasized: operational flexibility, economic value, environmental implications, and institutional feasibility. Operational flexibility covers start-up speed, ramping, minimum-load reduction, and reserve provision. Economic value includes fuel savings, ancillary-service revenue, arbitrage potential, and infrastructure-sharing advantages. Environmental implications include reduced standby operation, lower cycling-related emissions, and the possibility of displacing inefficient peaker use. Institutional feasibility covers participation rules, capacity treatment, and market-modeling arrangements that determine whether a hybrid plant can operate as intended.

This methodology has limitations. Much of the public evidence on gas-battery hybrids still comes from a small number of projects, especially in California. Long-term battery degradation, operating data over many years, and confidential dispatch economics are often unavailable. As a result, some conclusions are necessarily framed as directional rather than universal. Even so, the triangulation of project evidence with official market documents and peer-reviewed research provides a sufficiently robust basis for assessing the current and emerging role of natural gas-battery hybridization in the United States.

Table 1. Representative U.S. Natural Gas-Battery Hybrid Cases Discussed in this Manuscript

Project	**Market/Region**	**Configuration**	**Type**	**Analytical relevance**
SCE Hybrid EGT	CAISO / Southern California	Peaker gas turbines with 10 MW-class battery additions	Retrofit	Demonstrates reduced standby operation, faster response, and reserve-market participation.
Stanton Energy Reliability Center	CAISO / Los Angeles Basin	Two aeroderivative gas turbines paired with battery systems	Purpose-built hybrid	Shows how hybrid design expands a peaker’s operating envelope and supports local reliability.
Big Hollow Energy Center	MISO / Missouri	Planned 800 MW gas + 400 MW battery site	Forward-looking utility plan	Illustrates scaling of gas-plus-storage as a mainstream reliability investment rather than a pilot concept.

VI. RESULTS

➢ *Operational Performance Effects*

The most immediate result of hybridization is a substantial improvement in response speed. In the Southern California Edison hybrid peaker projects, the battery remained continuously synchronized with the grid, allowing the plant to inject power immediately when dispatched while the turbine started behind the scenes (Patel, 2017). This altered the operational logic of reserve provision. Instead of requiring a gas turbine to remain spinning at low load in order to satisfy response criteria, the battery effectively served as the first mover. The plant therefore met fast-response requirements with lower standby fuel consumption and lower wear on the turbine.

The Stanton Energy Reliability Center extends this logic in a purpose-built format. As described by Larson (2021), the plant combines two aeroderivative gas turbines with battery systems in a way that broadens the plant’s effective operating envelope. A practical implication is that the resource can behave like a fast-start plant without continuously consuming fuel. For a grid operator, this means the resource can help cover contingency events and ramping needs more effectively than a conventional peaker with similar nominal capacity but slower initial response.

Hybridization also materially improves load following and dispatch precision. Batteries can absorb short-term fluctuations and provide highly accurate output, which makes them well suited to regulation and other balancing services. The gas turbine, by contrast, can then be used for the more sustained portion of the response. This division reduces the need for the turbine to engage in aggressive short-cycle ramping, which can increase maintenance requirements and degrade heat-rate performance. In practical terms, the hybrid plant becomes more agile without subjecting the thermal component to the full burden of that agility.

A third operational result is the reduction or elimination of minimum-load operation during standby periods. This may be one of the most economically and environmentally meaningful effects of hybridization. Conventional peakers frequently remain online at minimum output to preserve readiness. In a hybrid arrangement, the battery can maintain immediate responsiveness while the turbine remains offline, which effectively lowers the plant’s minimum practical output toward zero in reserve-oriented operating modes. This improves unit commitment flexibility and reduces periods in which the plant generates low-value electricity simply to remain available.

The result is not merely faster response in a narrow technical sense. Hybridization changes the plant's role in grid operations. A conventional peaker often oscillates between full commitment and thermal standby. A hybrid plant can occupy a more nuanced operating space in which immediate response, reserve provision, and sustained generation are separated into functions rather than forced into one thermal operating mode. This is especially valuable in systems with high renewable variability, where many balancing needs are short and sharp rather than long and flat.

➢ *Economic Value Creation*

The economic evidence indicates that gas-battery hybridization can create value through multiple channels rather than a single dominant revenue stream. One source is reduced fuel use. If a battery allows the gas turbine to remain offline during reserve periods or avoids low-load standby operation, the plant burns less fuel during hours when it is not actually providing energy. This is particularly important for peakers, whose economics are often undermined by starts, idling, and operation during low-margin intervals. Lower start frequency and reduced part-load operation can also reduce maintenance costs by minimizing thermal stress and mechanical wear.

A second source of value is ancillary-service participation. Batteries are especially well suited for regulation and fast-response reserve products because they can change output quickly and accurately. When paired with a gas plant, the battery can unlock reserve participation without forcing the plant to provide that service entirely through the turbine. Ericson et al. (2017) identified this complementary value stream as one of the major reasons storage hybrids can outperform standalone installations in certain market contexts. The Southern California Edison case provides a concrete illustration because the battery's integration was associated with a stronger business case for spinning reserve and related services than a standalone peaker configuration could deliver.

A third source is arbitrage and dispatch optimization. Even where the battery is not especially large relative to the turbine, it can still help the plant avoid inefficient dispatch choices. For example, the plant may be able to stay offline during a brief price spike and use the battery to serve the initial interval, only starting the turbine if the price event or reliability need persists. Likewise, in systems with negative or very low midday prices and high evening prices, the battery can create flexibility around when and how the thermal unit is committed. This does not mean the battery replaces the turbine's energy role, but it can improve the timing and profitability of turbine operation.

A fourth source of value comes from infrastructure sharing. Gorman et al. (2020) and Seel et al. (2022) emphasize that hybrid projects often benefit from shared interconnection rights, land use, site development, and other soft-cost advantages. This is highly relevant for gas-battery hybrids because interconnection access is increasingly scarce and valuable in many U.S. regions. Retrofitting an existing gas site with storage may be economically superior to siting a standalone battery elsewhere if the existing plant already has the transmission access and local reliability relevance that the system needs.

At the same time, the economic case is not uniform across markets. Ancillary-service revenues can erode as more batteries participate and competition increases. CAISO's battery reports show that as battery deployment has expanded, a smaller share of total battery capacity has been used for ancillary services at any one time, reflecting both market saturation and the growing importance of energy-oriented dispatch (CAISO Department of Market Monitoring, 2024, 2025). This means early hybrid projects may have benefited from unusually favorable reserve economics that later entrants cannot assume. The implication is that future hybrid plants will likely need to stack value across reserves, energy, capacity, and infrastructure-sharing benefits rather than relying on one market alone.

➢ *Environmental and Reliability Outcomes*

The environmental results of hybridization are best understood as conditional but meaningful. A gas-battery hybrid is not a zero-emission resource. However, when the battery is used to reduce start frequency, eliminate standby combustion, and absorb short-duration balancing tasks, emissions can fall substantially relative to a conventional peaker operating under the same reliability requirements. Patel's account of Southern California Edison's hybrid system indicates expectations of major reductions in starts and operating hours, which in turn reduce fuel use and combustion-related emissions during low-efficiency intervals. These gains are especially important because peaker emissions are often disproportionate during start-up and partial-load operation.

The broader environmental significance lies in how hybridization changes the use profile of gas capacity. Instead of relying on thermal units to remain partially online as a precaution against volatility, the grid can increasingly use batteries to cover that precautionary function. The gas turbine becomes a resource for sustained need rather than immediate short-cycle balancing. This is environmentally preferable to the extent that it avoids hours of low-value combustion. Nian et al. (2019) suggest that even in combined-cycle applications, coordinated storage can improve thermal unit efficiency enough to produce measurable carbon reductions.

Reliability effects are equally important. A hybrid plant can provide rapid response during disturbances while still retaining the endurance of fuel-based generation. This makes the configuration particularly valuable in systems where long-duration reliability risk remains nontrivial. A standalone battery may excel during the first hour or two of an event, but a gas turbine can continue generating if conditions persist. The

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hybrid therefore combines the strongest reliability attributes of both technologies. This is one reason utilities continue to view gas-plus-storage projects as practical reliability investments even while they expand renewable capacity and standalone storage portfolios.

The evidence also suggests that hybridization can support renewable integration. In high-solar systems, shortfalls caused by cloud cover, evening ramps, or forecast error require fast resources that can respond without the inefficiencies of thermal standby. A gas-battery hybrid can meet this need more effectively than a conventional peaker by using the battery to absorb the short-term volatility and the turbine to support longer-duration needs. In that sense, hybridization does not merely reduce the operational drawbacks of gas plants; it also improves the power system's ability to accommodate variable renewables without sacrificing reliability.

VII. DISCUSSION

The results point to a clear conclusion: hybridization changes the function of a gas plant more than it changes its nameplate capability. A gas-battery hybrid is not simply a peaker with a battery attached. It is a different type of resource, one that occupies a strategic position between conventional thermal generation and standalone storage. The battery transforms the plant's temporal profile. It absorbs the ultra-fast response obligations that are costly or inefficient for the turbine, while the gas unit remains available for longer-duration energy delivery. This makes the hybrid plant particularly well suited to power systems that need both reliability and flexibility.

This finding has implications for how gas assets should be evaluated in decarbonizing systems. A common framing pits batteries against gas peakers as direct substitutes. That comparison is useful in some contexts, especially where a standalone battery can fully replace a peaker's reliability contribution. Yet it does not capture the transitional role of hybridization. In many regions, reliability needs still include duration requirements and fuel-based assurance that current battery portfolios do not always satisfy. A hybrid plant acknowledges this constraint while materially reducing the inefficiencies associated with conventional peaker operation. It therefore functions as a bridge solution: not a final decarbonization endpoint, but a meaningful improvement over the thermal status quo.

The market discussion also reveals that technology performance alone is insufficient. The value of hybridization depends on whether market design recognizes a hybrid plant as an integrated operational resource. CAISO's work on hybrid and co-located participation demonstrates that this recognition requires tariff design, dispatch logic, and settlement systems capable of handling multiple technologies behind one point of interconnection. PJM and MISO are moving in that direction, but the details matter. If a hybrid resource is forced into fragmented bidding or constrained by rules built for single-technology assets, its economic performance can fall short of its physical potential.

This raises a broader institutional point. Hybridization represents a challenge to traditional market categories. Historically, power markets separated generation, load, and reserves in ways that aligned well with conventional assets. Storage, and especially storage paired with generation, blurs these categories. A gas-battery hybrid may be generating, charging, holding reserve capability, and managing internal state-of-charge constraints all within a short interval. That complexity is precisely why regulatory adaptation matters. A market designed around static generator identities will have difficulty extracting the full reliability and economic value of hybrid resources.

There are also strategic questions about plant design and investment timing. In some situations, retrofitting an existing peaker with a modest battery may be the most practical path because it leverages existing interconnection, local reliability value, and site infrastructure. In other cases, especially where new capacity is being procured, a purpose-built hybrid design may produce stronger operational outcomes because the plant can be optimized from the outset around battery-turbine coordination. The Ameren Big Hollow proposal is significant in this regard because it suggests that large utilities are no longer viewing gas-plus-storage solely as a pilot concept. They are beginning to treat it as a credible component of long-term reliability planning (Ameren Missouri, 2025).

Even so, hybridization is not a universal answer. Some gas plants may be too old, too inefficient, or too poorly located to justify battery integration. In markets where reserve products are poorly compensated or price volatility remains modest, the value stack may be too thin. And as standalone battery duration increases, some applications currently suited to gas hybrids may eventually be served more economically by storage alone. The correct conclusion, therefore, is not that all gas plants should be hybridized, but that hybridization is likely to be economically and operationally attractive in a specific but important subset of applications: peakers with valuable interconnection rights, plants in renewable-heavy systems, and new flexible-capacity projects designed around reliability under transition conditions.

VIII. POLICY AND MARKET IMPLICATIONS

Several policy implications follow from the analysis. First, hybrid resources should be explicitly incorporated into market design rather than treated as awkward exceptions. FERC Order No. 841 opened the door for storage participation, but hybridization requires continued tariff development at the ISO level. Rules for interconnection limits, co-located participation, state-of-charge management, reserve qualification, and settlement treatment need to reflect the actual operating logic of hybrid plants. Otherwise, the system risks underusing a class of resources that is highly aligned with modern flexibility needs.

Second, resource planning should treat hybridization as a serious alternative to both simple gas replacement and pure standalone storage procurement. For utilities and regulators, this means evaluating not just megawatts, but the quality of those megawatts in terms of response speed, duration, and local reliability contribution. In some capacity procurements, a gas-battery hybrid may offer a more cost-effective and lower-emissions solution than a conventional peaker because it reduces thermal run hours while preserving firm capacity. In other procurements, a battery-only solution may prevail. The point is that hybridization should be part of the planning toolkit, not an afterthought.

Third, emissions policy can influence hybrid adoption if it recognizes the operational changes that batteries enable at thermal plants. A battery added to a gas plant may not eliminate emissions, but it can materially reduce them by changing when and how the plant runs. Air-quality and carbon policy should therefore account for operational retrofits that reduce combustion during standby and cycling-intensive periods. Where peaker emissions are a public-health concern, especially in urban areas, hybridization may offer a more immediate emissions-reduction pathway than waiting for full plant replacement.

Fourth, public and private research should expand beyond pilot-style narratives and toward long-term performance assessment. The current evidence base remains relatively thin in terms of longitudinal battery degradation, lifecycle cost tracking, and measured plant performance across multiple years of operation. More standardized reporting would help utilities, regulators, and investors compare retrofits, purpose-built hybrids, and standalone alternatives on more consistent terms. The growing number of hybrid and co-located projects in interconnection queues suggests that this knowledge gap will become more important, not less.

IX. LIMITATIONS AND FUTURE RESEARCH

This study is subject to several limitations that should be acknowledged. The first is data concentration. Much of the richest public evidence on gas-battery hybridization comes from California, which has distinctive market design, renewable penetration, and storage deployment characteristics. While the lessons are broadly relevant, they do not automatically transfer to every region. PJM, MISO, ERCOT, and non-ISO utility territories each present different combinations of price volatility, ancillary-service design, and planning institutions.

The second limitation is the small number of mature operating examples. Gas-battery hybridization remains less common than renewable-storage hybridization, so there are not yet many public cases with multi-year operational histories. This restricts the ability to make strong claims about long-run maintenance savings, battery replacement schedules, or performance under repeated extreme-weather events. The evidence nevertheless indicates that the concept is technically viable and economically plausible in the right market settings.

The third limitation is that many project-level performance figures remain proprietary or are reported through trade publications rather than standardized regulatory filings. This makes exact cross-case comparison difficult. A useful future research agenda would therefore include plant-level empirical studies using confidential or utility-reported operational data, especially comparing pre-retrofit and post-retrofit performance for existing peaker plants.

Several future research directions are especially important. One is battery sizing relative to gas-plant role. A battery sized for reserve and response services may produce a different value stack than one sized for multi-hour arbitrage. Another is the role of hybridization in combined-cycle plants rather than simple-cycle peakers. A third is the interaction between hybridization and future low-carbon fuels such as hydrogen blends, renewable natural gas, or synthetic methane. If gas turbines evolve toward lower-carbon fuel use, battery hybridization may remain relevant as the operational layer that improves response and reduces inefficient cycling. A fourth research priority is capacity accreditation and reliability modeling. Hybrid resources challenge conventional notions of firm capacity because they combine different duration and response characteristics behind one plant boundary. Better methods for accrediting and planning around those combinations would improve both market design and utility procurement.

➢ *Deployment Trends and Strategic Positioning*

Recent deployment and planning activity suggests that gas-battery hybridization is moving from demonstration to strategic option. This does not mean the configuration is becoming dominant relative to solar-storage or standalone battery projects. It does mean, however, that the concept has gained credibility among utilities, developers, and market operators. Berkeley Lab's work on hybrid power plants shows that co-located and hybrid configurations are no longer niche experiments in U.S. power-system development, even if most announced projects still involve renewable generation rather than thermal assets (Seel et al., 2022). The importance of this broader trend is that it normalizes the idea of designing plants around multiple technologies behind a common interconnection point.

For gas assets, the strategic logic is particularly strong where local reliability needs persist but regulators and utilities want to minimize combustion-based operating hours. A battery retrofit can preserve the locational value of a peaker plant while reducing the amount of time the turbine needs to run. This is especially useful in load pockets, urban reliability zones, and systems where transmission expansion is slow. The plant becomes less of a traditional always-ready thermal reserve and more of a targeted, flexible backstop. In such contexts, a hybrid may be easier to permit politically and defend economically than a conventional new peaker, because the battery visibly reduces the frequency and intensity of gas-fired operation.

The Ameren Big Hollow project illustrates how this logic is beginning to scale. It is not merely a small pilot bolted onto an existing turbine. Rather, it reflects utility planning that treats gas and storage as part of a common reliability architecture (Ameren Missouri, 2025). Even where the battery does not fully replace the role of thermal generation, it changes the type of thermal generation being procured. Instead of valuing a gas plant primarily for megawatt capacity, the utility values it for coordinated flexibility: immediate response from storage, sustained support from gas, and better use of interconnection infrastructure at a single site.

This trend also suggests that hybridization may alter how legacy gas assets are evaluated in resource planning and asset management. Plants that once appeared economically marginal under increased renewable penetration may recover strategic value if paired with storage. That does not guarantee viability, but it broadens the set of options available to planners deciding whether to retire, repower, or retrofit existing capacity. In other words, the relevant planning question may increasingly be not whether a gas plant survives in its current form, but whether it can be transformed into a more flexible hybrid resource with a smaller operational and environmental footprint.

X. PRACTICAL RECOMMENDATIONS FOR MANUSCRIPT AND INDUSTRY APPLICATION

For publication purposes, the evidence reviewed in this paper supports a practical set of recommendations that are relevant both to researchers and to industry actors. First, future scholarship should avoid treating all hybrid plants as analytically equivalent. A solar-storage hybrid, a wind-storage hybrid, and a gas-storage hybrid all share certain market-design issues, but their operational logic differs materially. Gas-battery hybrids deserve more distinct treatment because they combine a zero-marginal-fuel-loss storage device with a fuel-based thermal unit whose economics are highly sensitive to starts, ramping, and low-load operation.

Second, plant owners considering hybrid retrofits should frame the investment around value stacking rather than around a single revenue claim. The strongest cases are those where the battery simultaneously reduces standby fuel burn, supports reserve-market participation, improves dispatch timing, and leverages existing interconnection rights. A project justified solely on one ancillary-service market may face revenue erosion as competition increases. A project justified on multiple operational and market improvements is more resilient.

Third, regulators and market operators should improve transparency in how hybrid plants are accredited and settled. Clearer treatment of interconnection limits, state-of-charge management, and hybrid bidding structures would reduce uncertainty and make it easier to compare hybrid resources with conventional alternatives in procurement and planning proceedings. This is particularly important as more utilities propose gas-plus-storage combinations in integrated resource plans and reliability filings.

Finally, from a publication standpoint, a mature research agenda on gas-battery hybridization should move toward richer empirical evidence. Researchers should seek pre- and post-retrofit operating data, plant-level emissions data, and market-settlement records where possible. These data would allow stronger causal inference on fuel savings, cycling reductions, and reserve-market performance than currently available public reporting permits. Such work would substantially strengthen the academic literature and provide a more robust basis for policy and investment decisions.

XI. CONCLUSION

The hybridization of natural gas power plants with battery energy storage is emerging as a strategically important development in the U.S. electricity sector. It responds directly to a central challenge of the energy transition: how to maintain reliability and flexible capacity while reducing the operational inefficiencies and emissions associated with conventional thermal generation. By combining the speed and precision of batteries with the endurance of gas turbines, hybrid plants create a resource that is more responsive than a traditional peaker and more durable than a standalone battery.

The evidence reviewed in this paper indicates that gas-battery hybrids can materially improve plant start-up performance, reduce inefficient standby operation, enhance reserve and balancing capability, and create additional economic value through ancillary services, arbitrage, and infrastructure sharing. Project-level evidence from California demonstrates that these effects are not merely theoretical. At the same time, the broader market context shows that the success of hybridization depends heavily on regulatory and market design. FERC's storage reforms, CAISO's hybrid-resource framework, and evolving participation models in PJM and MISO all shape whether hybrid plants can operate and be compensated in line with their true capabilities.

Gas-battery hybridization should therefore be understood as both an engineering solution and an institutional one. It is not a universal replacement for all conventional gas capacity, nor is it an alternative to continued growth in standalone storage and renewable generation. Rather, it is a transitional and context-specific strategy that can improve the performance of gas assets in systems where firm, flexible capacity remains necessary. In the near to medium term, that role is likely to be significant.

For utilities, regulators, and market operators, the key lesson is that hybridization deserves serious attention as part of the broader reliability toolkit. For researchers, the next step is to deepen the empirical base with plant-level operational data, long-run performance analysis, and improved modeling of capacity and emissions outcomes. For the power system as a whole, the rise of gas-battery hybrids signals an important shift: the future value of dispatchable generation lies not only in how much capacity it can provide, but in how intelligently it can be integrated with storage to meet a faster, cleaner, and more variable grid.

REFERENCES

[1]. Ameren Missouri. (2025, June 27). Ameren unveils new hybrid energy center combining natural gas and energy storage to supply reliable energy when Missouri needs it most.
[2]. California Independent System Operator. (2019, July 18). Hybrid resources issue paper.
[3]. California Independent System Operator. (2022, February 8). Hybrid resource - interim participation options.
[4]. California Independent System Operator, Department of Market Monitoring. (2024, July 16). 2023 special report on battery storage.
[5]. California Independent System Operator, Department of Market Monitoring. (2025, May 29). 2024 special report on battery storage.
[6]. Ericson, S. J., Rose, E., Jayaswal, H., Cole, W. J., Engel-Cox, J., Logan, J., McLaren, J. A., Anderson, K. H., Arent, D. J., Glassmire, J., Klawiter, S., & Rajasekaran, D. (2017). Hybrid storage market assessment: A JISEA white paper. National Renewable Energy Laboratory / Joint Institute for Strategic Energy Analysis. https://doi.org/10.2172/1399357
[7]. Federal Energy Regulatory Commission. (2018). Electric storage participation in markets operated by regional transmission organizations and independent system operators (Order No. 841).
[8]. Gorman, W., Mills, A. D., Bolinger, M., Wiser, R., Singhal, N. G., Ela, E., & O'Shaughnessy, E. (2020). Motivations and options for deploying hybrid generator-plus-battery projects within the bulk power system. The Electricity Journal, 33(5), 106739. https://doi.org/10.1016/j.tej.2020.106739
[9]. Larson, A. (2021, October 1). Stanton Energy Reliability Center hybrid supplies power when Southern California needs it most. POWER.
[10]. MISO. (2025, January 16). Hybrid resource participation model: Co-located market participation.
[11]. Nian, V., Jindal, G., & Li, H. (2019). A feasibility study on integrating large-scale battery energy storage systems with combined cycle power generation - Setting the bottom line. Energy, 185, 396-408. https://doi.org/10.1016/j.energy.2019.07.028
[12]. Patel, S. (2017, September 1). Two SCE gas-battery hybrid projects revolutionize peaker performance. POWER.
[13]. PJM Interconnection. (2025, December 17). PJM Manual 18: PJM capacity market.
[14]. Seel, J., Gorman, W., Barbose, G. L., Bolinger, M., Crespo Montanes, C., Forrester, S., Kim, J. H., Kahrl, F., Mills, A. D., Millstein, D., Paulos, B., Rand, J., Warner, C., & Wiser, R. H. (2022). Batteries included: Top 10 findings from Berkeley Lab research on the growth of hybrid power plants in the United States. Lawrence Berkeley National Laboratory. https://doi.org/10.2172/1864545
[15]. U.S. Energy Information Administration. (2020, May 18). Large battery systems are often paired with renewable energy power plants.