Annual Storage Report 2021

Published June, 2022

Gridmatic

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Gridmatic Storage Report

Analysis of storage systems in ERCOT in 2021

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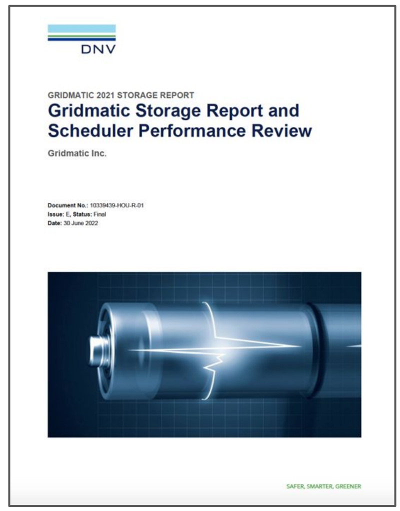

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Gridmatic

Annual Storage Report 2021

Published June, 2022

Executive Summary

To achieve desired outcomes, energy storage operators must actively manage storage resources in electricity markets. This report is designed to help storage stakeholders, including asset operators (IPPs, utilities, power marketers), investors, and developers better understand the differences between potential and actual market performance, along with factors that optimize this performance. We will first review performance of merchant battery systems in the ERCOT market via available disclosure data, then compare them to simulated Gridmatic and perfect battery schedulers.

The report covers two facets of results in ERCOT:

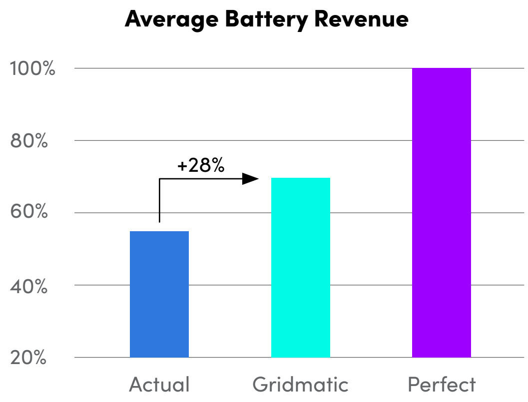
What Was

1. **Revenue by market product** – We quantified the dominance of ancillary services as the revenue generator for storage systems at 96.4%. We also found that systems that bid predominantly into one or two market products made less money than those that optimized their bids across multiple market products. We outline the impact of the ORDC scarcity price adder on revenue and the related impact of Winter Storm Uri on revenue *(spoiler: it was big!).*
2. **Revenue peakiness** – Even without Winter Storm Uri, storage revenue was peaky, with the top 10% of days accounting for 27%–54% of revenue. The report outlines what storage owners should do to address peakiness.
3. **Availability** – Battery outages can have significant ramifications on profitability. This report analyzes whether the storage systems in ERCOT achieved the typical guarantees from battery vendors.
4. **Commissioning and testing** – We review market participation data and conclude that the typical one month assumption severely underestimates actual commissioning period durations.

What Could Have Been

Our analysis finds that actual storage revenue averaged 54% of the revenue that could have been achieved with perfect foresight of electricity prices. There is ample room for improved performance in the market.

We show that Gridmatic's AI-powered bids would have achieved an uplift of 28% over the actual battery revenue on average. While perfect foresight is impossible, we found that price forecasting and optimization can have a major impact on merchant battery operations.



We acknowledge the limitations of this report due to data availability and the nascent stage of the battery storage industry. Nevertheless, we hope that you find the results in this report meaningful, helping you make better informed decisions as to operational strategies and when planning future battery systems. We encourage you to engage with us to share your thoughts.

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Introduction

A recent Energy Information Administration report estimates that large-scale battery storage could contribute 10,000 megawatts to the grid between 2021 and 2023—10 times that available in 2019. Can these battery systems deliver on their potential to provide both grid flexibility and a financial return to their investors?

Storage is key to avoiding continued reliance on conventional sources of system flexibility and generation assets. The flexibility of storage—one of its strengths—is also a challenge in that there is a greater need to optimize operation to take advantage of arbitrage opportunities; reduce temporal mismatches with renewable energy assets and demand; and participate in ancillary services markets. The market performance of battery storage in 2021 gives us a sneak peak of how these critical grid resources will deliver in the coming years.

Gridmatic

Gridmatic is an AI-enabled power marketer, founded in 2017 to apply machine-learning algorithms to forecast energy supply, demand, and pricing in wholesale energy markets. Gridmatic has had five years of successful market participation and is currently active in six ISOs: CAISO, ERCOT, MISO, NYISO, PJM, and SPP. The company applies its algorithms to grid-scale storage to optimize scheduling and dispatch of physical assets.

Purpose of report

In support of its research efforts, Gridmatic has developed intelligence that provides never-before-seen insights into the financial performance of storage systems. We believe that the results highlighted in this report will be of interest to various storage stakeholders, including asset operators (IPPs, utilities, power marketers), investors, and developers.

These insights will enable readers to:

- Understand the difference between potential and actual market performance of merchant battery storage systems
- Optimize the performance of existing battery systems by making more informed decisions about operational strategies
- Improve pro forma models when planning future battery systems

Caveats

Regional Scope

This report focuses on the ERCOT wholesale electricity market, due to the high level of interest in battery energy storage development and operations, and the thorough disclosure data available for storage resources in ERCOT.

Data

We acknowledge the limitations of the available data and the limited scope of this report given that the industry is still in its early stages and the limited numbers of existing storage systems. However, we believe that the results are nonetheless meaningful and important enough to publish now, and we encourage you to engage with us to discuss your thoughts.

Uri

Winter Storm Uri caused significant outlier performance results for battery projects that are unlikely to repeat during their project lifetimes. This report presents battery revenue figures in 2021 with and without the week of Winter Storm Uri to allow for comparisons to future years.

Please see Appendix A for additional notes and caveats.

Battery pseudonyms

To retain confidentiality of systems and developers, batteries in this report are identified by pseudonyms:

Capacitaur	Magnetod
Conductypus	Resisteo
Electrithe	Rhinarc
Faradamos	Rotorithe
Fluxaffe	Sparkaroos
Galvanix	Turbinea
Hertzopod	Varcipillar
Insuloth	Volteon
Jouleon	Wallawatt
Loadle	

Names were generated via a Pokémon-style random name generator that we seeded with electricity-related words. The batteries represented by these names are the actual grid-tied batteries that operated in the ERCOT market in 2021.

The report sets a baseline of information for ongoing analysis of industry trends and will be updated regularly as new data becomes available. We hope that this report will jump-start conversations among storage asset operators, investors, developers, and other stakeholders.

Findings
What Was

Topic #1:

Revenue by Market Product

The struggle is real-time

Summary

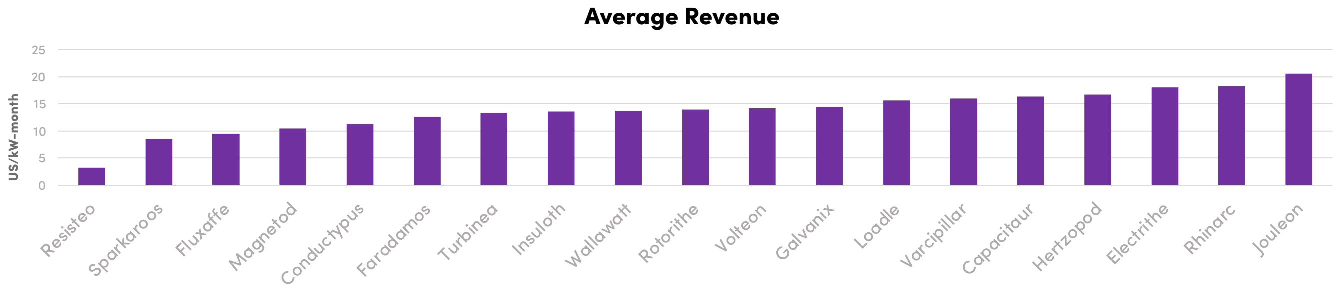
Overall, the vast majority of revenue for battery storage systems in ERCOT was from ancillary services, excluding Winter Storm Uri.[1] The leading system achieved an ex-Uri average revenue of $21/kW-month. Winter Storm Uri proved an amazing revenue opportunity for batteries, enabling some systems to return multiples of their capital installation costs in a single year.

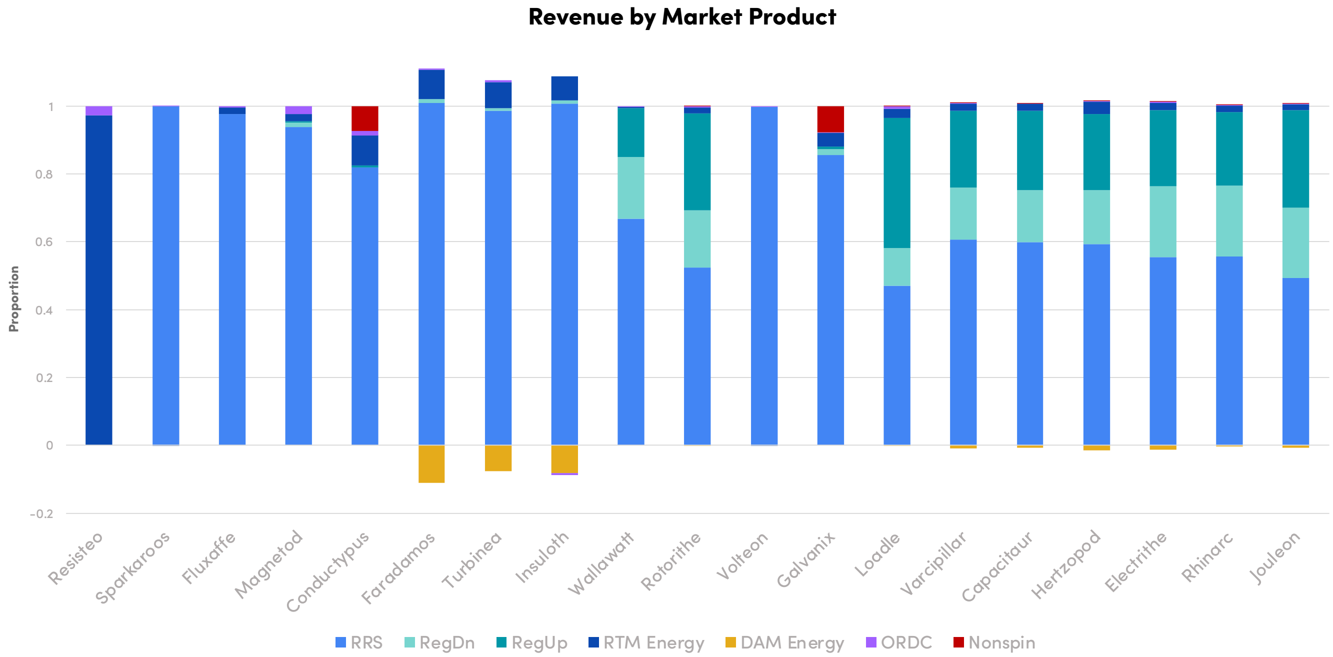
BESS revenue came almost entirely (96.4%) from ancillary services. Of this, the revenue was primarily from Reg Up (14.8%) and RRS (68%).

Takeaways

- When analyzing performance comparisons and trends, note that 2021 was an outlier year and that Winter Storm Uri had a disproportionate impact on storage revenue.
- Since almost all revenue for storage systems in ERCOT was from ancillary services, it is critical to monitor the ancillary markets. If batteries flood the market, prices could collapse as they did in PJM's RegD market.

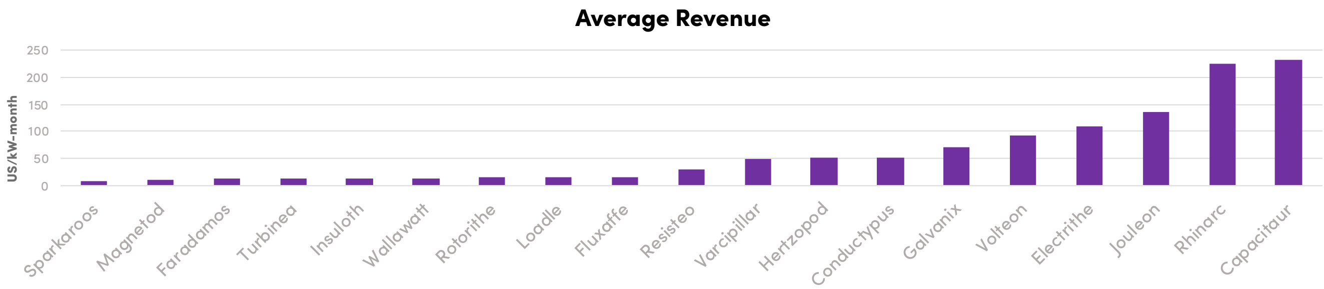
Findings

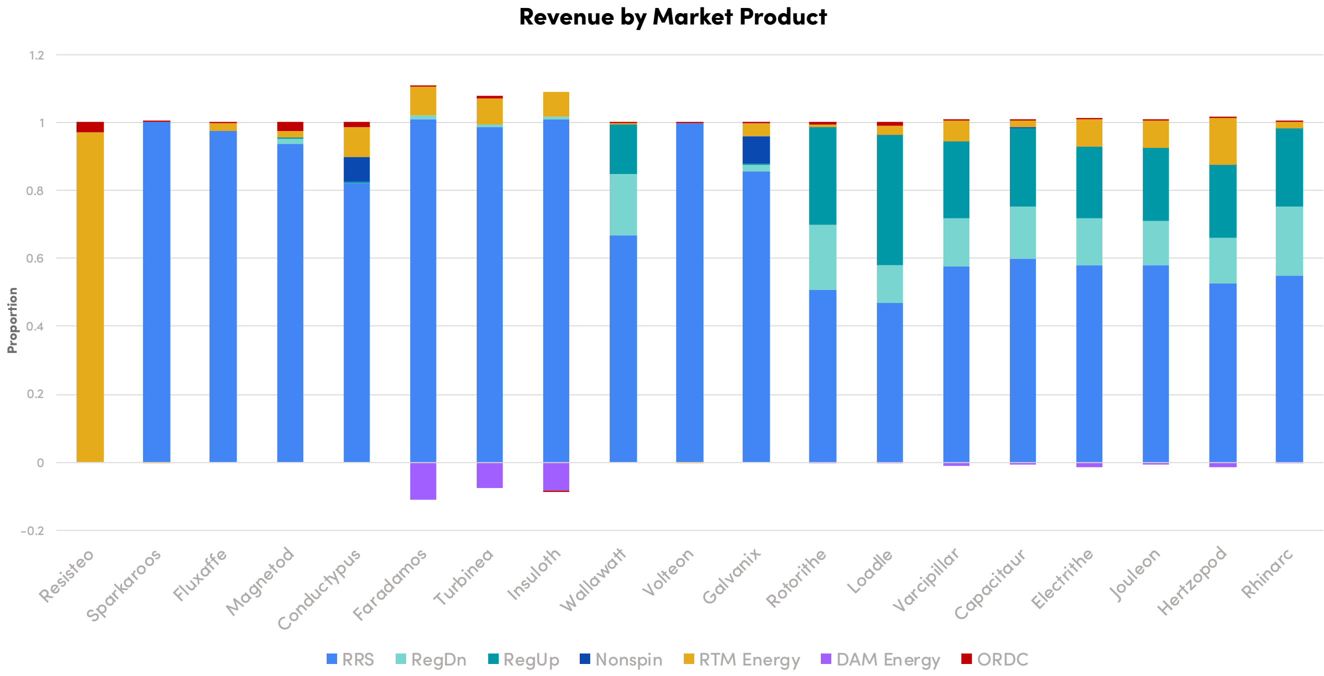




Excluding Winter Storm Uri

In ERCOT in 2021, excluding Winter Storm Uri, battery resources averaged revenue of $14/kW-month. *Jouleon* led all resources with an average revenue of $21/kW-month. *Jouleon* is a one-hour battery, as are many of the other batteries in our sample. Given that the capital cost for a fully installed 1-hour duration grid-scale battery was approximately $397/kW in 2021[2], $21/kW-month represents a return of CapEx of less than two years, a highly attractive return for this battery's investor in 2021.





Including Winter Storm Uri

The findings including Winter Storm Uri show a sharp contrast. Mighty *Capacitaur* earned an average of $233/kW-month over the course of 2021 when including its revenue during the storm, meaning it likely returned more than five-times its CapEx in that one week of the storm. Winter Storm Uri was a terrible event in terms of human impact, but it led to a historic windfall for some storage operators.

When we include the storm, the product mix of battery revenue changes, too. Ancillary Services represent an average of 92% of battery revenue, with RTM Energy representing 1% of revenue, and ORDC responsible for 6% of revenue. ORDC is a scarcity price adder applied to RTM energy that only kicks in during scarcity events, such as Winter Storm Uri. RRS remained the dominant revenue stream, but the ORDC scarcity price was meaningful when including the Winter Storm Uri revenue.

Additional Findings

The battery resources with the highest and lowest revenue differed by two primary factors: bidding optimization and time in the market. Systems that bid predominantly into one or two market products made less money than those that optimized their bids across multiple market products. Some systems with lower revenue were either not online or not available during the most profitable hours. We were not able to identify a strong locational component separating the high revenue batteries and the low revenue batteries because the majority of revenue for these systems comes from ancillary services, which is not location-dependent.

ERCOT is the only U.S. RTO/ISO without real-time co-optimization of energy and ancillary services. One impact of this lack of real-time co-optimization is that battery resource owners incur significant risk of not fulfilling their real-time ancillary service obligations due to outages or mismanaged state-of-charge after receiving day ahead ancillary service awards. The findings here indicate that battery resources are accepting and managing this risk.

As of 2021, the Reg Up and Reg Down requirement in ERCOT is approximately 500 MW, whereas the RRS requirement is approximately 3,000 MW. In the near-term, we expect the Reg Up and Reg Down revenue opportunity to decline for battery storage resources as the market becomes saturated. We expect battery resources to continue to generate significant revenue from RRS until more batteries are added to the market.

A key finding of our analysis is that no battery lost meaningful merchant revenue during Winter Storm Uri.

Another finding relates to battery storage performance during Winter Storm Uri. There is a commonly held belief that some batteries lost significant money during Winter Storm Uri. Our findings show that no battery lost meaningful merchant revenue during the Winter Storm. Instead, we understand that some batteries signed hedge contracts that required firm delivery of ancillary service products and that these batteries were unable to deliver during some expensive price hours during the Winter Storm. The findings here indicate that the key source of financial downside risk came from the hedge contract rather than the merchant market. Battery operators may be better served with strategies that target either 1) merchant operation, or 2) de-risked tolling-type contracts, in order to avoid the downside risk of hedge contracts.

One battery in the sample, *Resisteo*, did not participate in ancillary services at all in 2021. *Resisteo* is one of the batteries in the sample co-located with renewables, so we speculate that its operation is limited by the overall commercial strategy of the renewable-plus-storage project, perhaps reflecting a bilateral off-take contract that restricts merchant operation.

Some resources in the sample show a percentage-of-revenue of less than 0% for Day Ahead Market Energy or Real-Time Market Energy. In these cases, the battery lost revenue in one of these markets over the course of the year, typically due to charging during high-price hours. It is also possible that apparent losses in DAM energy were part of a DART arbitrage strategy. For these systems, gross positive revenue is shown as greater than 100% such that net revenue for all market activities is equal to 100%.

Topic #2:

Revenue peakiness

We're not in Kansas anymore...

Summary

It should come as no surprise that storage revenue is peaky. Excluding Winter Storm Uri, the top 10% of days accounted for 27%–54% of revenue in 2021, which is reasonably consistent with 2020. With Uri, the top 10% of days accounted for 54%–96% of revenue.

Takeaways

To manage revenue inconsistency, storage owners should:

1. Prioritize technology reliability
2. Plan maintenance carefully
3. Optimize bids to manage risk

These conclusions are not unique to the ERCOT market, but rather are likely true for storage deployments in all ISOs.

Findings

In addition to revenue by market product, we looked at the distribution of revenue over time. In this section, we look at the revenue of each of the 19 commercial batteries during each day of the year.

Of the 19 commercial battery resources in our sample, 11 were online during Winter Storm Uri, and 8 were either off-line or achieved COD later in 2021. Including Winter Storm Uri, and considering only the batteries online during Winter Storm Uri, the top 10% of days accounted for 54%-96% of revenue in 2021. Winter Storm Uri also sparked some negative revenue days for *Resisteo* and *Fluxaffe* due to charging during high price hours.

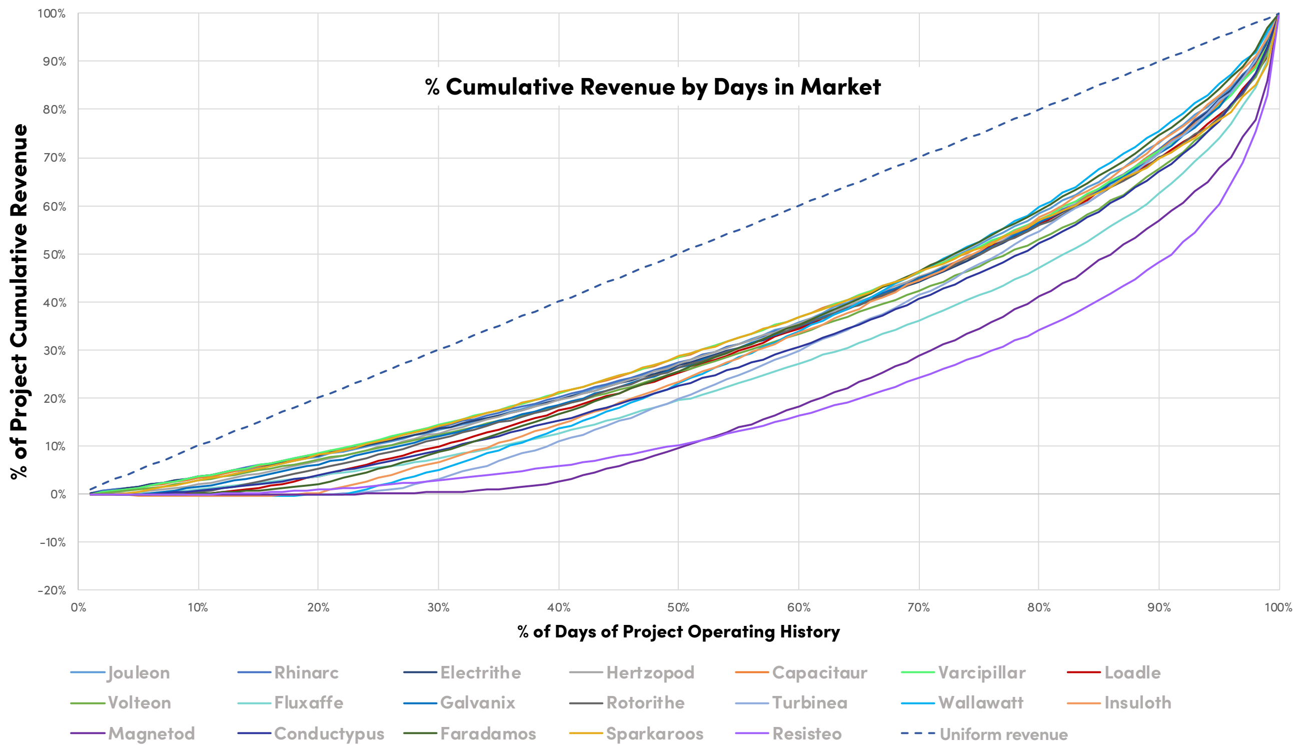
For the 11 battery resources that were online during Winter Storm Uri, we have excluded the week of 2/12/2021–2/22/2021 from our "Excluding Winter Storm Uri" analysis.[3] Excluding Winter Storm Uri, the top 10% of days accounted for 27%-54% of revenue in 2021.

Battery resources have often been considered to be potential replacements for peaker power plants; hence, it is no surprise that they would have peaky revenue, even without Winter Storm Uri. The uneven distribution of storage revenues across the year highlights the importance of multiple aspects of storage operations:

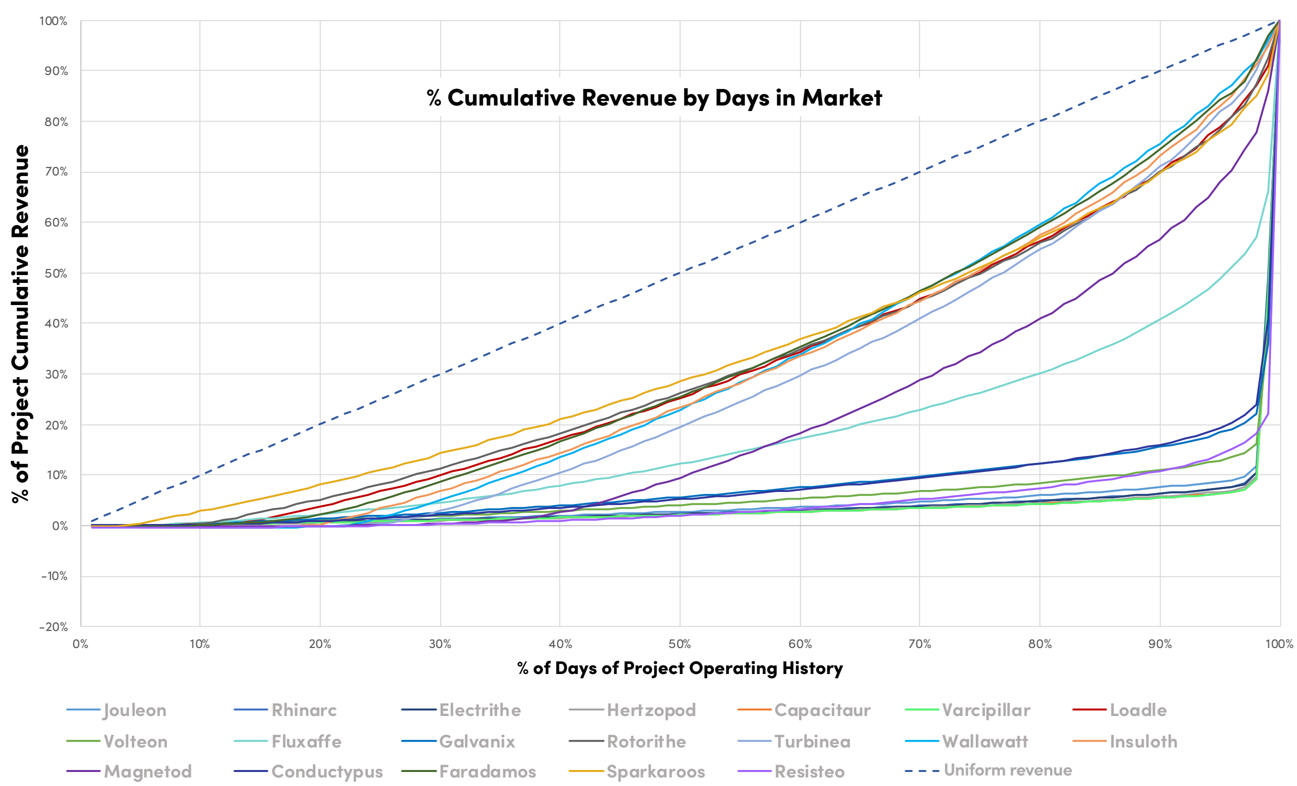
1. Technology reliability - Given the potentially enormous opportunity cost of an unexpected outage, resource owners should prioritize reliability in their technology choices.
2. Maintenance planning – Storage operators should only plan scheduled maintenance during periods of expected low revenue opportunity, such as hours defined by ERCOT as off-peak.
3. Bid optimization - Many battery resources operators self-schedule in the real-time market and miss price spikes due to sub-optimal bidding. Operators should submit optimized bid curves that lead to feasible storage schedules in order to realize high revenue during peak days.

In 2021, the top 10% of days accounted for 27%-54% of annual revenue.

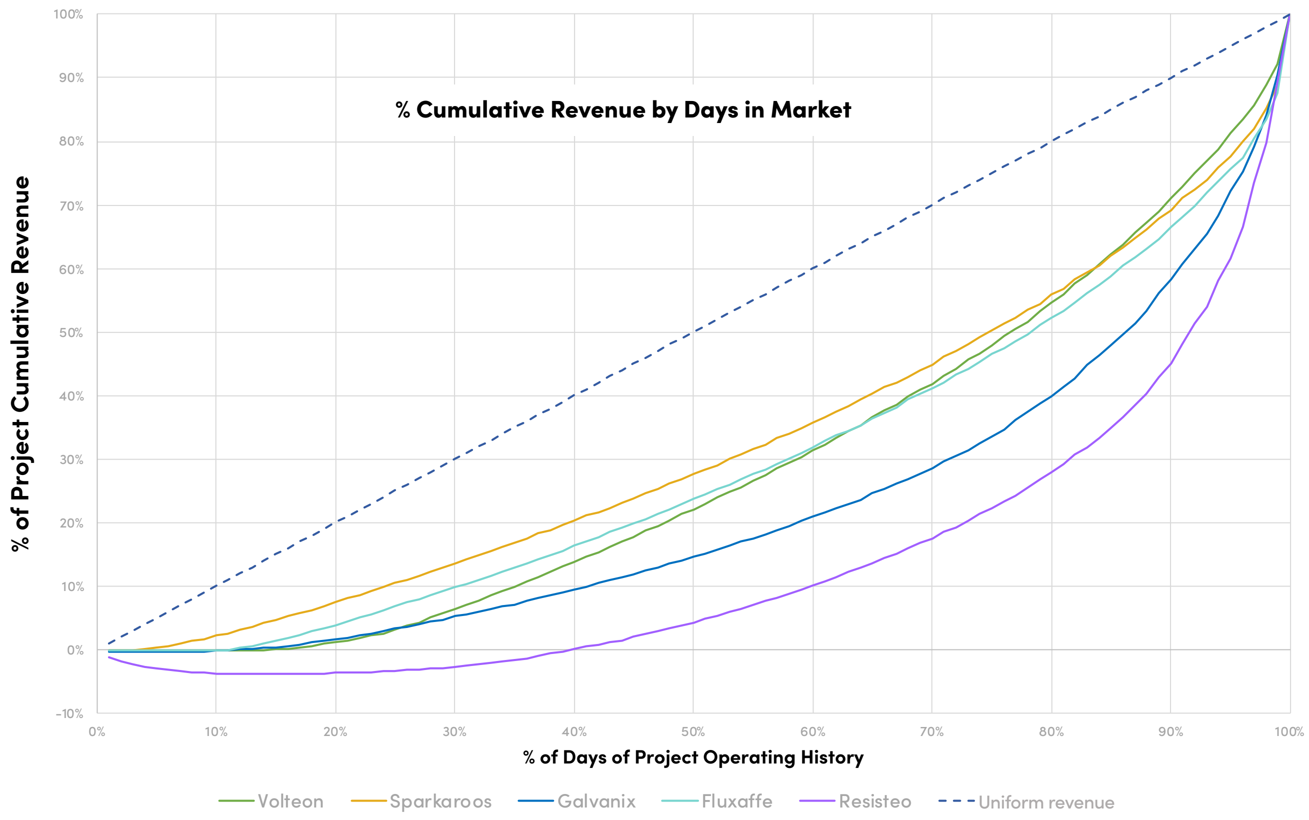
2021 – Without Uri



2021 – With Uri



2020


% Cumulative Revenue by Days in Market
% of Project Cumulative Revenue
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
-10%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Days of Project Operating History
Volteon
Sparkaroos
Galvanix
Fluxaffe
Resisteo
Uniform revenue

Topic #3:

Availability

Battery systems have delivered as promised... mostly

Summary

Battery outages can have significant impacts on profitability, exacerbated by the time required to get technicians to storage systems that are typically unmanned. We found that many projects achieve the typical vendor guarantees of 97–98% availability, but not all. System reliability remains a challenge for asset operators.

Takeaways

- Some battery systems are significantly under-performing relative to expected availability, indicating unexpected challenges with equipment or service providers.
- The *buyer beware* nature of battery supplies means that owners and operators need to shoulder a heavier burden in risk management, whether in broadening assumptions in pro formas or putting more emphasis on contingency planning and mitigation.

Findings

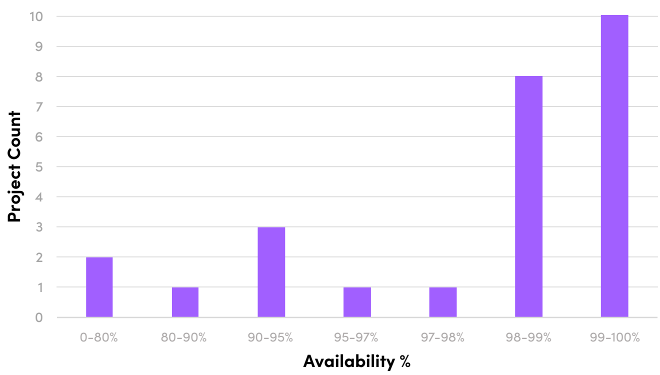
In addition to reviewing battery revenue metrics, we used ERCOT disclosures data to review the battery resource availability during 2021.[4] We used ERCOT resource status from the Real-Time Market to determine availability.[5]

Our calculation overestimates overall system availability because disclosure data allows us to identify full system outages, but we are not able to count partial outages in which the system still operates at de-rated capacity. Moreover, we cannot differentiate between resource-caused outages and grid-caused outages, which may be prevalent in certain resource locations. Those caveats aside, we believe the results identified provide useful insights to grid-scale storage owners and operators.

During 2021, the maximum system availability was 100%, achieved by only one battery in our study, *Wallawatt*. *Wallawatt* achieved COD during summer 2021, and so the result might not be sustained over a longer period. On the other end of the spectrum, the lowest measured system availability was 54% for *Coyohm*. To your improved health in 2022, *Coyohm*! Across our sample, the average system availability was 94.6%, and the median system availability was 98.8%.

Availability is a key metric for battery profitability. Failures of equipment such as inverters, enclosure HVAC, battery electronics, and site communications result in time out of the market until the failure can be remedied. Most battery locations are unmanned; hence, it can take multiple days to get qualified repair personnel to the site. Battery equipment manufacturers and integrators typically offer annual availability guarantees of 97–98%. We found that actual results for many projects are at or above these typical guarantee levels; however, a number of projects have significantly lower availability, indicating that system reliability remains an industry challenge.

Histogram of BESS Availability - 2021



Topic #4:

Testing and Commissioning Period

The wrong kind of long duration

Summary

Project commissioning durations ranged from 24-246 calendar days. A large portion of the commissioning period is testing, which has a wide distribution of 1-to-38 days. Development plans typically assume a one-month commissioning period, whereas actual testing and commissioning periods were typically 3-to-6 months.

Takeaways

- Project developers should spend more effort in due diligence of—and contingency planning for—commissioning plans. Developers should pay particular attention to equipment track records, market-testing processes, and suppliers' equipment systems integration capabilities.
- Owners and operators should make contingency plans for delayed operation and any knock-on effects with respect to financial impact, fiscal year tax credit eligibility, etc.

Findings

As with our analysis of battery availability, we used disclosure data to review the testing and commissioning time of battery resources in ERCOT during 2020 and 2021.[6] We define the commissioning period as the time starting when the battery is first synchronized to the grid and ending at project COD.[7] Among projects that came online in 2020 or 2021, the median time for project commissioning was 80 calendar days. The shortest commissioning period in the data was *Wallawatt*, with 24 calendar days. *Loadle* had the longest commissioning period at 246 days, but upon reaching COD, it operated at 99.6% availability for the remainder of the year. Slow but steady *Loadle*.

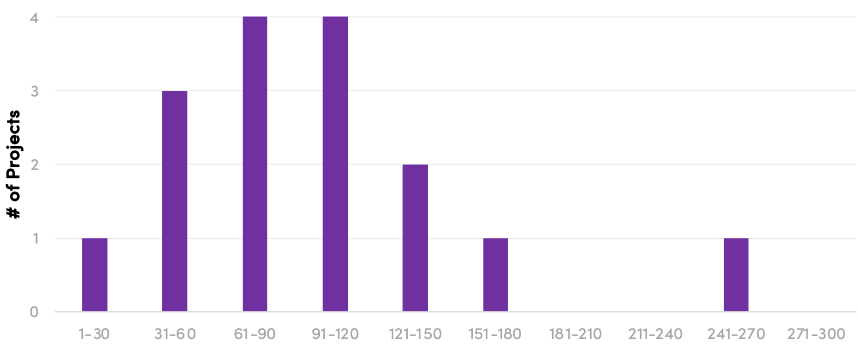
Among projects that came online in 2020 or 2021, the median number of days during which the projects were in testing was 16 across 2020 and 2021. The distribution of testing days was wide-ranging. *Wallawatt* spent just one day testing, while *Insuloth* tested for the equivalent of 38 days, consisting of multiple part-day tests spread across five months.

Our sample of 14 batteries excludes projects that came online prior to 2020, although we did observe that those older projects had fewer or zero testing days from 2020-2021.

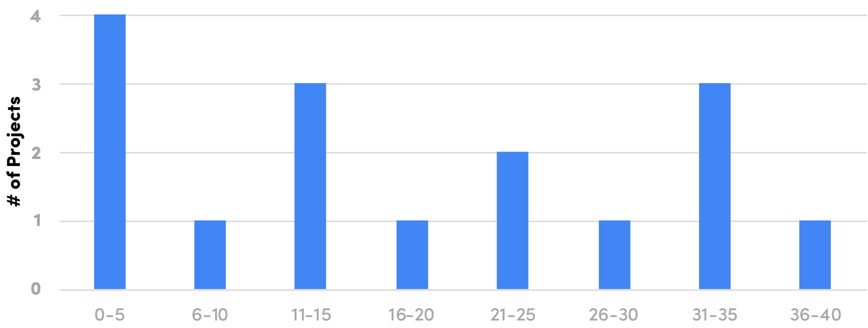
We find the one month commissioning period assumption was achieved infrequently in ERCOT in 2020-2021. A more typical testing and commissioning period was three months, and some extended beyond six months. The data does not explain these extended commissioning periods, but we can infer that equipment issues or other development-related issues caused system delays. It is also possible that ERCOT market testing processes could be contributing to extended delays. Our conclusion is that project developers should closely evaluate both the commissioning plan for new battery projects and their suppliers' equipment systems integration capabilities.

One month is a common but erroneous development assumption for the commissioning period to reach commercial operation for a grid-tied battery in North America.

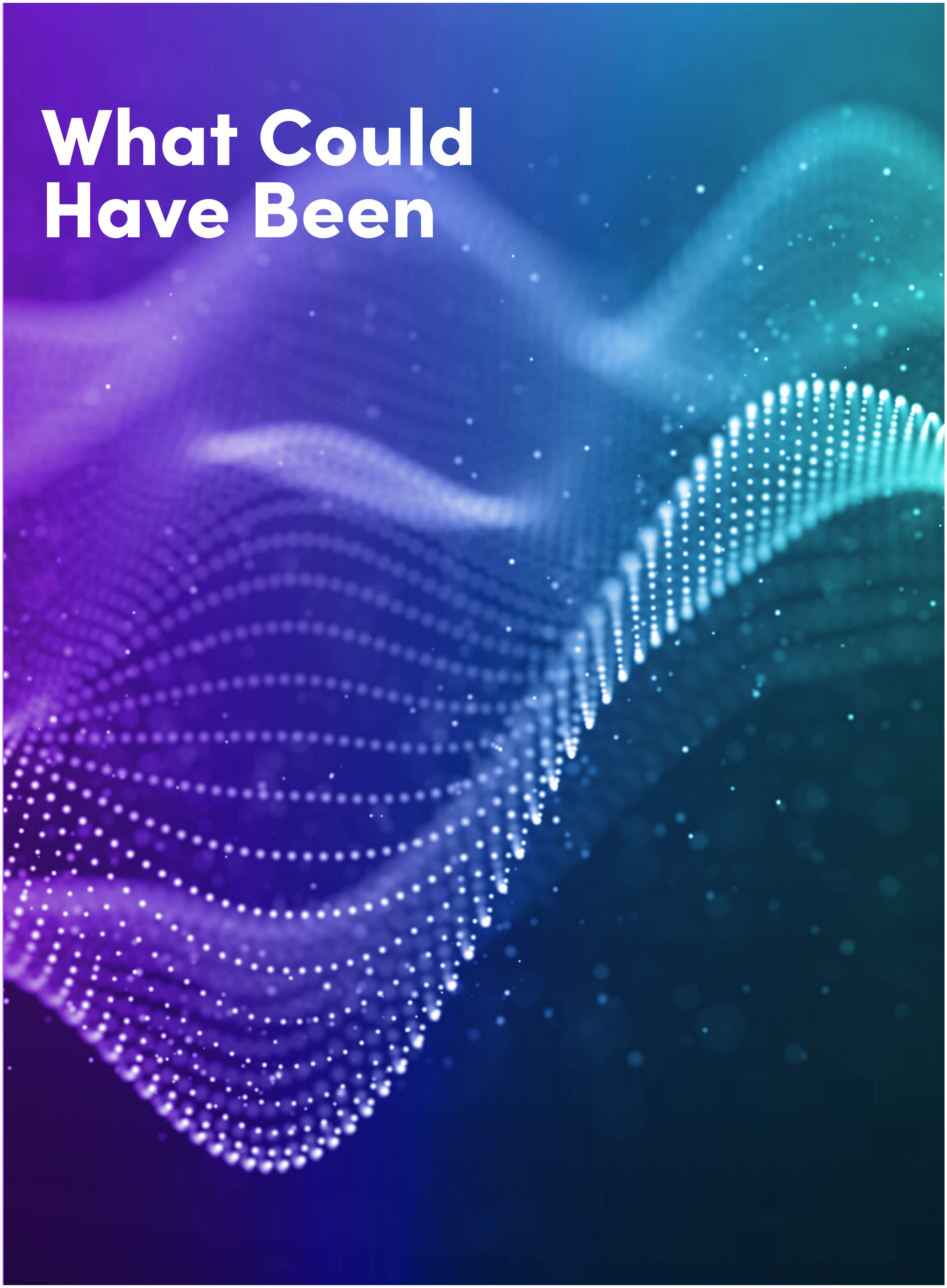
Synchronization to COD (Days)



Total Testing Period (Days)



What Could Have Been



Gridmatic Impact

Introduction

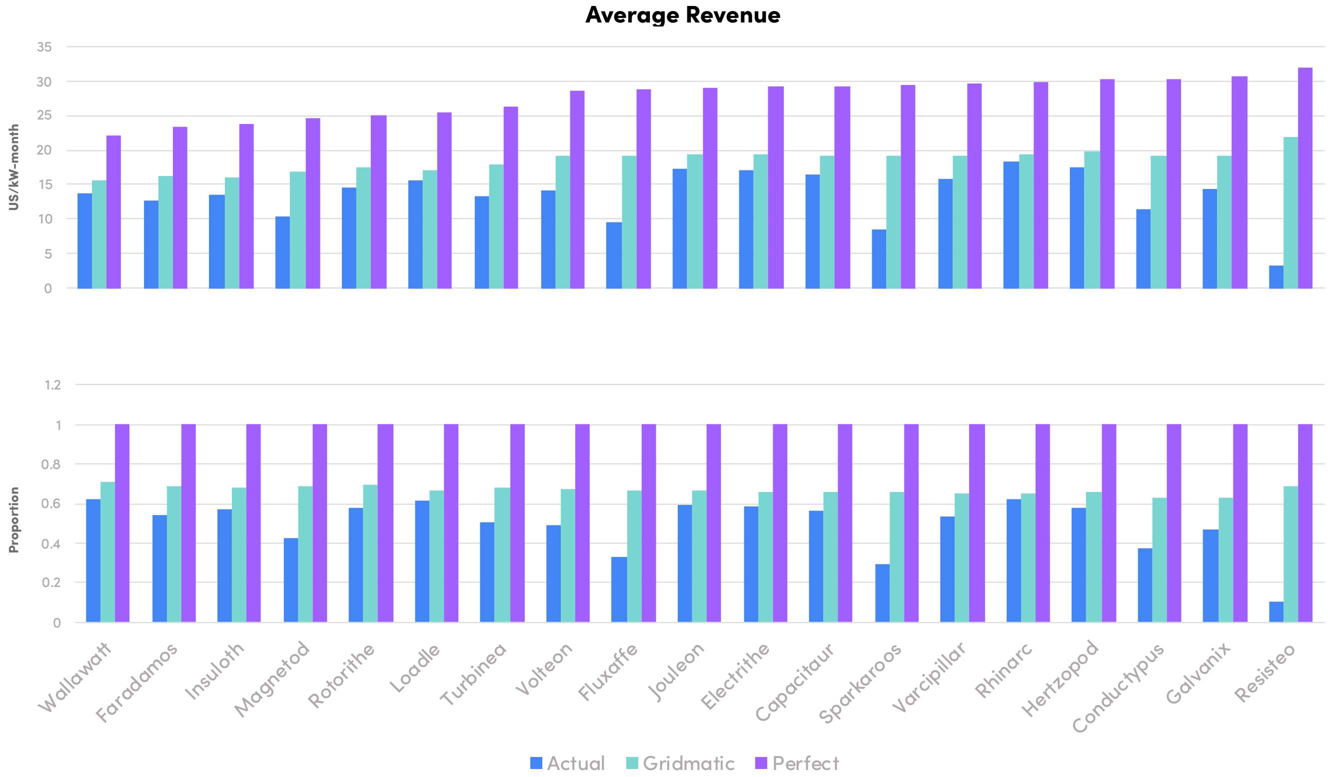
To provide insight into our own storage business, Gridmatic regularly analyzes the gap between optimal and actual revenues achieved by grid batteries in the field. Here we hope to peel back the curtain on some of those insights. We will review the 2021 financial performance of the 19 commercial batteries in the ERCOT market, operated in one of three ways:

- **Actual** – results observed by the each battery in 2021, based on ERCOT disclosure data
- **Perfect** – the optimal revenue achieved by the Gridmatic battery scheduler in backtest simulation, assuming perfect foresight of all energy and ancillary prices and deployments
- **Gridmatic** – the revenue achieved by the Gridmatic battery scheduler in backtest simulation, given the forecasts generated by Gridmatic at the time of bid-submission.

The Actual results match those shown in Topic #1 of this report. The Perfect and Gridmatic cases are backtests based on assumptions further detailed in the appendix.[8] We invite those interested in deploying the Gridmatic battery scheduler on their own systems to set up a live ongoing simulation with us. This way, you can verify firsthand the Gridmatic Scheduled results and backtested price forecasts illustrated in this report. We present the main findings excluding Winter Storm Uri, which we think is most representative, followed by the results including Winter Storm Uri.

Findings

The Actual revenue, averaged across the 19 batteries, was just 54% of the Perfect revenue over the course of the year.[9] For those wondering if merchant storage revenue resources are already close to optimized, these results demonstrate that the answer is an emphatic "no." However, the Perfect results are not achievable. Future prices and ancillary deployments are inherently uncertain.

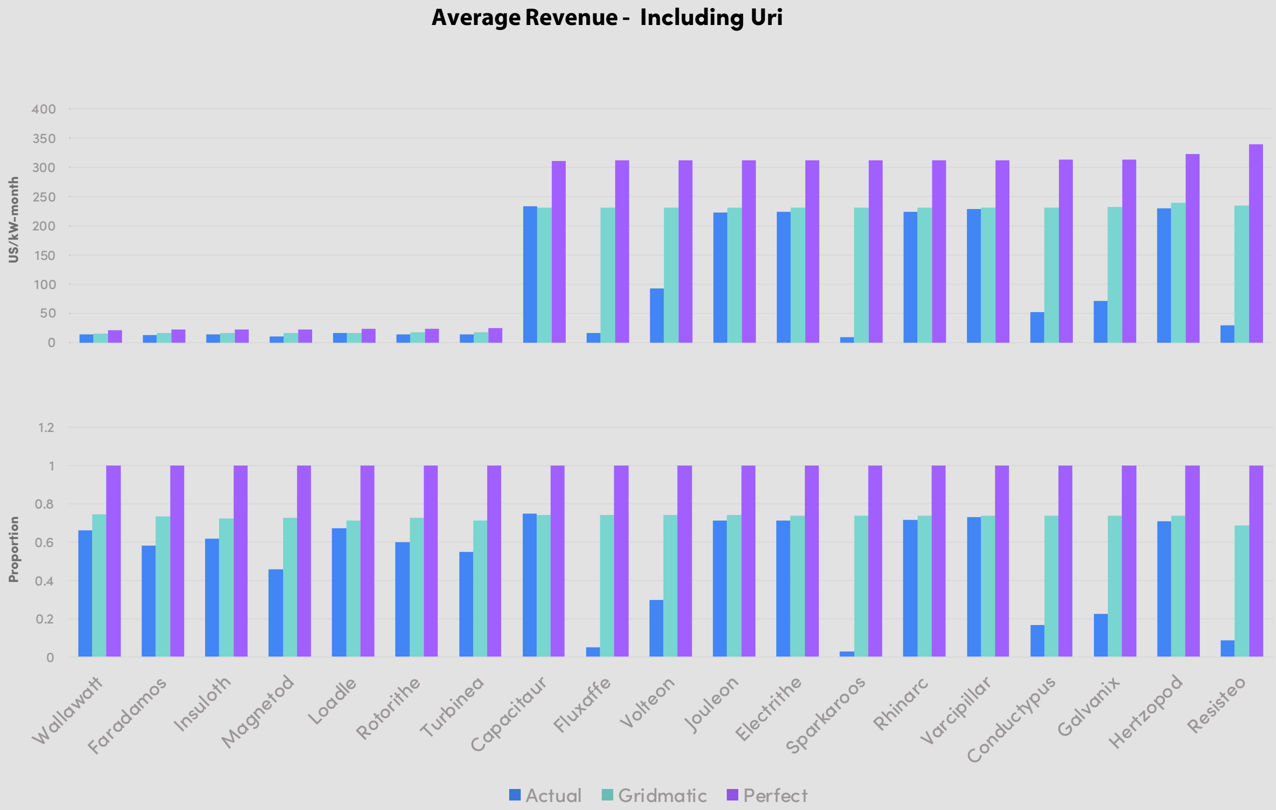


Gridmatic focuses substantial engineering effort on making good forecasts. These forecasts, combined with scheduling optimization, have a significant impact on revenue. On average across the 19 batteries, Gridmatic achieved a 28% uplift over the Actual revenue. The Gridmatic Scheduler is backtested in a framework that closely mimics the real-world market process, including bid submission timelines.

To optimize a battery's performance, operators must manage tradeoffs between five separate revenue streams in DAM and RTM markets, while respecting battery warranties, physics, and market rules. This complexity is exactly what makes battery scheduling an ideal candidate for Gridmatic's advanced computational approach.

The revenue uplift achievable on individual batteries varies, and there are certain batteries where the Actual revenue shows outperformance over the Gridmatic scheduled revenue. There are two key reasons for the variation in uplift. One reason is that there is a large variation in the market performance of the various operators of batteries in ERCOT today. A second less obvious reason is based on ERCOT ancillary service rules and revenue accounting. ERCOT allows Qualified Scheduling Entities (QSEs) to move ancillary awards between different units after the time of DAM award, but before RTM delivery. The upshot is that a given battery may not deliver the ancillary obligation it receives and is paid for in the DAM. Using disclosure data, we have confirmed that some batteries in 2021 consistently were paid ancillary service awards that were not feasible to deliver and instead traded these obligations to other resources in the QSE. Intra-QSE trading is the causal factor in cases where the Actual revenue exceeds the Gridmatic scheduled revenue. The simplest way to account for this was to attribute the revenue from ancillary awards to the battery with the DAM market award, even in cases where this DAM award would necessitate an intra-QSE trade. A more detailed accounting requires additional QSE level analysis–something you may find in next year's report!

Winter Storm Uri was a deadly and tragic event for many families, first physically, and then financially. It exposed the life-saving value of power during a crisis. Batteries that supported ERCOT during Uri received an unprecedented revenue windfall.

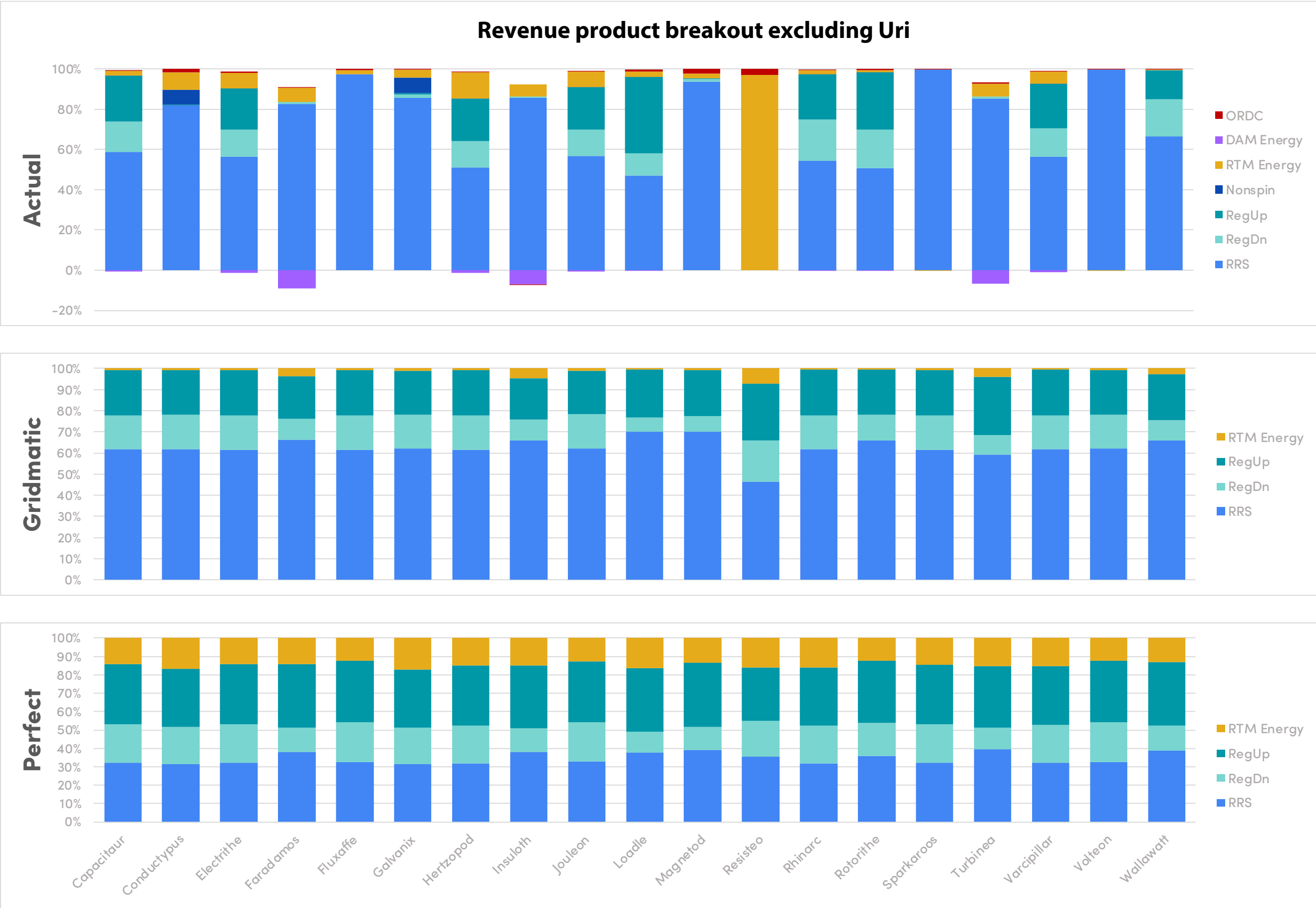


With Uri included, the Actual revenue on average across the 19 batteries was 44% of the Perfect revenue over the course of the year. The average revenue uplift achievable by Gridmatic over the Actual batteries was 68%. The average figures take into account that the impact for some of the batteries is identical to the case with Uri excluded because those batteries were not online during Uri.

During Uri, there was significant uncertainty regarding allowable market operations. Winter Storm Uri prompted an Energy Emergency Alert (EEA) event, and during this time ERCOT instructed grid resources to restrict charging from the grid. We have limited information on the exact nature of the restrictions, but in theory, Regulation

Down and charging energy may not be allowed by battery resources during an EEA event. In practice, we see in disclosure data that during Winter Storm Uri batteries operating in ERCOT did receive Regulation Down awards and did charge from the grid, though most online batteries limited their participation to RRS. It is not clear, even in retrospect, which products batteries could purchase. To simulate the white-knuckling and confusion of the EEA conditions, the Gridmatic Scheduler is limited to a simple RRS-only strategy. The Perfect Scheduler behaves normally, since it represents a prescient scenario.

This caveat aside, the results including Uri show additional revenue uplift opportunity from an optimized bidding strategy during extreme grid events.



Looking at those same results from a revenue mix perspective yields further insights:

Actual

The top graph shows the actual wholesale market product mix of the batteries. There are a variety of strategies. They mostly rely heavily on RRS, the spinning reserve product in ERCOT. An average of 68% of commercial battery revenue in ERCOT came from RRS in 2021. RRS is attractive because it is relatively well paying, and it does not require much cycling of the battery. This makes state of charge management easier, particularly for a manually-bid battery.

Gridmatic

Relative to the Actual batteries, the Gridmatic scheduled batteries are both more consistent and diverse in market participation. The variation in products between batteries is much smaller, consistent with ancillary service products being priced system-wide rather than nodally. The Gridmatic Scheduler was able to capture substantially more revenue from Reg Up and Reg Down. These two products typically complicate state of charge management, because their throughput requirements are uncertain. Without real-time co-optimization in ERCOT, battery providers cannot trade out of their positions if they mismanage battery state of charge. Gridmatic can capture more revenue from these products because the Scheduler strategically incorporates expectation of the products' throughputs. This helps both physically manage the state of charge and financially leverage the RTM energy price when throughput is high. Gridmatic's AI-powered forecasting, combined with state of charge management, can be very lucrative in unlocking additional revenue.

Perfect

The third chart shows results if the operator had perfect knowledge of the market. As shown, even more revenue comes from market products other than RRS. A more meaningful portion of the revenue comes from RTM energy arbitrage. While Gridmatic is able to predict price spikes better than the Actual scenario, the Perfect results show that there is significant additional money to be made from even better price forecasting. This is a difficult problem that we continue to work on. Energy price spike prediction will only grow in importance, as ancillary prices decrease, and energy arbitrage becomes a bigger part of the revenue mix for storage projects.

Overall, these results tell us that there is a significant gap between actual performance observed in grid batteries and what could realistically be achieved via Gridmatic's AI-based optimization. Owners of merchant batteries should re-evaluate their optimization approach to ensure that they are not sacrificing meaningful additional revenue with their current approach.

About the Authors

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David Miller is VP of Business Development at Gridmatic. David has spent eight years in the energy storage industry. Prior to Gridmatic, he worked at Greensmith, Wartsila, and Shell. He has overseen strategy, business development, financing, and deployment of grid-scale battery systems across five U.S. ISOs and in nine countries. David began his career at Energy & Environmental Economics Inc. (E3), where he was a consultant to the Electric Power Research Institute on Li-ion energy storage market valuation, and the California Public Utilities Commission, for its Permanent Load Shifting cost-effectiveness proceeding. He received an MBA from Harvard Business School and a B.A. in Economics from Stanford.

Austin Park

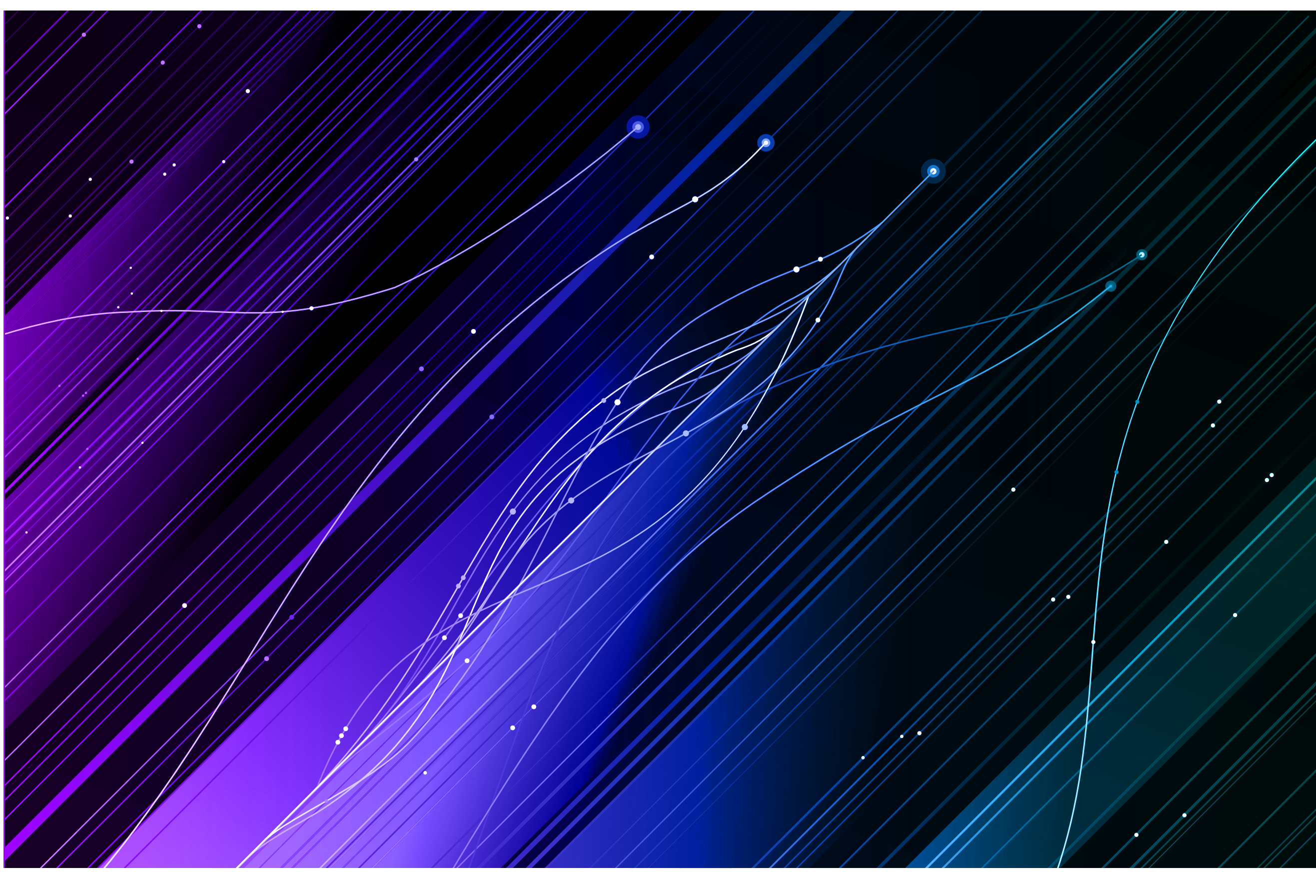
Austin Park is a Machine Learning Engineer at Gridmatic. He is a former Co-director of the Stanford Energy Policy Community. Austin completed his M.S. in Energy Resources Engineering at Stanford, focusing on data analysis for renewable integration and economy-wide decarbonization. He worked at an internship integrating energy datasets on the data commons team at Google and was an analyst at Bloomberg New Energy Finance, where he published research on the costs and benefits of drone adoption for various energy sectors. Austin is a frequent speaker on topics related to energy policy.

About Gridmatic

Gridmatic is an AI-enabled power marketer, founded in 2017 to apply machine-learning algorithms to forecast energy supply, demand, and pricing in wholesale energy markets. Gridmatic has achieved four years of success in financial energy market participation and is currently active in six ISOs: CAISO, ERCOT, MISO, PJM, NYISO, and SPP.

Gridmatic is now focusing on applying its algorithms to grid-scale storage to optimize scheduling and dispatch of physical assets. The Gridmatic system applies deep learning and control theory to large datasets to produce risk-adjusted offer curves. This AI-driven market optimization—that has been trading successfully in financial energy markets—is applied to storage systems to address the profitability gap resulting from suboptimal market participation.

For storage owners, the Gridmatic system targets the lowest-cost markets for energy purchases, preventing overly conservative bids while ensuring battery SOC to fulfill obligations. The system can provide ISO scheduling coordination and market settlement, along with resource trading and risk management. Gridmatic operated under two business models: 1) a service-based offering with a revenue share, and 2) an off-take agreement in which Gridmatic pays a fixed amount for the dispatch rights to the facility.



Appendix A

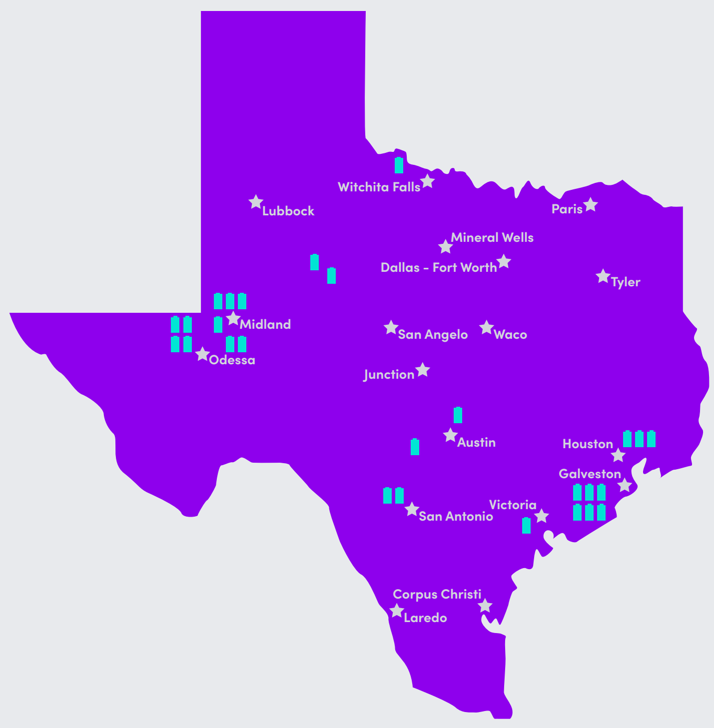
ERCOT

This report focuses on the ERCOT wholesale electricity market, due to the high level of interest in battery energy storage development and operations in the ISO. Battery storage in the region is booming, as evidenced by the *ERCOT Seasonal Assessment of Resource Adequacy*, published in November 2021 for Winter 2021-2022, which reported storage resource capacity of 1,204 MW, compared with 285 MW in the previous year. Moreover, ERCOT provides thorough disclosure data covering operational performance of storage resources 60 days after the date of operation. We rely upon this disclosure data to provide the insights in this report.

Battery resources in ERCOT

This Gridmatic Annual Storage Report includes 27 battery storage resources that operated in the ERCOT market in 2020 and 2021. The report covers the period through 12/31/2021, and we considered only battery storage resources that achieved commercial operation[10] by 9/30/2021 to ensure a meaningful sample for each resource. Of the 27 batteries, 8 provided only the ERCOT Fast-Responding Regulation Service[11] product ("FRRS"), a pilot program capped at 65 MW of resources. The FRRS batteries are paid the market price for Reg Up and Reg Down, but do not provide the Reg Up and Reg Down products. Instead they respond to trigger events that require less battery cycling than Reg Up and Reg Down, making FRRS financially lucrative for battery storage owners. FRRS is a pilot program and is effectively closed to new entrants. Hence, we consider the 8 "FRRS batteries" to be pilot market systems and treat them as distinct from the remaining 19 "commercial batteries" in our study. We include the FRRS batteries in the Topic #3 Availability, but exclude them from the remaining sections of the report that involve revenue and dispatch optimization.

Locations of battery storage resources in ERCOT in 2021



A note on Winter Storm Uri in 2021

In ERCOT, the energy-only market is designed to compensate generators only when they produce, and incent new-generation investment via high energy prices in the event of energy scarcity. By design, the market has more volatile energy prices than other ISO/RTOs in the U.S., which use capacity or resource adequacy payments to incent generation and stabilize energy prices. For this reason, it is expected that battery resources in ERCOT will make large portions of their revenue during limited high-prices events, similar to a peaker power plant. While battery revenue is expected to be peaky in ERCOT, Winter Storm Uri created peaky revenue of historic proportions for battery storage.

During Winter Storm Uri, wholesale electricity prices reached the system-wide offer cap of $9,000/MWh and remained at that price for multiple days over the week. The average U.S. household uses 11 MWh per year.[12] Electricity at $9,000/MWh over the course of the year would result in a $99,000 average household electricity bill. The price of electricity during Winter Storm Uri was a significant outlier compared to more typical price spikes. High electricity prices during Winter Storm Uri led to high revenue opportunities for generators to incent them to come online and stay online to support the grid. “Peaker net margin” is a common metric used to compare peaker power plant profitability, measuring the cumulative profitability of peaker plants based on energy prices over a calendar year. The peaker net margin in ERCOT was $4.17/kW-month in 2020 and $12.5/kW-month in 2019, which was a relatively high value due to scarcity pricing in August 2019.[13] The annual peaker net margin in 2021 increased by an unprecedented $54.17/kW-month during the week of Winter Storm Uri alone.[14]

Winter Storm Uri is an outlier event that is highly unlikely to recur in the near future. Battery projects operating during Winter Storm Uri had an opportunity to generate wholesale electricity revenue that is unlikely to repeat during their project lifetimes. Hence, we present battery revenue figures in 2021 with and without the week of Winter Storm Uri, to allow for comparisons to future years.

Additional caveats

This report includes the following market products in the revenue analysis: Day Ahead Market energy revenue, Real-Time Market energy revenue, and the four ancillary services typically provided by battery storage resources: Regulation Up ("Reg Up"), Regulation Down ("Reg Down"), Responsive Reserve Service ("RRS") and Non-Spinning Reserve Service ("Non-Spin"). In all results, real-time energy throughput that is called as a result of an ancillary service dispatch is classified as Real-Time Market energy revenue/cost. Ancillary service revenue only includes the ancillary service capacity payments.

This report does not include any revenue coming from bilateral contracts that storage owners may enter into outside of the ERCOT marketplace due to lack of access to this information.

The simulations of the Gridmatic scheduler and the Perfect scheduler both exclude Day Ahead Market energy revenue and virtual bidding / DART arbitrage. This is in contrast to the Actual results, which include Day Ahead Market energy if that battery participated in that market. For the Gridmatic scheduler, DART arbitrage is part of our core trading business already without control of battery storage resources, and so we do not attribute DART arbitrage revenue to the storage resource in these results. For the Perfect scheduler, we do not believe DART arbitrage is appropriate to simulate because DART arbitrage under a perfect price forecast is far from achievable.

Ancillary award revenue is attributed to the battery resource that received the award from the DAM clear. In some cases, batteries received awards that were impossible to satisfy. When this happens, the QSE managing resource has the ability to move the ancillary award to a different resource before RTM delivery. As a result, the Actual scenario's battery revenue is overestimated for some resources, and underestimated for others. Unfortunately, not all resources managed by the QSEs in this report are batteries. Furthermore, not all batteries managed by those QSEs were online before 9/30/2021–the COD deadline for inclusion in this report. Disclosure data reveals that in each case where Actual revenue exceeds the Gridmatic scheduled revenue, the battery received more awards in DAM than it served in RTM. To keep the analysis as simple as possible, revenue was attributed to batteries based on DAM awards, even if the DAM award would require intra-QSE trading.

References

Topic #1

[1] The revenue percentage calculations in this section are weighted by the total dollars of revenue achieved by the batteries and are not equally weighted across projects. The intention is to show the total storage revenue opportunity available to all market participants.

[2] BloombergNEF Energy Storage System Costs Survey 2021, December 21, 2021.

Topic #2

[3] Sample Period:
2021 with Uri: 1/1/2021-12/31/2021
2021 without Uri 1/1/2021-2/11/2021, 2/23/2021-12/31/2021

Topic #3

[4] Source: "60-Day SCED Disclosure Reports.", 01/01/2021 to 12/31/2021. For the Availability topic, we include all 27 batteries that operated in 2021 and achieved COD prior to 09/30/2021, per the definition in footnote 10. The availability measurement period for each resource starts at the latter of the individual resource COD or 01/01/2021, and ends on 12/31/2021.

[5] In our calculation of availability, GEN statuses that are included as "unavailable" are: "OUT," "ONTEST", or no data available. Statuses that are included as "available" include "ON", "ONREG", "ONOS", "FRRSUP", and "OFF". We include "OFF" within our "available" categorization based on our interpretation of the data. The OFF resource status is meant to indicate that the resource is not participating in the market, but available if necessary in case of emergency (as opposed to "OUT" which is not available even in emergency). In practice, we found the OFF status appeared to be used in a manner differently from how it is defined. We identified resources with an OFF status in DAM Disclosure Reports that have DAM offer curves and cases in which resources have OFF status in SCED Disclosure Reports with telemetered real output. For this reason, we have made the simplifying assumption that "OFF" indicates available. In the most extreme case, Resisteo in our sample was OFF while having nonzero telemetered output in SCED during 4% of the sample period. All other batteries were OFF (with or without telemetered output) less than 2% of the time. Our treatment of the "OFF" resource status as available may result in an overestimate of actual system availability, but we believe this does not impact the results materially.

Topic #4

[6] Source: "60-Day DAM Disclosure Reports.", 01/01/2020 to 12/31/2021. For the Testing and Commissioning topic, there are a total of 16 batteries that meet our definition for both synchronization and COD in 2020 or 2021 up to 9/30/2021. We picked 9/30/2021 as our end date for synchronization and COD rather than 12/31/2021 in order to have a post COD-period of at least 3 months to review asset performance and confirm our COD assumption.
The calculation for number of days in testing is to take the hours the resource status was "ONTEST" and divide by 24. From the data, we found that many testing periods are 24 contiguous hours, but many test periods are less than 24 hours as well. Our calculation would treat a 12 hour test as 0.5 days. We also reviewed the total number of days the projects were in testing, including during the commissioning period but also during the post-COD period. After a resource reaches commercial operation per our definition, the resource may go through additional tests to qualify for additional market services or to correct deficiencies in performance.

[7] We define the synchronization date as the date in which the resource first displays a telemetered resource status of "ONTEST", "ON", "ONREG", or "ONOS" in the ERCOT 60-Day DAM Disclosure Reports. We use the same definition for COD as in footnote 10. Some of the commissioning days are spent in market testing, as discussed below, but much of the commissioning period is also spent completing project construction tasks.

Gridmatic Impact

[8] There are multiple assumptions required for the Perfect Foresight and Gridmatic Scheduled cases:

I. Market price inelasticity – We assume that additional market participation by resources in a particular market service does not impact its price. In practice, this will not be true, but price elasticity calculations are outside the scope of this analysis.

II. Sizing – We use the publicly announced power capacity and duration of each battery. For the Commercial Batteries in our ERCOT, power capacity values ranged from 2 MW to 100 MW, and duration ranged from 1 to 4.2 hours.

III. Cycle limit – We assumed that each battery has a cycle limit of 365 cycles per year. While real world systems may have different cycle limits based on differing technology and service plans, 365 cycles per year is a common, if conservative, assumption. Cycles vary by battery and scenario. Averaged across batteries, the Gridmatic Scheduler has the fewest cycles, followed by Actual, and then Perfect. Note that the cycle count is a controllable component of the risk-reward tradeoff. Battery owners more attracted to merchant risk can choose to cycle more aggressively, which will yield higher returns over the short-run. There are, of course, limits to the upside. Upping a merchant battery's cycle count shows diminishing returns. The settings for the Gridmatic Scheduler in this report are conservative, and should sit well within the comfort zone of most warrantee providers and operators.

IV. ITC - We do not assume any grid charging limitations that may be self-imposed by battery operators seeking to monetize the solar investment tax credit for their battery equipment.

V. Availability - we do not account for battery system unavailability in the Perfect Foresight and Gridmatic scheduled cases. While we do have SCED data regarding resource status (shown in Topic #3 Availability section of the report), we do not have information regarding partial outages, and we cannot determine which outages were planned or unplanned. For this reason, we have not attempted to adjust our revenue figures for physical availability, but it is reasonable to assume some real-world revenue reduction relative to the results shown here.

VI. Ancillary throughput – energy dispatch based on deployment for ancillary services is based on actual historical 4 second interval AGC data and 10 second interval grid frequency provided by ERCOT MIS. Battery storage throughput and cycling is calculated on a 4 second interval for the Gridmatic and Perfect cases.

VII. Market participation – the Actual results include some DAM Energy market participation, which is included here. The Gridmatic and Perfect results include only RTM Energy participation and do not include DAM Energy market participation. The rationale is that DART Arbitrage trading from a Perfect Scheduler is unrealistic, and DART Arbitrage by Gridmatic is excluded from our base energy storage scheduler operation, though it is something we offer as part of our core trading business.

VIII. Bid rules – Allowable storage GEN and CLR bid rules are based on the ERCOT Nodal Protocols as of December 31, 2021.

IX. The Perfect Scheduler is not an absolute upper bound. Rather, it is a relaxation of that upper bound such that it is a reasonably achievable results in all respects, except one: prescience. The Perfect Scheduler has perfect knowledge of prices and ancillary throughputs. It does not have free reign with respect to cycling (see III), nor does it include DAM Energy (see VII).

[9] If we include Winter Storm Uri, I would add the following comment: There is a further caveat to the performance of the Perfect Foresight and Gridmatic Scheduler for the period during Winter Storm Uri. Winter Storm Uri was an Energy Emergency Alert (EEA) event, and during such events, grid resources were instructed by ERCOT to restrict charging from the grid. We have limited information on the exact nature of the restrictions, but in theory, Regulation Down and charging energy may not be allowed by BESS resources during an EEA event. In practice, we see that during Winter Storm Uri batteries operating in ERCOT did receive Regulation Down awards charged from the grid. As a result, we have not limited the ability for the Perfect Foresight or Gridmatic Scheduler to participate in Regulation Down or energy charging in our backtest. This assumption may lead to an overestimate of revenue for the Perfect Foresight and Gridmatic Scheduler cases, and we would update based on better data availability of charge restrictions. More generally, we believe the results presented here that exclude Winter Storm Uri are more applicable for forward-looking analysis.

Appendix A

[10] The definition of COD date used in this report is: The first hour in the which the resource receives an ancillary service award (in the Day Ahead Market), or in the case of a resource that is not participating in ancillary service markets during the study period, the first hour in which the resource receives an energy award (in SCED).

[11] ERCOT, "Fast Responding Regulation Service – Completed"

[12] EIA "Energy Use in Homes"

[13] Potomac Economics, "2020 State of the Market Report for the ERCOT Electricity Markets", May 2021

[14] UT Austin, "The Timeline and Events of the February 2021 Texas Electric Grid Blackouts." July 2021, page 61

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