Unlock ERCOT's Energy Storage Economics

The Case for a Stand-alone 2-hour Battery

August 2023

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Executive Summary

This white paper presents the case for deploying 2-hour battery energy storage projects in the Electric Reliability Council of Texas (ERCOT) region. Energy storage systems are emerging as essential assets for grid reliability and resiliency in ERCOT – one of the few wholesale power markets with a growing load base that faces unique challenges – including the islanded nature of its system and significant growth in variable renewable generation. To ensure the seamless integration of renewable energy and to meet peak demand cost-effectively, the deployment of battery energy storage systems (BESS) is crucial.

The price signals for reliability in ERCOT emerge in energy prices, rather than capacity products with minimum duration requirements as in other ISOs, favoring lower-cost, short-duration battery energy storage systems (BESS). So the majority of the early deployments of BESS were 1-hour systems that could take advantage of relatively high prices for power applications such as frequency response and regulation. However, with the shift to energy applications such as energy arbitrage in the future, and policy changes underway in ERCOT to support resource adequacy, developers and asset owners should rethink the shorter duration paradigm that was the norm in ERCOT for BESS.

Through comprehensive revenue simulations, Stem has demonstrated that a 2-hour BESS can increase cash flows relative to a 1-hour system.

This white paper also includes a preliminary price analysis of the ERCOT Contingency Reserve Service (ECRS), the latest ancillary service ERCOT deployed on June 10, 2023. The BESS resource can only qualify to provide capacity it can sustain for 2 hours. Additionally, the paper discusses emerging policy provisions that support our recommendation of moving towards 2-hour (or longer) BESS projects as a more financially attractive proposition. The paper's insights can guide project developers, investors, and asset owners toward sizing their BESS projects accordingly to maximize the potential merchant revenues realizable through these projects.

The remainder of this paper will discuss the details of Stem's revenue simulations and the software used to form the final analysis. For context, the appendices contain an expert analysis of ERCOT's market fundamentals and available revenue streams.

Simulation Results

Stem ran simulations for a 15-year project term for the 1-hour and 2-hour duration BESS. The after-tax cash flow analysis results indicated at least 15% improvements in the internal rate of returns (IRR) in each major zone of ERCOT. The simulation and proforma modeling clarified that the 2-hour BESS, despite higher capital costs, commands a better IRR on an after-tax cash flow basis leading to higher valuations relative to 1-hour BESS in all four ERCOT load zones.

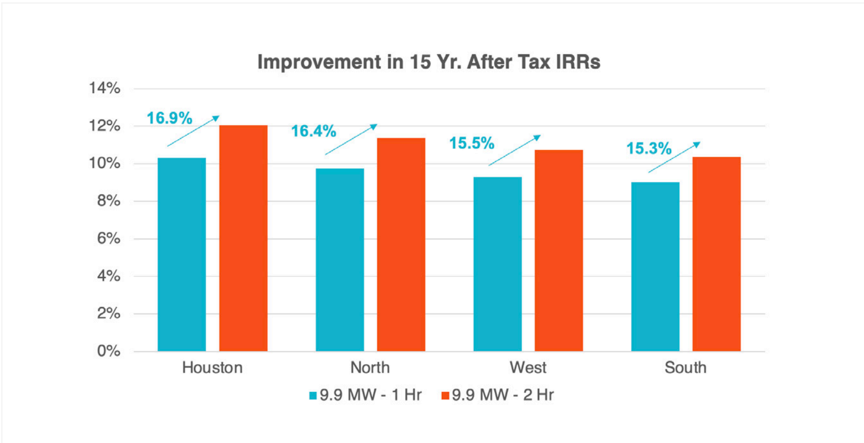

Figure 1.1: Internal Rate of Returns for 1-hour and 2-hour BESS

The 2-hour BESS, despite higher capital costs, commands a
better IRR

Results indicated at least
15% improvements

These results are based on the economics of a 2-hour battery relative to a 1-hour battery for a 9.99 MW BESS in all four major zones – Houston, North, South, and West. ERCOT's energy and Ancillary Service revenue streams were considered in these simulations, as discussed in Appendix B.

The primary cost and financial assumptions used to build the discounted cash flow models are provided in Table 1.1.

Inputs & Assumptions	1-Hr BESS	2-Hr BESS
Upfront OEM Costs ($/kW)	$672	$1,023
Upfront Install Costs ($/kW)	$225	$225
Ongoing costs ($/kWh/Yr)	$8.0	$8.0
ITC Rate	30%	30%
Fed Income Tax Rate	21%	21%
Depreciation Schedule	5-Yr MACRS	5-Yr MACRS

Table 1.1: Cost and Financial Assumptions for Flow Models

Simulation Process

Stem has developed industry leading software, Athena® – which seamlessly integrates into energy platforms and optimizes energy storage. Stem's Athena edge-to-cloud platform is used to operate and optimize the BESS projects. Athena's Merchant Analyzer™ (MA) application simulates the battery operations for the entire specified project life of the BESS. The MA tool is capable of simulating stand alone as well hybrid BESS project revenues.

The Merchant Analyzer application uses the same optimization engine used for actual market bidding for a live BESS resource to produce long-term revenue forecasts

While the simulation used to produce results for this paper assumes that the future market prices are known with perfect foresight, Stem is working on model predictive controls (MPC) simulations that effectively serve as the 'virtual twin' of an actual BESS being optimized under live operating conditions in which the future prices are uncertain and not all bids or offers (even price taking) will clear because of grid conditions or congestion issues. However, the analysis for this paper – which focuses on the comparison of 1-hour BESS value relative to 2-hour batteries in ERCOT – is still valid as the evaluation framework is consistent and held constant across the entire analysis. So, the conclusions of relative value still hold and will be the same if we were to use MPC simulations.

The Merchant Analyzer application can simulate the actual operational process as represented in Figure 2.1.

The major aspects of the Analyzer simulation process is described in greater detail here, including inputs and assumptions, constraints, and optimization.

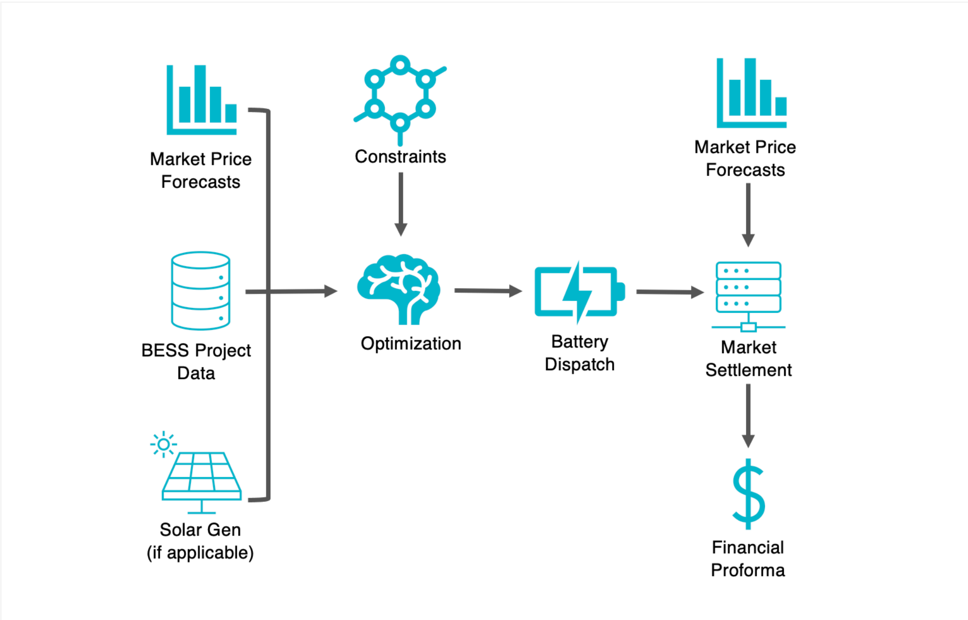

Figure 2.1: The Merchant Analyzer app simulates actual operational processes

Inputs and Assumptions

Market Price Forecasts

The market price forecasts constitute a key input that has an outsized impact on the project revenues. So, Stem is cautious about the price forecasts (also commonly referred to as "forward curves" in the industry) it uses to provide revenue guidance to customers.

Stem doesn't generate its long-term price forecasts to maintain objectivity in the revenue guidance it provides using its simulation capability. We procure forward curves from 3rd party experts who specialize in long-term market fundamentals-based modeling to generate hourly and sub-hourly prices for energy and ancillary services in all major markets, including ERCOT. The simulation application allows for flexible ingestion of these market price forecasts covering the entire project term and accommodates the asset owner's preferences on long-term market outlook. These price forecasts mirror ERCOT's hourly granularity for DA energy and ASvc prices and 15-minute settlement granularity of the Real-Time (RT) energy prices.

Project Data

The Merchant Analyzer (MA) application also incorporates a flexible configuration of inputs to reflect the physical BESS asset details such as power capacity, energy capacity, duration, maximum point of interconnection (POI) capacity, BESS efficiency, availability, and degradation behavior.

The MA application can simulate a hybrid storage asset for AC-coupled and DC-coupled configurations. For a hybrid BESS project, the solar hourly generation profile for 8,760 is required. For DC-coupled configurations, the DC-DC converter efficiency is required. Typically, DC-coupled Solar + Storage systems are designed so that the BESS always charges from the solar resource but can discharge into the grid. In the AC-coupled configuration, if profitable, the BESS resource can grid-charge during non-solar hours.

The simulation also considers the minimum amount of charging that must come from the co-located solar asset every hour, if specified. The simulated solar charging could exceed the input percentage but will never be less.

Constraints

The MA application ensures that the simulated battery operations adhere to various constraints, which can be classified as either fixed constraints (never allowed to be violated) or soft constraints (allowing violation at a penalty price). The MA application considers several optional constraints, such as:

- Restrictions on the number of cycles allowed within a given year.
- Minimum revenue requirement per cycle, ensuring that the battery is not operated when the generated revenue is insufficient to cover the wear and tear costs associated with cycling.
- Meeting an average state of charge (SOC) target throughout the simulated operations.
- Compliance with warranty constraints imposed by the battery's original equipment manufacturer (OEM) or the power conversion system (PCS) supplier.
- Adherence to interconnection export limits.
- Meeting specific ramp rate requirements.
- Complying with all applicable market rules.
- Fulfilling cost of service requirements.

By incorporating these constraints, the MA application ensures that the simulated battery operations remain within specified boundaries and align with relevant operational and financial considerations.

Optimization

The optimization process used in our simulations are perfect foresight (Oracle simulations) with no market price or solar generation forecasting errors. Our simulation assumes that the optimization maximizes revenues on a cumulative basis over a daily period, but this range can be extended to a weekly, or longer periods. During actual operation, the optimizations are done on a continuous 4-day lookahead basis and are updated regularly every hour.

In the simulation, the annual throughput limitation is evenly divided over the entire year, however, this limitation can be overridden in actual operations. So, during actual operation the summer/winter months, with higher market price volatility, are expected to have more cycling than the shoulder months. The battery state of health is monitored, and the dispatch adjusted such that the state of health of the battery at the end of the year is within warranty limitations. The simulation used in this paper assumes that all bids/offers into the market are cleared, however, the improved MPC simulation is calibrated to the clearing rate actually seen in a particular wholesale market based on historical operational data for similar price-taking BESS assets.

The simulation used in this paper assumes that the battery can hold a constant charge for multiple days without any self-discharge. However, in operation, during periods of idling, the BESS naturally loses charge. The amount of charge lost is based on the associated battery technology, the resting state of charge, and the idling period, and may lead to a significant loss in capacity. The MPC simulation is better able to mimic this behavior.

The optimization problem is formulated as a mixed integer linear program (MILP), which co-optimizes energy and ancillary services, maximizing the cumulative revenue over a 24-hour period. In ERCOT, the Day-Ahead (DA) energy bids are not asset specific and doing so would put the asset owner of the BESS asset in a virtual position. Hence the optimization engine (OE) does not generate energy bids in the DA market. It only generates energy offers. The OE optimizes across forecasted prices in both DA and RT markets and generates the bids/offers accordingly. If DA energy offers are awarded, Real-Time energy bids would be generated to accommodate for the SOC requirements for meeting the DA energy obligations. The OE always picks the most profitable combination of energy and ancillary service products with sufficient SOC and within market & asset physical constraints.

ECRS – The New Revenue Stream

ERCOT deployed a new ASvc called ECRS on June 10th, 2023. Stem's simulations in this paper did not include ECRS but will be included in a later revision.

It is important to note that BESS resources must sustain their power capacity (MWs) for at least 2 hours for them to be eligible to provide ECRS.

All early indications from the price analysis that Stem conducted indicate that the ECRS is a valuable service and has commanded higher prices relative to other ASvc, albeit the sample is limited, given the concise ECRS price history available at the time of writing this paper.

ECRS – Deeper Dive

According to ERCOT, ECRS may be provided by: (1) unloaded, online generation resource capacity; (2) quick start generation resources (QSGRs); (3) load resources that may or may not be controlled by high-set, under-frequency relays; (4) controllable load resources (CLR); and (5) generation resources operating in synchronous condenser fast-response mode.

Upon implementation of ECRS, ERCOT will change the methodology used to compute non-spin quantities to use 6-hours ahead average net load forecast error. ERCOT expects the deployment of ECRS will impact the non-spin quantities procured as shown in Figure 3.1.

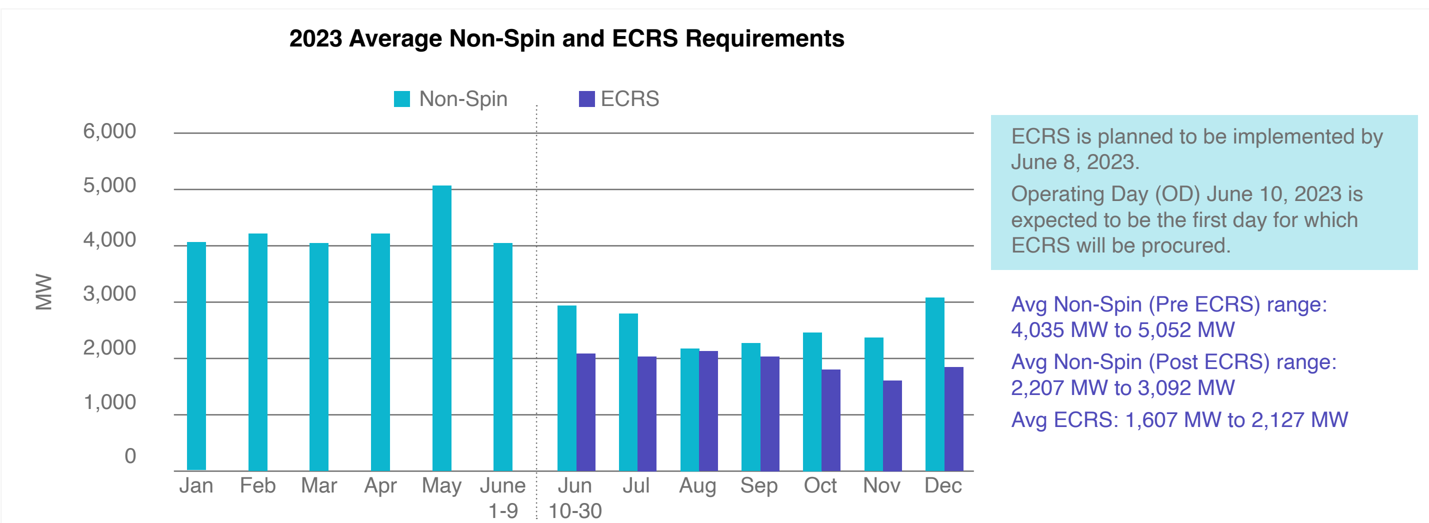

Figure 3.1: Deployment of ECRS will impact the non-spin quantities Source: ERCOT

Some of the constraints enforced on the resources providing ECRS include:

- Must be pre-qualified by ERCOT to provide ECRS
- Offline quick start resources are eligible to provide non-spin and ECRS simultaneously as long as the total responsibility (non-spin + ECRS) is less than the resource high sustained limit (HSL)
- ECRS awards for both online and offline resources is limited to 10 * maximum emergency ramp rate of the resource
- A single resource cannot contribute more than 50% of the ASvc plan for ECRS

ERCOT may deploy ECRS to: (1) restore frequency within 10 minutes of a significant frequency deviation to recover deployed regulation service; (2) compensate for intra-hour net load forecast uncertainty and variability on days in which large amounts of online thermal ramping capability is not available; or (3) compensate for the limited amount of capacity available for ERCOT's security-constrained economic dispatch (SCED).

ECRS deployments can be (1) automatic from SCED dispatchable resources when the frequency drops below 59.91 Hz; or (2) manual to respond to large net load ramps OR when additional capacity is needed.

Since its introduction, below is a sample of events that triggered ERCOT to deploy ECRS in the June 10th to 19th period: Manual ECRS deployment of 600 MW on June 14th, 2023, at 19:20 and on June 18th, 2023, also at 19:20 because of insufficient capability for forecasted 10-min ahead netload.

Automatic SCED deployment of 430 MW on June 16th, 2023, at 18:31 to stabilize frequency that dipped below 59.91 Hz because Unit 1 of the Comanche Peak nuclear power plant shut down due to a technical problem with a feedwater pump, as reported by the American Nuclear Society (ANS).

ECRS – Preliminary Price Analysis

Stem experts looked at ECRS and other ASvc prices from June 10th to Jun 24th, 2023. At the writing of this paper, that was the extent of the historical prices available for ECRS. The sample, albeit very tiny, gave some initial insights into how the ECRS was clearing relative to the other ASvcs. It should be noted that the pricing during this period was relatively elevated, especially around June 20th, 2023, when ERCOT issued a voluntary conservation notice to cut down usage due to extreme heat, high demand, low wind output, and higher-than-normal forced thermal outages.

The 15-day or 360-hour period analysis indicated that ECRS was the highest-priced ASvc for over 74% of the total hours. Figure 3.2 plots the ECRS prices in terms of multiples of the other ASvcs. Given the nature of ECRS, one would expect it to clear between RRS and non-spin, however, the initial price analysis has failed to confirm that hypothesis. We find that the afternoon and evening hours (hour ending 13 to 20) show markedly high ECRS prices relative to the other ancillary services as shown in Figure 3.2.

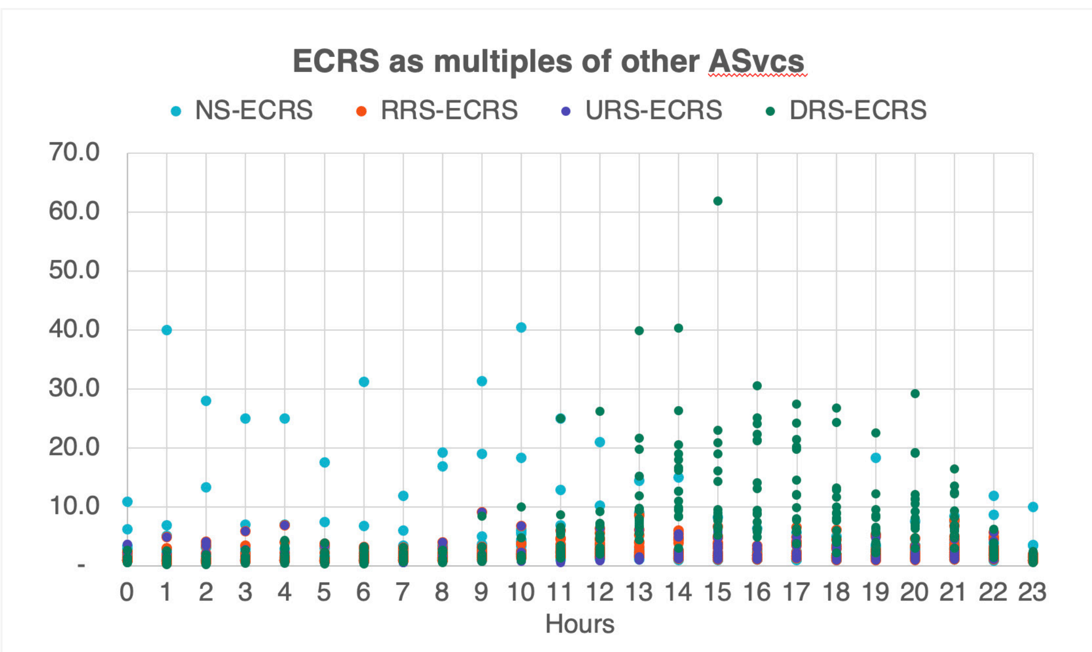

Figure 3.2: ECRS as multiples of other ASvcs[1]
Source: ERCOT MCPC Data

[1] NS – non-spin, RRS – responsive reserve service, URS – Reg-up, DRS – Reg-down, ECRS – ERCOT contingency reserve service

Table 3.1 provides additional insights into the attractiveness of the ECRS prices relative to the ASvcs over the total of 360 hours.

ECRS	Number of Hours	% of Hours
Highest	268	74.4%
2nd Highest	52	14.4%
3rd Highest	14	3.9%
4th Highest	18	5.0%
Lowest	8	2.2%

Table 3.1: ECRS Prices

Table 3.2 provides the relative duration of the premiums and average premium that ECRS commanded over the other ASvcs and the expected premium if this sample is any indication of the future in terms of the multiple of each ASvc.

ECRS	Number of Hours	% of Hours	Avg Multiple	Exp Multiple
> Non-spin	318	88.3%	3.64	3.33
> RRS	293	81.4%	2.43	2.15
> Reg-up	285	79.2%	1.99	1.75
> Reg-down	289	80.3%	6.93	5.71

Table 3.2: Relative duration of premiums

The way to interpret Table 3.2, if we pick the Reg-up row as an example, is to say that ECRS exceeded Reg-up prices over 79% of the time, and when they did, they were close to twice the Reg-up prices on average. If this sample is used to forecast the expected premium that ECRS would command over the Reg-up prices, the ECRS price should be 1.75 times the Reg-up prices. However, given the sample size is very small, Stem strongly cautions against drawing any kind of long-term conclusions.

From this preliminary analysis, Stem finds that ECRS can be a material source of revenues available to BESS projects in ERCOT. However, the minimum duration for these systems is 2-hours.

From this preliminary analysis, Stem concludes that ECRS can be a material source of revenues available to BESS projects in ERCOT. However, the minimum duration for these systems is 2-hours.

Notable Policy Updates

Following winter storm "Uri" in February 2021, the Texas Legislature unanimously passed Senate Bill 3 (SB 3), and Governor Greg Abbott signed it into law in June 2021 – this initiated the redesign of the ERCOT market, which was carried out in 2 phases.

The key phase 1 changes, which have all been implemented, include provisions such as: (1) lowering the high systemwide offer cap, which typically prevails throughout the year, to $5,000/MWh from $9,000/MWh; (2) raising the minimum contingency level or the minimum amount of reserves considered necessary to avoid a cascading blackout – from 2,300 MW to 3,000 MW; and (3) accelerating the implementation of the ECRS (see section B.4).

A critical aspect of the Legislature's directive to the Public Utility Commission of Texas (PUCT) was to incentivize more dispatchable generation. To achieve this objective, SB 3 instructed the PUCT to establish a reliability standard for the ERCOT market and use this standard to develop a new ancillary or reliability product designed to incentivize enough dispatchable generation to support the grid during high demand.

As part of phase 2 of the market redesign effort, in January 2023, the PUCT recommended to the Texas Legislature that a novel wholesale market mechanism, referred to as the Performance Credit Mechanism (PCM), be added to the existing energy-based, competitive wholesale market structure. The PCM is designed to establish a reliability standard and corresponding amount of performance credits (PC) that must be produced by dispatchable generators, during the hours of highest reliability risk. The PCM also requires load-serving entities, such as retail electric providers, to purchase PCs based on load served during those hours of highest reliability risk.

Before the 2023 Texas Legislative Session concluded on Memorial Day, it added specific guardrails such as the $1 billion annual cost cap for PCM. Importantly, the legislature allowed energy storage to be eligible to earn PCs, because the statute defines storage as "generation" and credits could be earned only by "dispatchable" generation. That said, the PUCT must develop rules implementing the PCM, and given the "capacity" like the construct of the PCM, it may be likely to have minimum duration requirements which are likely to be greater than 1-hour.

Additionally, the Legislature imposed a new "firming" requirement on renewables to create better dispatchability, which could be met through energy storage. New legislation directs the PUCT to develop a new ancillary service – called the Dispatchable Reliability Reserve Service (DRRS) – intended to help manage intra-day uncertainty from load forecast errors and unplanned outages; energy storage capable of 4+hour deployments could potentially qualify, depending on the details of the rules and/or ERCOT protocols that would implement this new service.

Conclusions

The simulation and proforma modeling results indicate that the 2-hour duration BESS resources, despite higher capital costs, command better internal rate of returns on an after-tax cash flow basis leading to higher valuations relative to 1-hour BESS in all the 4 ERCOT zones.

The 2-hour duration BESS resources, despite higher capital costs, command better internal rate of returns

We used Athena's Merchant Analyzer™ application to simulate the battery operations for the entire specified project life of the BESS. Stem doesn't generate its own long-term price forecasts to maintain objectivity in the revenue guidance it provides using its simulation capability. For this analysis, we procured forward curves from 3rd party experts who specialize in long-term market fundamentals-based modeling to generate hourly and sub-hourly prices for energy, and ancillary services for all the four major load zones in ERCOT.

Athena's simulation application uses the same optimization engine used by Athena in operations to optimize BESS resources in real operations. The optimization problem is formulated as a mixed integer linear program (MILP), which co-optimizes energy and ancillary services, maximizing the cumulative revenue over a 24-hour period.

To evaluate the economics of a 2-hour battery relative to 1-hour battery, we ran simulations for these two configurations for a 9.99 MW BESS in all the four major zones of ERCOT viz. Houston, North, South, and West. In these simulations the following energy and ASvc revenue streams were considered:

· Energy arbitrage in the DA and RT markets
· RRS
· Reg-up
· Reg-down

Also, in the context of 1-hour vs. 2-hour BESS duration conversation, it is important to note that ERCOT recently deployed a new ASvc called ECRS on June 10th, 2023. Our simulations in this paper did not include ECRS but from a preliminary analysis of the ECRS prices since its launch, we can conclude that ECRS can be a material source of revenues available to BESS projects in ERCOT, however, the minimum duration for these systems is required to be 2 hours to be eligible for ECRS.

Finally, as part of ERCOT's Phase 2 market redesign efforts, the PCM has emerged as the product of choice to fulfill the critical requirement of incentivizing dispatchable generation. BESS resources qualify as dispatchable generation in the statute so will be eligible to earn PCM revenues after it is implemented. While the PUCT must develop rules implementing the PCM, but given the "capacity" like construct of the PCM, it is likely to have minimum duration requirements greater than 1-hour.

The objective of the paper is to guide project developers, investors, and asset owners towards sizing their BESS projects optimally to maximize the potential merchant revenues realizable through these projects.

Appendix A ERCOT Market Fundamentals

ERCOT schedules power on its electric grid that connects more than 52,700 miles of transmission lines, and 1,100 generation units. It serves about 90% of Texas state's electric load. ERCOT is a summer peaking system with the latest peak load record of 80 GW set in the summer of 2022. The generation supply in ERCOT is dominated by natural gas-fired generation and onshore wind, with solar resources growing fast. ERCOT has a non-binding 13.75% target reserve margin, and with minimal import capacity from neighboring ISOs/RTOs, it is practically an islanded system.

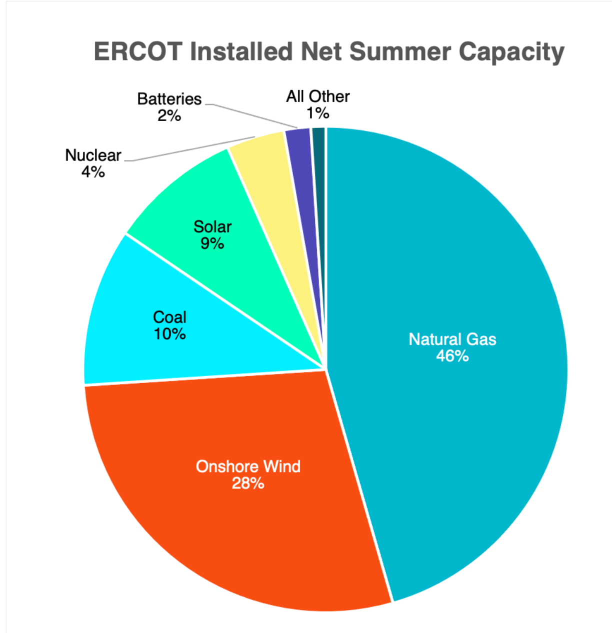

Figure A-1: ERCOT Installed Net Summer Capacity
Source: US Energy Information Administration (EIA) (as of Apr 2023)

Energy Only Market

Structurally, ERCOT is an "energy only" market due to its lack of a capacity market mechanism – this is a key differentiating aspect of the market compared to other ISOs. ERCOT generators must rely upon energy and ancillary services (AS) market price signals to drive new-build decisions.

Operating Reserve Demand Curve

ERCOT relies upon the "scarcity-pricing" or the Operating Reserve Demand Curve (ORDC) mechanism to compensate generators for providing capacity to meet peak demand. The ORDC mechanism creates an RT price adder to reflect the value of available reserves, calculated as the product of the Value of Lost Load (VOLL) and Loss of Load Probability (LOLP). The ORDC specifies a minimum reserve level of 3,000 MW and caps the RT price to $5,000/MWh[2]. The reserve price reflecting the availability of (or lack of) reserves at any given time is added to the nodal RT locational marginal price (LMP) based energy price the resource is paid.

This market construct can result in notably high energy price volatility, exacerbated during tight supply/demand balance (low reserve margins), typically occurring during extreme weather events, real-time deviations from forecasted wind output, or other unexpected generator outages.

ERCOT Load Zones

The market is comprised of four competitive load zones: (1) North, (2) South, (3) Houston, and (4) West, in addition to four smaller load zones that represent non-opt-in entity (NOIE) areas, including: (1) Austin Energy, (2) City Public Service (San Antonio), (3) Lower Colorado River Authority (Central / East Texas area along the Colorado River), and (4) Rayburn Electric Cooperative (Northeast). NOIEs represent municipally owned utilities and electric cooperatives that have decided not to operate as competitive retailers and, therefore, do not provide customer choice of supply within their territories.

[2] Energy price + price adders are capped at $5,000/MWh, but prices can go above that mark due to congestion.

ERCOT Market Trends

Several market trends support merchant storage applications, as outlined below:

Growing demand base

An expanding demand base leads to higher short-term energy prices and increases the procurement of ancillary services. This creates favorable conditions for merchant storage applications.

Impact of installed wind capacity

The installation of wind capacity has two effects. Firstly, it reduces off-peak energy pricing. Secondly, it introduces supply intermittency, resulting in higher energy price volatility. This volatility creates improved opportunities for energy arbitrage.

Additional solar installations

In combination with existing wind capacity, installing additional solar capacity further increases system intermittency, daily price spreads, and the overall value of merchant storage. This means merchant storage systems have greater potential for capturing value from price fluctuations.

Transmission congestion

Transmission congestion creates geographically advantageous opportunities for energy arbitrage at specific system nodes. Merchant storage systems can exploit these opportunities by strategically buying and selling electricity to maximize profits.

Low reserves and emergency grid conditions

During periods of low reserves, emergency grid conditions can occur – this leads to spikes in Real-Time (RT) prices, creating lucrative opportunities for merchant storage systems capable of discharging during high-priced intervals. Such systems can capitalize on the high RT energy revenues available.

These market trends collectively contribute to a favorable environment for merchant storage applications, presenting potential revenue opportunities and value capture for those in the energy storage sector.

Appendix B Revenue Streams

Participants in the ERCOT market – generators, retailers, energy storage providers – can earn revenue through different mechanisms, including energy market transactions, ancillary services, capacity payments, and other market-based products. Understanding and effectively navigating these revenue streams is essential for market participants to optimize their operations and maximize their financial returns in the dynamic and competitive ERCOT market landscape.

ERCOT's energy and ancillary service markets provide the primary revenue streams to grid-scale BESS resources in front-of-the-meter (FTM) sites. The markets and products available in each market are described in Figure B.1 and are discussed in detail in this section.

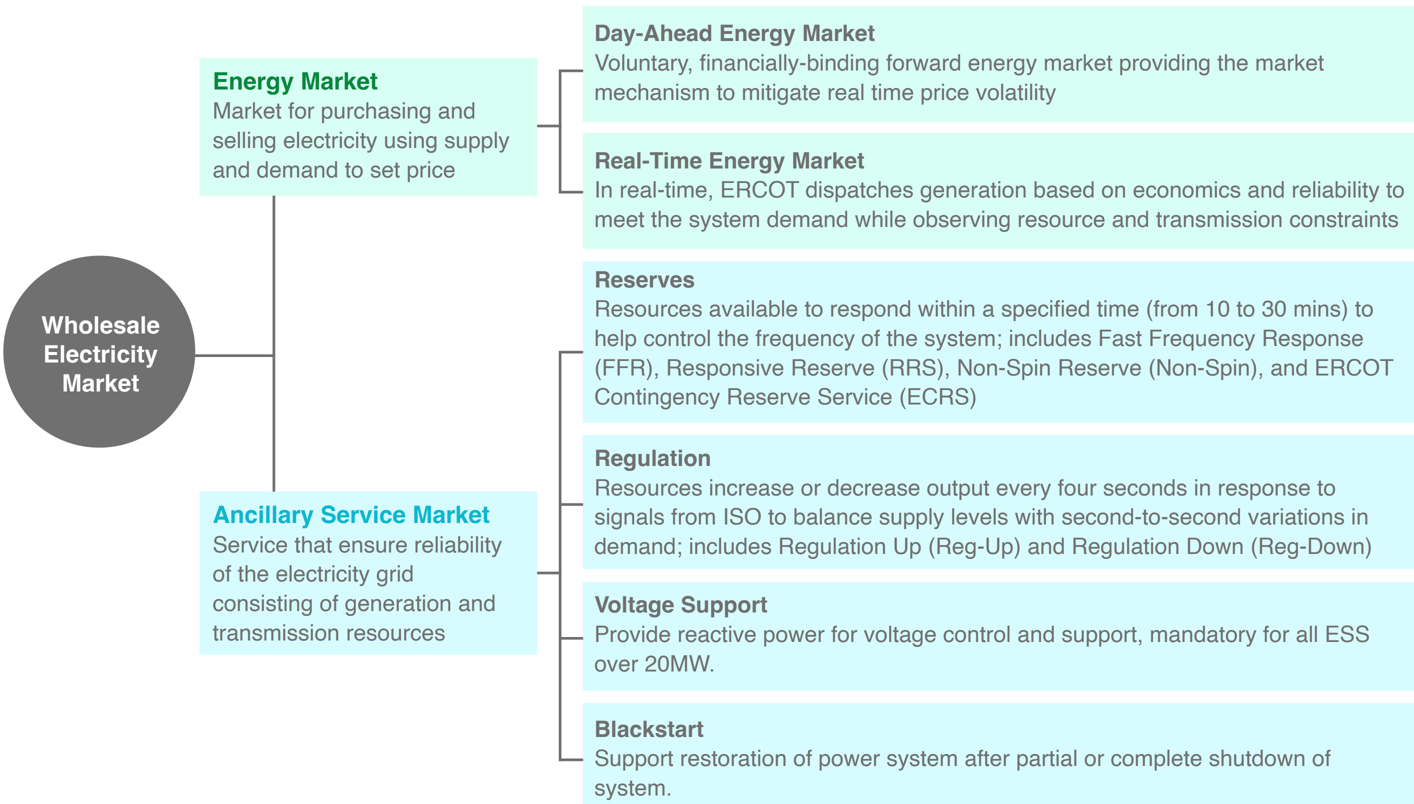

Figure B.1: Available Markets and Products

Energy Arbitrage

The Top-Bottom (TB) energy arbitrage strategy is the basis for the BESS revenue streams in the Day-Ahead (DA) and Real-Time (RT) energy markets. According to this strategy, the TBx value per day is defined as the differential between the "x" highest-priced hours of the day when the BESS is capable of discharging and the "x" lowest-priced hours of the day when the BESS charges. For instance, for a 2-hour BESS, the TB2 value is the differential between the sum of the top 2 and the bottom 2 hours, representing the energy arbitrage revenues.

The asset owner's primary decision to realize energy arbitrage revenues is whether to bid into the DA market or wait until real-time operations and make real-time charging / discharging decisions. The DA market is much "deeper" as almost 80% of the demand is procured in the DA market; however, the price spikes in the RT market tend to be peakier because of the ORDC mechanism described in section A.1. The ability to forecast the DA and RT prices largely determine the energy arbitrage revenue potential that an asset owner can realize.

Responsive Reserve Service (RRS)

ERCOT purchases responsive reserve service (RRS) in the DA market to balance the next day's supply and demand of electricity on the grid if a generator trips offline. A BESS resource, which can be dispatched within a 10-minute ramp period from receipt of the dispatch signal from ERCOT, can provide RRS. The BESS resource must have a duration of 1-hour or more to qualify for this ASvc.

Specifically, the BESS resource earns RRS revenues by providing operating reserves that are intended to: (1) arrest frequency decay within the first few seconds of a significant frequency deviation on the ERCOT Transmission Grid using primary frequency response (PFR), and fast frequency response (FFR); (2) help arrest and stabilize frequency after the first few seconds of a significant frequency deviation; and (3) provide energy during the implementation of an Energy Emergency Alert (EEA).

The size of ERCOT's RRS market as of early 2023 was approximately

3,000 MWs

Non-Spinning Reserve (non-spin)

The size of ERCOT's non-spin reserves market as of early 2023 was approximately

4,500 MWs

Non-spin reserve capacity that can be available within 30-minutes is purchased by ERCOT in the DA market to cover errors in the load forecast or to replace deployed reserves. A BESS resource, which can be dispatched within a 30-minute ramp period from receipt of the dispatch signal from ERCOT, can provide non-spin reserves. The BESS resource must have a duration of at least 4-hours to qualify for this ASvc.

Specifically, the BESS resource earns non-spin revenues by serving as off-line generation resources that can be synchronized and ramped to a specified output level within 3- minutes. In this case, the BESS resource should be able to sustain the specified level for at least four consecutive hours to qualify for this ASvc.

ERCOT Contingency Reserve Service (ECRS)

The ECRS capacity that can be available within 10-minutes is purchased by ERCOT in the DA market to cover forecasting errors or to replace deployed reserves. A BESS resource, which can be dispatched within a 10-minute ramp period from receipt of the dispatch signal from ERCOT, can provide ECRS. For this ASvc the BESS resource can only qualify to provide capacity it can sustain for 2 hours.

Specifically, the BESS resource earns ECRS revenues by providing operating reserves that are intended to: (1) restore RRS capacity within 10 minutes of a frequency deviation that results in significant depletion of RRS by restoring frequency to its scheduled value to return the system to normal; (2) provide energy during the implementation of an Energy Emergency Alert (EEA); (3) provide backup regulation; and (4) be sustained at a specified level for two consecutive hours.

According to ERCOT, the hourly average ECRS quantity between Jun 10 and Dec 31, 2023, is expected to be

~1,931 MWs[3]

[3] Source: ECRS Market Readiness and Qualification Workshop held by ERCOT on April 03, 2023

Regulation Up (reg-up)

The frequency regulation offers are not symmetrical in ERCOT.

The reg-up capacity is deployed every 4 seconds and can immediately increase generation output to manage the system grid frequency. A BESS resource, which can be dispatched within 5 seconds from receipt of a dispatch signal from ERCOT, is able to provide this service. The BESS resource must have a duration of at least 15 minutes to qualify for this ASvc.

Specifically, the BESS resource earns reg-up revenues by discharging into the grid to increase the system frequency within 5 seconds of the receipt of the signal from ERCOT.

The primary decision that the asset owner makes to realize reg-up revenues is whether to reserve the charge of the BESS resource for this ASvc or whether to earn revenue in the energy market or by providing other ASvcs.

The size of ERCOT's reg-up market as of early 2023 was approximately
450 MWs

Regulation Down (reg-down)

The size of ERCOT's reg-down market as of early 2023 was approximately
450 MWs

The reg-down capacity is deployed every 4 seconds and can immediately decrease generation output to manage the system grid frequency. A BESS resource, which can be dispatched within 5 seconds from receipt of a dispatch signal from ERCOT, is able to provide this service. The BESS resource must have a duration of at least 15 minutes to qualify for this ASvc.

Specifically, the BESS resource earns reg-down revenues by charging from the grid to decrease the system frequency within 5 seconds of the receipt of the signal from ERCOT.

The primary decision that the asset owner makes to realize reg-down revenues is whether to reserve the charge of the BESS resource for this ASvc or whether to earn revenue in the energy market or by providing other ASvcs.

About Stem, Inc.

Stem (NYSE: STEM) is a global leader in AI-driven clean energy solutions and services.

Stem (NYSE: STEM) provides clean energy solutions and services that maximize the economic, environmental, and resiliency value of energy assets and portfolios. Stem's leading AI-driven enterprise software platform, Athena® enables organizations to deploy and unlock value from clean energy assets at scale. Powerful applications, including AlsoEnergy's PowerTrack, simplify and optimize asset management and connect an ecosystem of owners, developers, assets, and markets. Stem also offers integrated partner solutions that improve returns across energy projects, including storage, solar, and EV fleet charging.

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