



Annual ERCOT Storage Report 2022

Published May 2023



Executive Summary

Energy storage plays a crucial role in the transition to cleaner energy, and effectively managing storage resources within electricity markets is essential to achieve our desired goals. This report aims to assist key stakeholders, including independent power producers, utilities, power marketers, investors, and developers, in understanding the disparities between potential and actual market performance. By identifying the factors that optimize performance, this report provides valuable insights to drive the efficient utilization of energy storage resources.

This second annual report serves as an update to the [2021 edition](#). The methodology used in the previous report, which was validated by [DNV](#), has been maintained for this year's analysis.

Results

Average energy storage system revenue across systems in ERCOT experienced a decrease from 2021, but remains relatively attractive. The downward revenue trend is anticipated to continue due to decreasing Ancillary Service prices. The most notable finding is the reduced percentage of revenue from RRS, especially in the second half of the year, with an even more pronounced decline expected in 2023. Almost all batteries primarily derive revenue from Ancillary Services, with top-performing batteries generating a larger portion of their revenue from non-RRS Ancillary Services.

Gridmatic Backtesting

In 2022, batteries' Actual revenue was, on average, 51% of the theoretical Perfect revenue, a slight decrease from 54% in 2021. This decline is attributed to the reduced performance of RRS and the growing importance of forecasting other revenue streams. Meanwhile, Gridmatic's performance saw slight improvement due to the AI-based forecast and optimization learnings from 2021 results. This led to a 46% increase in average revenue, per backtests, compared to Actual figures. The results in this report illustrate the revenue breakdown by market product, with the Gridmatic Scheduler focusing less on RRS and more on RegUp and RegDn revenues which are more challenging revenue streams to capture.

A preview of 2023: Updated state of charge requirements

In December 2022, ERCOT updated the Business Practice Manual (BPM) to define state of charge (SOC) expectations for Energy Storage Resources (ESRs) providing Ancillary Services (AS), significantly impacting market participants' operations. The new SOC expectations require ESRs to have enough SOC to satisfy all discharging AS awards for the full duration, limiting operational flexibility and reducing the ability to satisfy AS awards throughout the day. The revenue impact on batteries is substantial, especially for shorter duration ESRs. For example, a 1-hour battery could experience a real-world revenue reduction of over 20%, incentivizing the installation of batteries with durations longer than 1 hour in the market. The December 2022 changes are not reflected in the Actual, Gridmatic, or Perfect results shown here given that they were not in place during the period covered in the report. Details of the change are described further in Section 5.

Table of Contents

Executive Summary	2
Introduction	5
Findings	
Total revenue	8
Revenue by product	9
Revenue by product per resource	12
Availability	14
Peakiness	15
Gridmatic Backtesting	18
New SOC expectations impact	21
About the authors	24
About Gridmatic	25
Notes	26

Introduction

In 2022, the US energy storage sector deployed 4.8 GW, nearly equal to the combined installations of 2020 and 2021. According to the [US Energy Storage Monitor](#), an additional 75 GW of deployments are projected between 2023 and 2027, with approximately 81% (about 60 GW) attributed to the grid-scale segment. In ERCOT, about 5 GW of deployments (projects with financial security and notice to proceed provided) are expected by 2024 alone.

With this growth, there is a pressing need to optimize operations, focusing on arbitrage opportunities, minimizing temporal discrepancies between renewable energy assets and demand, and participating in Ancillary Services markets. Our [2021 report](#) served as a baseline with 19 systems, while the 2022 report features 52 systems, highlighting the pace of growth and emergence of fleet trends.

The Inflation Reduction Act (IRA) of 2022 is expected to drive growth in storage manufacturing and deployments, making these trends an essential indicator of what the industry can anticipate in the coming years.



Gridmatic

Established in 2017, Gridmatic is an AI-enabled power marketer that utilizes machine learning to predict energy supply, demand, and pricing in wholesale energy markets. With six years of successful market participation, the company is currently active in all seven U.S. ISOs. Gridmatic employs advanced algorithms for grid-scale storage, optimizing the scheduling and dispatch of physical assets.

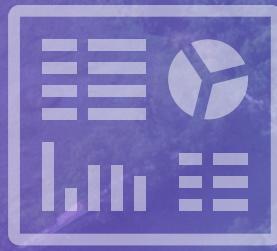
Purpose of Report

The aim of this report is to disseminate storage insights to a wider audience. Focusing on batteries within ERCOT, the data source for this report is derived from 60-day lagged disclosure data provided by ERCOT. Later this year, we plan to release a comparable report for CAISO.

Battery Pseudonyms

In order to maintain the confidentiality of systems and developers, the batteries discussed in this report are referred to by pseudonyms. Pseudonyms for systems added in 2022 were generated using ChatGPT. The batteries represented by these names are the real grid-tied batteries that operated within the ERCOT market during 2022.

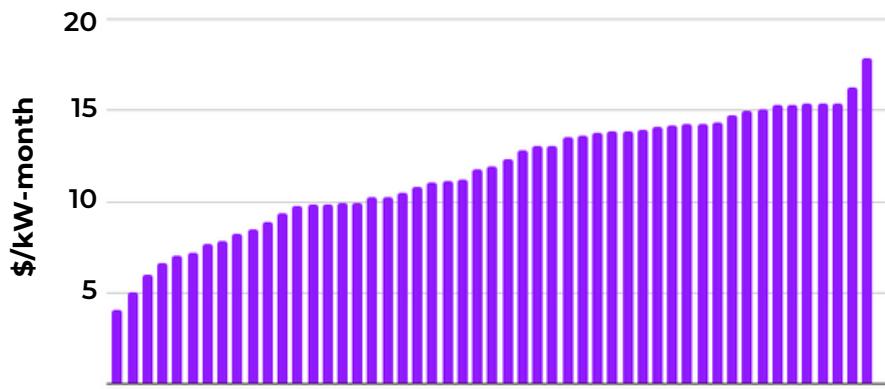
Findings



Total Revenue

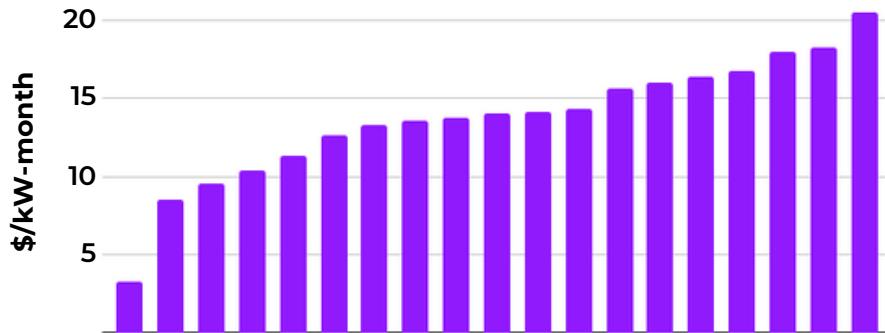
Even though revenue for energy storage systems saw a decrease from 2021, it still remains attractive. The downward trend in revenue is expected to continue as Ancillary Service prices for these systems keep decreasing.

2022



2021

Excludes Winter Storm Uri

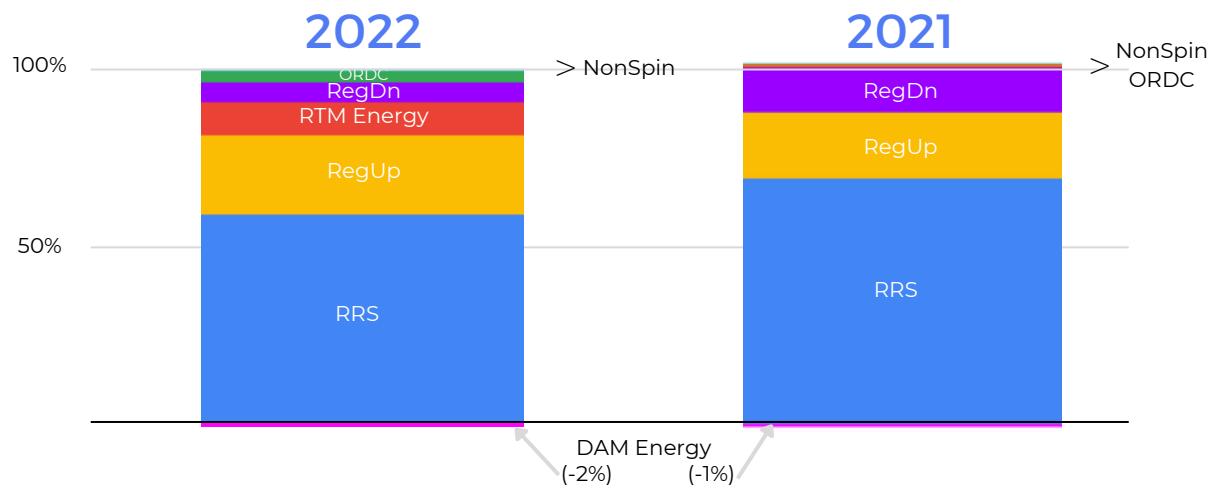


In 2022, the average revenue for energy storage systems was \$11.45 per kW-month across the 52 systems in the report, while in 2021 (excluding Winter Storm Uri), it was \$14.00 per kW-month for the 19 systems analyzed.

Considering a typical 1-hour battery with an installation cost of \$400 per kW, the return on investment, assuming 2022 revenues, would be just over 3 years. This ROI period would be longer for storage systems with longer durations.

Revenue by product

The most significant finding is the decrease in the percentage of revenue originating from RRS. This was particularly evident during the second half of the year. The trend is expected to become even more pronounced in 2023.



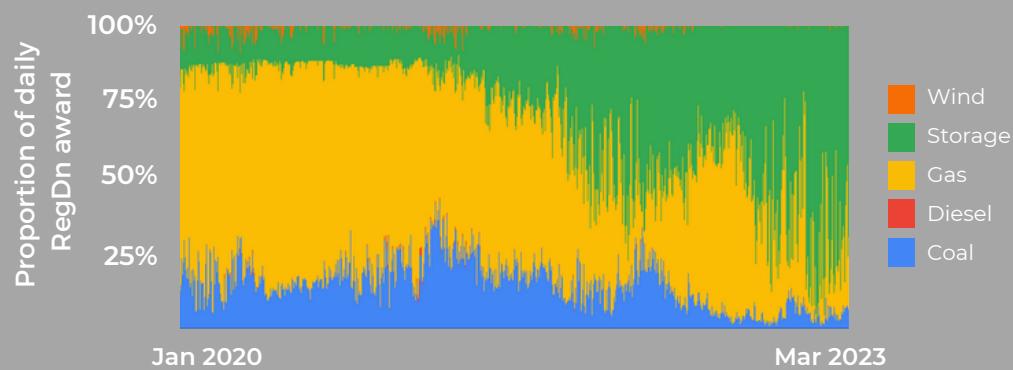
In 2021, nearly 70% of all battery revenues were generated from RRS. However, in 2022, this figure dropped to just under 60%. The relative share of RegDn revenue also decreased, while increases were observed in RegUp, real-time energy, and ORDC revenue.

Real-time energy revenue showed the highest growth out of all the products and rose from 3% in 2021 to 10% in 2022. As Ancillary Service revenue falls, real-time energy is expected to support a greater fraction of storage revenue.

Share of Ancillary Services

Amid concerns that the energy storage market is reaching saturation point, the graph below shows that for RegDn, batteries are indeed fulfilling the majority of awards, displacing other sources such as coal and gas.

Average RegDn Responsibility by Resource Type

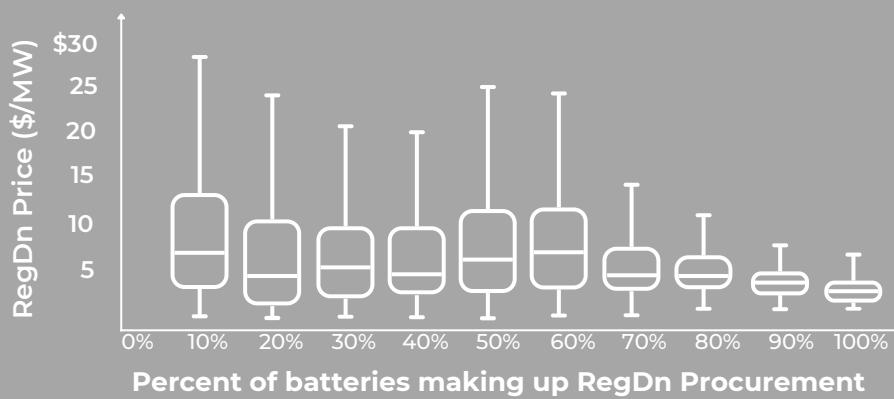


Further, the proportion of RegDn has grown despite overall growth in RegDn procurement:



The RegDn clearing price decreases and reduces in range as the proportion of RegDn award fulfilled by storage increases.

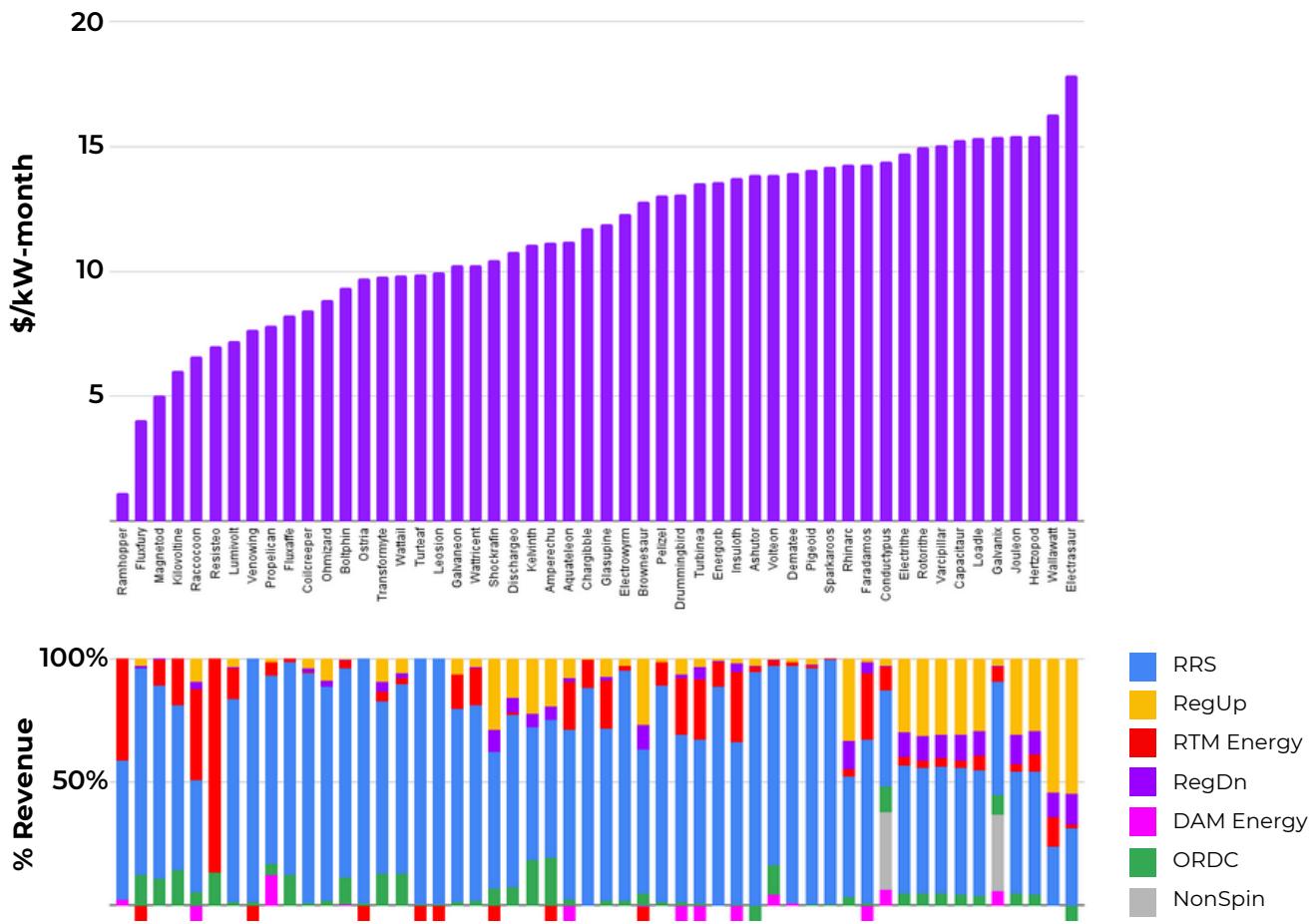
Market Clearing Price for Capacity



Note: Data is from Jan 2022 to Mar 2023.

Revenue by product per resource

The majority of revenue for nearly all batteries is derived from Ancillary Services. Interestingly, the top-performing batteries in terms of revenue are generating a more significant portion of their income from Ancillary Services other than RRS.



The upper chart presents the total revenue for each project, which corresponds with the Total Revenue section above, while the graph below illustrates the revenue breakdown for each project. Various strategies are employed, but the majority of revenue for nearly all batteries comes from Ancillary Services.

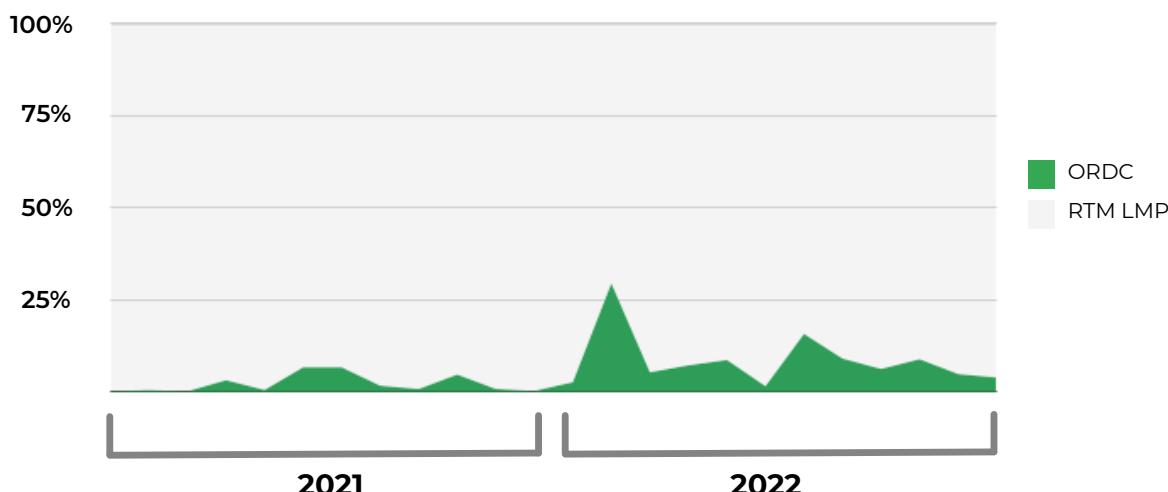
The fact that the highest-performing batteries are generating more of their revenue from Ancillary Services other than RRS suggests that they might be implementing more sophisticated dispatch strategies or potentially have a longer duration.

ORDC

Over the last two years, ERCOT has implemented modifications in its control practices regarding the usage of RUCs (Reliability Unit Commitments). As a result, ERCOT has chosen to activate power plants that may not be economically viable or available under normal circumstances. The ORDC (Operating Reserve Demand Curve) has three major pricing components, which, when summed together, produce an outright scarcity price.

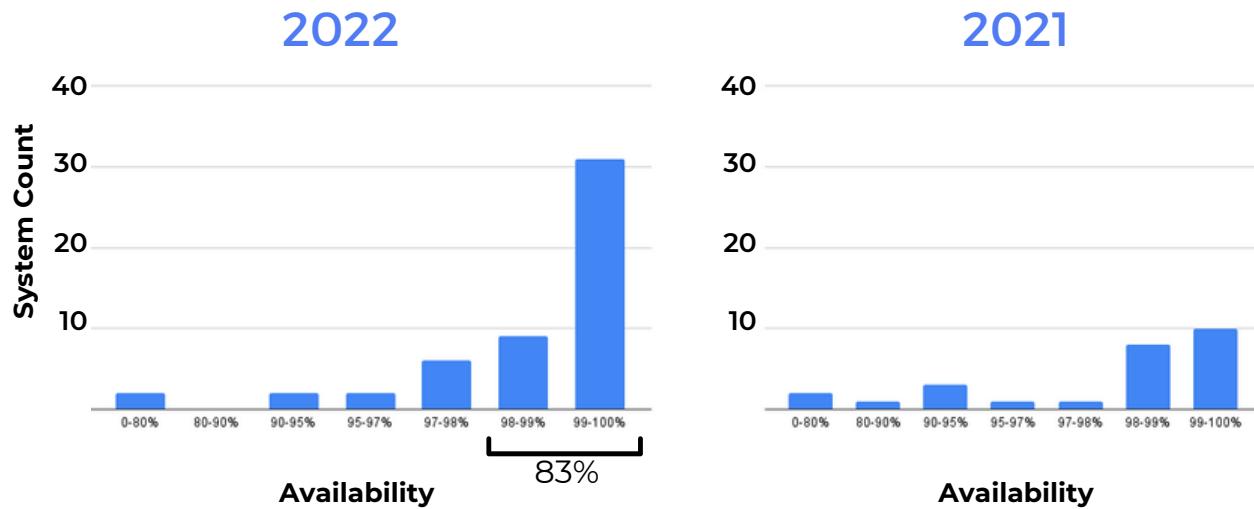
Control-room-initiated reliability deployments (including RUCs) drive the value of one of these three components, so the use of RUCs therefore creates a non-zero scarcity price in many instances. Following the challenges faced during Winter Storm Uri, ERCOT is prioritizing a wider operating margin of safety. Consequently, ERCOT is adopting a more proactive approach to RUCs, leading to a higher frequency of ORDC triggers. ORDC adders present potentially attractive revenue opportunities for limited-duration battery storage resources because ORDC is a capacity payment that compensates available generation resources in the real-time market regardless of the energy they discharge. More frequent reliability deployments (and ORDC activation) therefore enhance the value proposition for battery systems.

As part of post-Uri ERCOT changes ORDC makes up a greater fraction of Real-Time Market (RTM) settlement point prices:



Availability

In the [2021 report](#), we observed mixed availability results, with a few poorly performing systems, while most systems achieved 98% availability or better – a target often set by vendors. The situation improved in 2022, with fewer systems experiencing equipment issues. Notably, 83% of the systems reached an availability of 98% or higher.

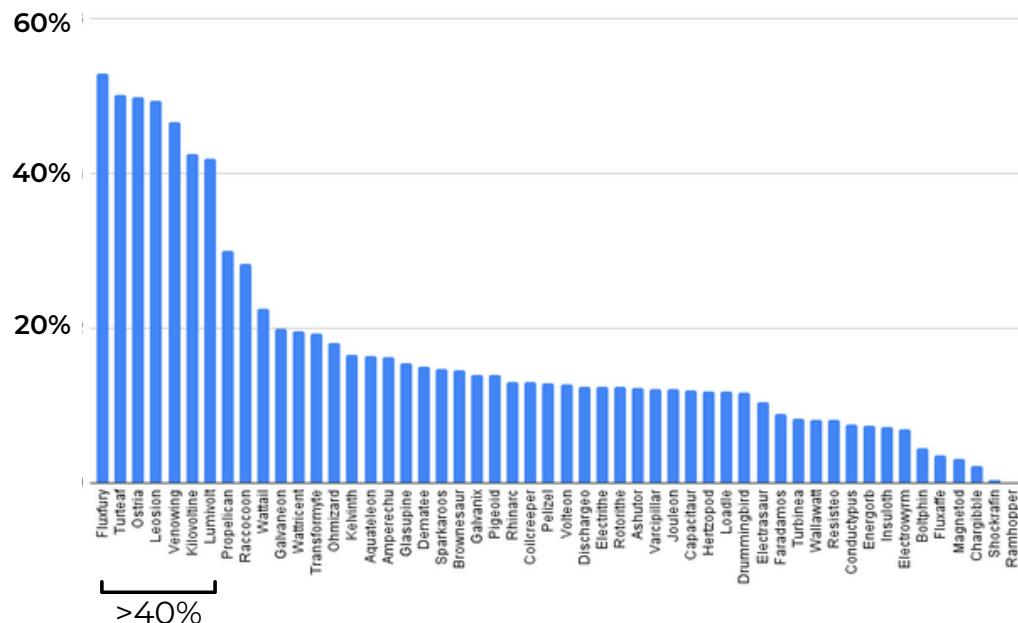


The reduction in equipment-related availability issues might be attributed to the industry's maturation, leading to better prevention or quicker resolution of these problems. Additionally, it is possible that supply chain-related unavailability was less severe in 2022 compared to 2021.

Peakiness

Revenue continues to be peaky. One weather event, such as Winter Storm Elliott which occurred in December 2022, can be a significant proportion of a battery's revenue. The graph below shows that for 7 systems, the two peak days of Winter Storm Elliott contributed over 40% of their total annual revenue.

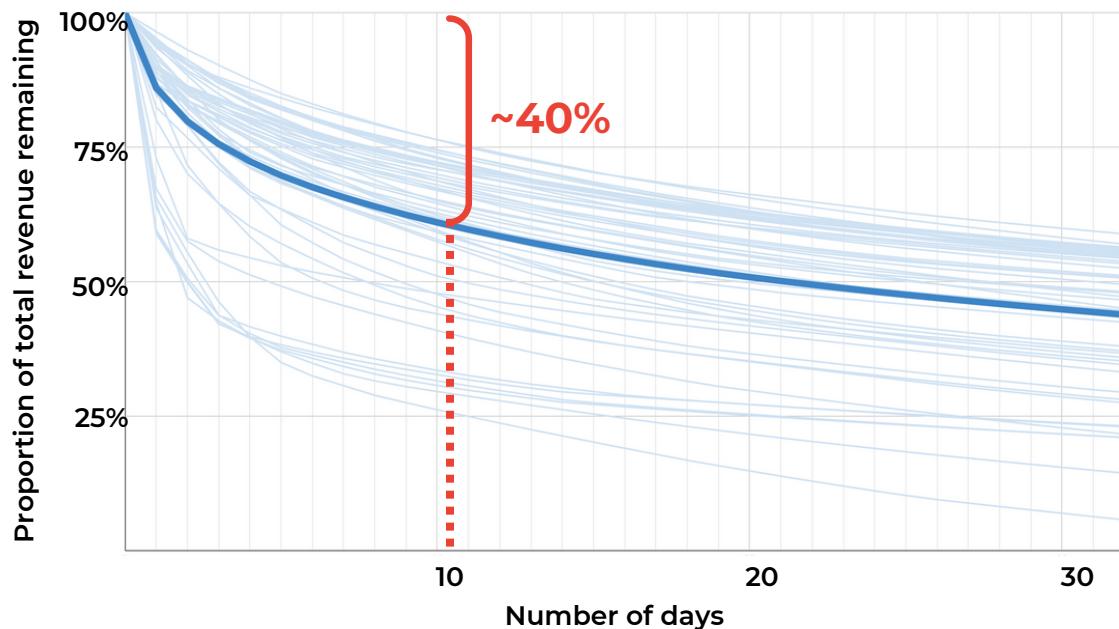
Percentage of revenue from Winter Storm Elliott



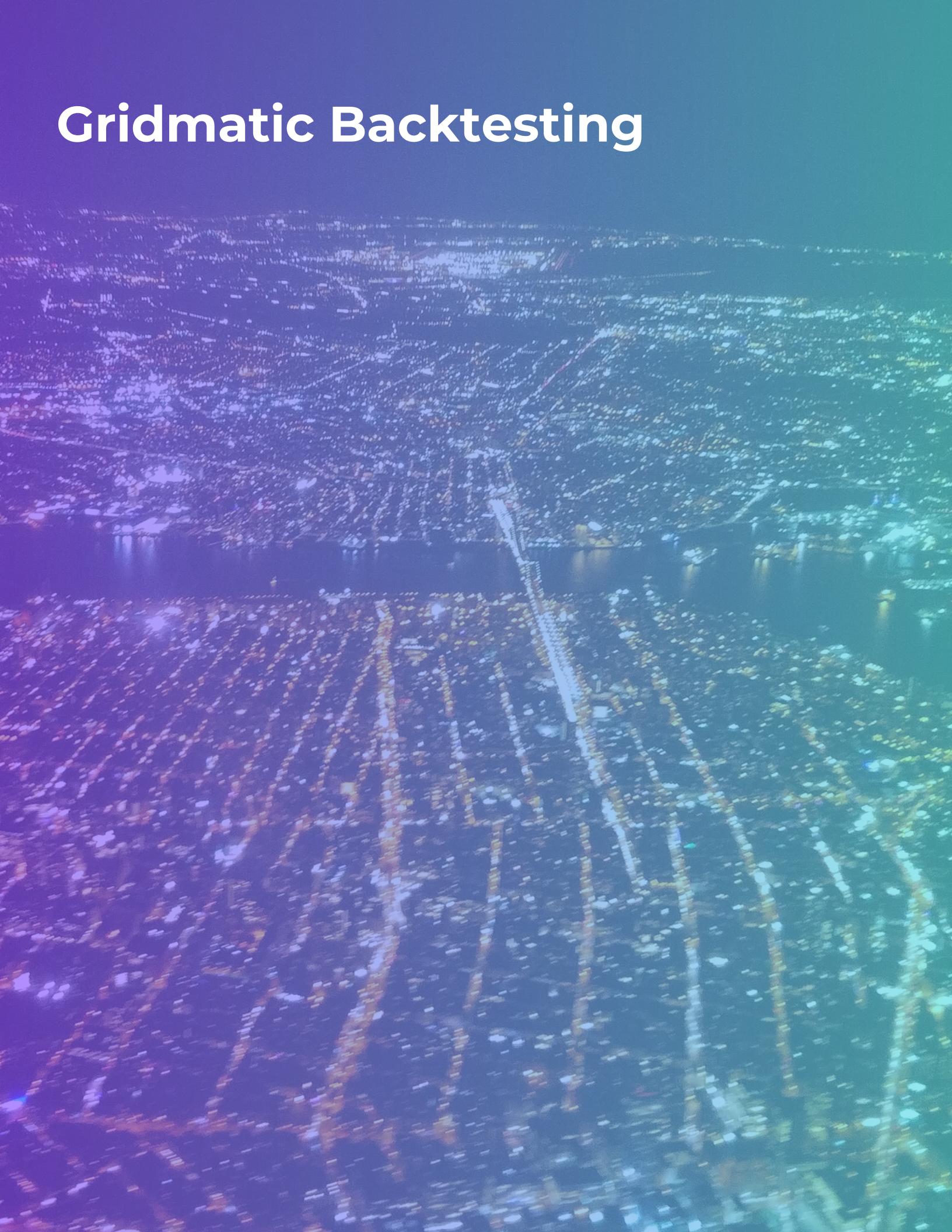
Note: Batteries have differing CODs throughout the year, but all batteries analyzed above had been operational for at least 1 quarter.

The graph below shows how much revenue would have been lost if we subtract out the highest profit days. On average, the top 10 days make up about 40% of total revenue across the fleet.

Each thin blue line represents one of the 52 batteries in our sample, and the thick blue line represents the average.



Gridmatic Backtesting

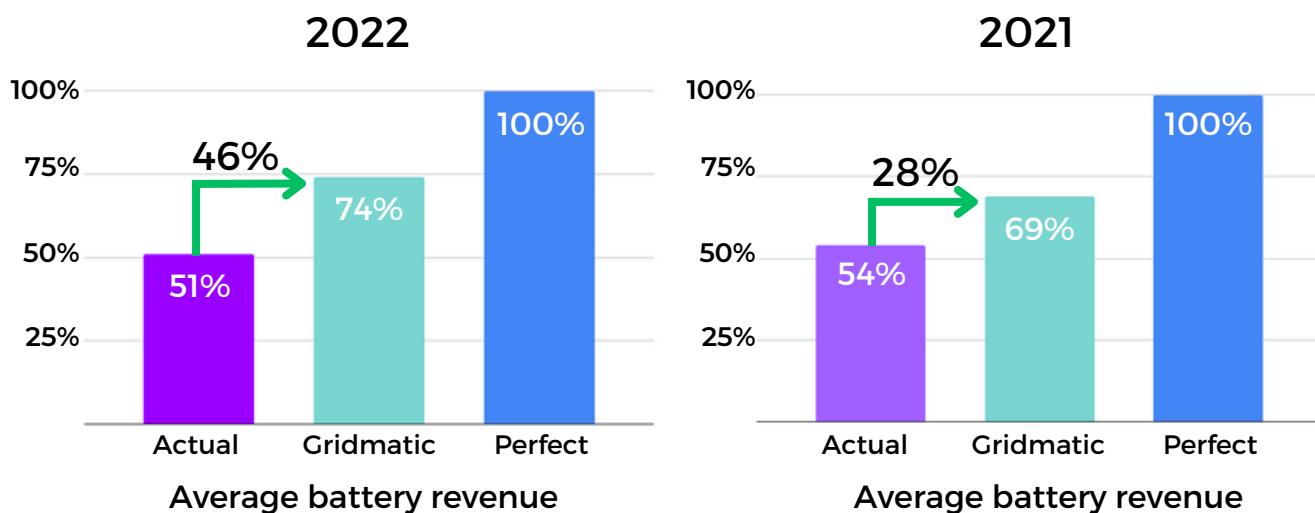
An aerial photograph of a city at night, showing a dense grid of illuminated streets and buildings. A prominent diagonal grid pattern overlays the city, consisting of thick, light-colored lines that intersect to form a series of squares across the urban landscape. This grid pattern is more concentrated in the lower-left quadrant and extends towards the center of the image. The city lights are reflected in the water of a river or bay visible in the background, creating a mirror effect. The overall scene is a blend of organic city life and a structured, mathematical overlay.

Total Revenue

Gridmatic's AI-based optimization platform combines our proprietary market price forecasts, which have a track record of six consecutive years of profitable performance in the Day Ahead energy market, with our storage bid optimizer, to provide the leading storage optimization framework.

The charts below compare the actual performance of batteries to a perfect foresight optimizer, which is a backtest using fully known prices, as well as the Gridmatic Scheduler, which is a backtest utilizing the forecasts available to Gridmatic at that time.

Gridmatic average uplift of 46% in 2022

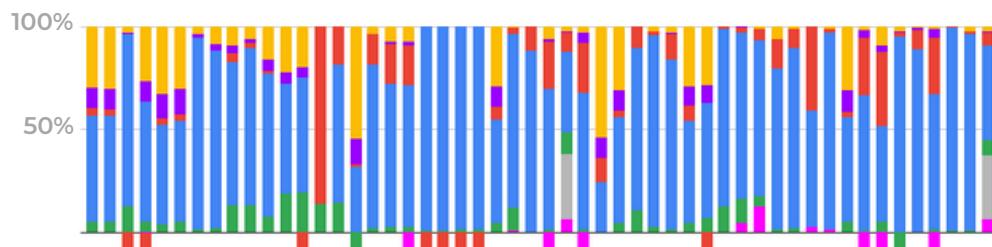


In 2021, the actual batteries delivered, on average, 54% of the revenue of the Perfect Scheduler. In 2022, this figure slightly decreased to 51%. We largely attribute this decline to the reduced performance of RRS and the increasing importance of forecasting other revenue streams. However, Gridmatic's performance experienced a slight improvement. The Gridmatic and Perfect Schedulers exclude DAM Energy participation, but it is included in the Actual batteries where applicable.

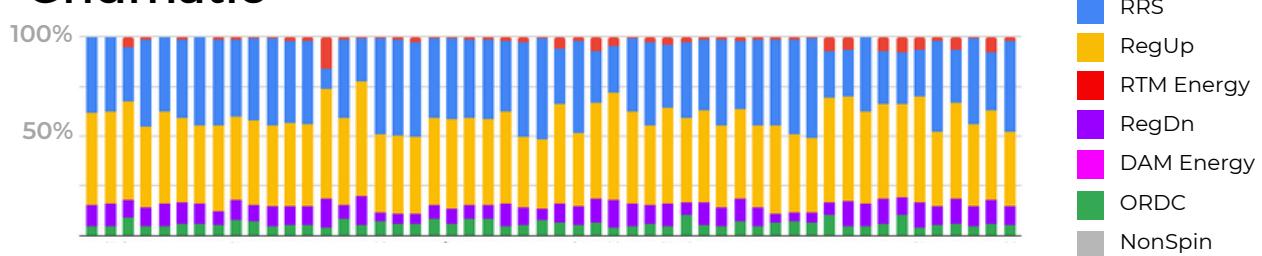
The AI-based forecast and optimization progressively improve over time. Consequently, 2022 benefited from learning the outcomes in 2021, resulting in higher revenue generation. On average, Gridmatic captured a 46% increase in revenue compared to what actually occurred.

Revenue by product for each battery resource

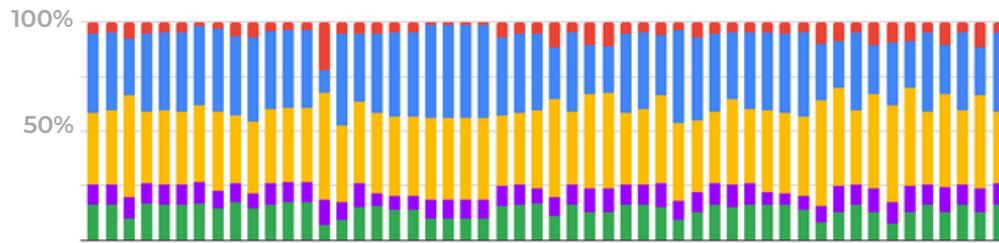
Actual



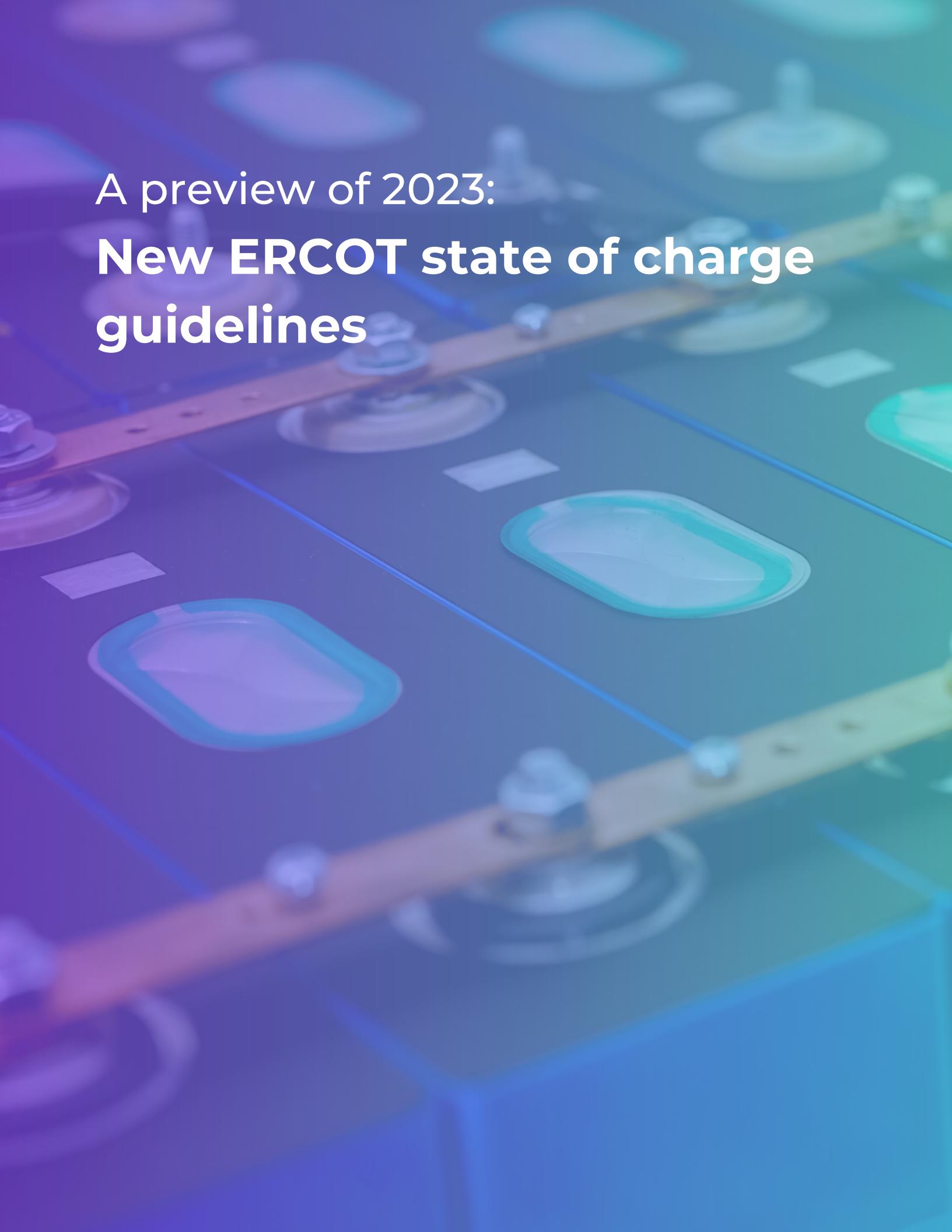
Gridmatic



Perfect



The charts above display the breakdown by market product. The top chart is the same as the Revenue by Product per Resource shown earlier, which encompasses a variety of strategies, including RRS. When examining the Gridmatic Scheduler's approach, the share of RRS is significantly lower, with more revenue derived from RegUp (indicated by yellow) and RegDn (indicated by purple), which are more challenging to forecast.



A preview of 2023:

New ERCOT state of charge guidelines

ERCOT state of charge guidelines

In December 2022, ERCOT updated the Business Practice Manual (BPM) to define state of charge (SOC) expectations for Energy Storage Resources (ESRs) providing Ancillary Services (AS). These BPM updates reflect impactful changes compared to how ESR market participants had previously been operating based on their understanding of the Protocols.

One impactful new BPM SOC expectation applies at the beginning of any hour in which an ESR has a discharging Ancillary Service award (i.e., RegUp, RRS, Non-Spin). The new SOC expectation is that the ESR must be capable of satisfying all discharging AS awards held on the generation side for the full duration of the award. For example, if the ESR held 10 MW of RegUp or RRS on the generation side, it must have at least 10 MWh of SOC because RegUp and RRS have a 1-hour duration.

Previously, Market Participants had understood ESR SOC management to be the responsibility of the resource owner. For example, if the ESR held 10 MW of RegUp on the generation side, it would be acceptable to have less than 10 MWh of SOC so long as the ESR operator was able to satisfy the ancillary award. In this scenario, the ESR operator could manage its SOC to satisfy ancillary awards via multiple methods, including maintaining RegDown on the charge side, charging in the real-time energy market, or relying upon another resource within a QSE pool as a backstop.

The new SOC expectations limit the operational flexibility of ESRs to deliver Ancillary Service awards. The impact is that ESRs will be able to satisfy a lower quantity of Ancillary Service awards over the course of the day, particularly for shorter duration ESRs for which the SOC requirements will become a frequent constraint in operations. Since Ancillary awards all occur in the DAM in ERCOT, SOC management of AS awards in the Real Time Market (RTM) is especially challenging. We expect to see many battery operators exhibit conservatism by offering lower volumes of Ancillary Services in the DAM than is optimal in order to ensure they will be able to manage SOC in the RTM.

We analyzed the impact of this change via a backtest of storage systems in ERCOT, comparing net revenue results for 2-hour, 1.5-hour and 1-hour batteries.

Summary

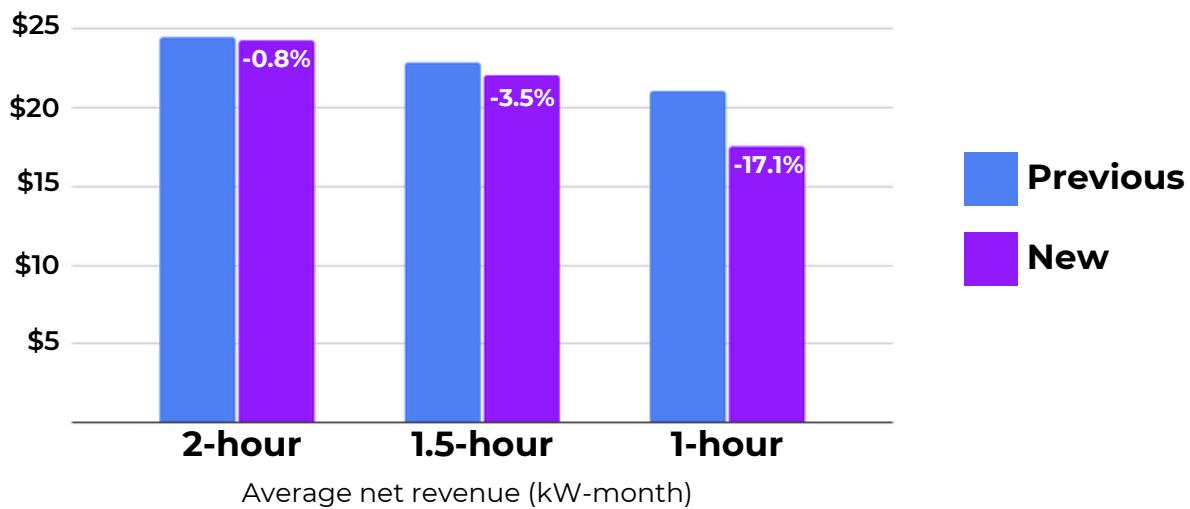
Under the new requirements, change in battery net revenue is correlated to duration, with shorter duration batteries likely to exhibit lower net revenue per MW than longer duration systems. In our backtests, the 1.5-hour and 2-hour batteries have a decrease in average net revenue of less than \$1/kW-month but the 1-hour battery has a decrease of \$3.60/kW-month.

The majority of the lower expected net revenue for shorter-duration batteries comes from lower RRS and RegUp participation.

Findings

Gridmatic backtested 2-hour, 1.5-hour and 1-hour batteries, comparing average USD/kW-month net revenue, using a 12 month lookback period of February 2022 through January 2023. The trading algorithm used in this analysis is a “perfect foresight” analysis, meaning that all market prices are known to the Gridmatic battery optimizer ahead of time. For this reason, the absolute dollar value of revenues is higher than we expect an actual ESR resource to achieve, but we expect the correlation between change in battery net revenue and ESR duration to be similar in real-world results.

In tests comparing batteries of various durations under the new protocols compared to the previous protocols, 2-hour batteries had a slight decrease in net revenue of 0.8%. 1.5-hour batteries exhibited about a 3.5% decrease, and 1-hour batteries have a significant decrease in net revenue of 17.1%.



Average net revenue under new ESR SOC expectations compared to previous:

	Battery Duration		
	2-hour	1.5-hour	1-hour
Previous (\$/kW-month)	\$24.52	\$22.84	\$21.11
New (\$/kW-month)	\$24.33	\$22.04	\$17.50
Difference in net revenue	(0.8%)	(3.5%)	(17.1%)

The decrease stems from the shorter-duration batteries' reduced participation in revenue opportunities due to their awards being limited by their SOC. For example, a 1-hour battery and 1.5-hour battery could only be awarded nameplate capacity for RegUp or RRS while having 100% SOC and 66% SOC respectively. Some net revenue sources such as RegDown and Real-Time net revenue (Real-time energy + ORDC) are preserved or even increase slightly, but RegUp and RRS revenues both decrease.

When we add in the conservatism required under imperfect knowledge, we expect the real world revenue impact to a 1 hour battery following the guidelines to be well north of 20%. This is a big incentive to have a duration longer than 1 hour, and we expect new batteries going into the market to be greater than 1 hour duration.

About the authors



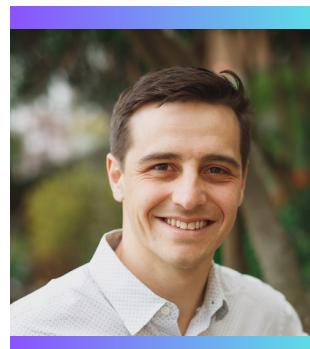
David Miller

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.



Mia Nakajima

Mia is a Data Scientist at Gridmatic, with prior experience as an Energy Analyst at TRC Companies and Research Assistant at the Center for the Built Environment at UC Berkeley. She holds a B.A. in physics and statistics from UC Berkeley.



Austin Park

Austin is a Machine Learning Engineer at Gridmatic. He is the former Co-director of the Stanford Energy Policy Community, where he created a data-driven algorithm to facilitate renewables adoption. He has integrated energy data sets at Google, published analyses on drones' energy sector impact at Bloomberg NEF, and worked on energy efficiency at Lawrence Berkeley National Laboratory. He holds a B.S. in civil engineering from UCLA and an M.S. in energy resources engineering from Stanford University.

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 five years of success in financial energy market participation and is currently active in all seven ISOs: CAISO, ERCOT, MISO, PJM, NYISO, SPP, and ISO-NE. Gridmatic applies 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 operates 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.

Notes

The methodology used in this report remains consistent with the [2021 Storage Report](#), having been validated by DNV, the world-leading consulting, testing and certification company for the global energy sector. However, we have made the following updates:

Battery resources in ERCOT

This Gridmatic Annual Storage Report includes 52 battery storage resources that achieved COD in the ERCOT market prior to 09/30/2022. The report covers the period through 12/31/2022, and we considered only battery storage resources that achieved commercial operation by 9/30/2022 to ensure a meaningful sample for each resource. We exclude from the study 8 batteries providing the ERCOT Fast-Responding Regulation Service 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 52 "commercial batteries" in our study.

Non-Spin

The bid rules assumed by the Gridmatic and Perfect scheduler are based on the ERCOT Nodal Protocols as interpreted prior to the Business Practice Manual update regarding SOC expectations in December 2022. The Gridmatic and Perfect schedulers also exclude Non-Spin participation. NPPR 1096 was approved in May 2022 limiting the ability of Energy Storage Resources to provide Non-Spin, and was not implemented until the end of 2022. For most of 2022, ERCOT did not qualify batteries for Non-Spin eligibility, though some of the Actual batteries did participate in Non-Spin during 2022 if they had qualified previously. Given the limitations for Energy Storage Resources to provide Non-Spin during 2022, we made the simplifying assumption to omit Non-Spin from the Gridmatic and Perfect schedulers for this report.

Cycles

We use 365 cycles/year as an assumption except where the system had a clearly higher constraint, in which case we set a constraint matching the actual cycle count observed.

Outages

The Perfect Foresight and Gridmatic scheduler consider full-day outages (with a status of 'OUT'), but do not account for partial outages. To ensure a more realistic estimation of the Gridmatic impact, we have excluded these full-day outages from our analysis. We do not have specific data regarding partial outages from the SCED data, as indicators such as high/low service limits were found to be inconsistent in identifying partial outages.

Winter Storm Uri

Winter Storm Uri occurred in 2021, but its impact has been excluded from the 2021 figures in this report to provide a more representative comparison with 2022. If you are interested in understanding the effects of Uri, our [2021 report](#) covers the topic in detail.



For more information on Gridmatic, please contact us at info@gridmatic.com