ERCOT Ancillary Services Study

FINAL WHITEPAPER

September 2024

Executive Summary

This report has been developed by ERCOT as part of the Ancillary Services Study to assist the Public Utility Commission of Texas (PUC) in meeting the requirements of Public Utility Regulatory Act (PURA) § 35.004(g) (enacted in Senate Bill 3 (87 R.S.)). Ancillary Services (AS) are an important mechanism for maintaining the reliability of the ERCOT Interconnection. The importance of AS has grown and continues to grow as variability and uncertainty of both supply resources and customer demands on the grid continue to increase. AS are needed to provide supplemental operational capabilities that would not otherwise be provided solely by, or explicitly incented by, the energy market. AS are procured to (1) meet supply and demand balancing related reliability objectives defined in North American Electric Reliability Corporation (NERC) Reliability Standards, and (2) reduce operational risks associated with variability and uncertainty. The amounts of AS procured have increased in recent years due to (1) increases in intra-hour and hourly net load variability and uncertainty and (2) a policy change in 2021 to maintain an acceptable level of reliability risk. This report reviews the key elements of ERCOT's AS program including product definitions, key characteristics, and deployment triggers; the criteria that form the basis for analysis used to determine quantities of different types of AS; pending changes that may significantly impact AS; and ERCOT's recommendation on changes to AS.

ERCOT considers the existing AS products namely Regulation Service (Reg-Up and Reg-Down), Responsive Reserve Service (RRS), ERCOT Contingency Reserve Service (ECRS), Non-Spinning Reserve Service (NSRS or Non-Spin), and the forthcoming Dispatchable Reliability Reserve Service (DRRS) sufficient for meeting the system's frequency control and uncertainty risk mitigation needs. ERCOT is not recommending additional AS products at this time but recommends that monitoring should continue on the impact of ERCOT's evolving resource mix and large load growth on system inertia and frequency control; in the future, new AS products might be needed to mitigate any additional operational risk posed by further changes in the resource mix or loads.

Regarding AS quantity determinations, ERCOT recommends:

(1) Exploring building a "full statistical" analysis of risks for which the non-frequency recovery portion of ECRS and Non-Spin are procured; and
(2) Exploring the benefits of determining some portion of AS quantities closer to the Operating Day based on days-ahead forecasted conditions.

ERCOT recommends that for Regulation, RRS, and the frequency-response portion of ECRS, the current mechanisms that quantify the risks and meet applicable NERC reliability standard requirements should be continued. Several questions will need to be answered before AS quantity determination using an approach outlined in recommendations (1) and (2) can be adopted. Further, the impact of the above approach to changes in the overall AS quantities is highly dependent on how prevailing policy decisions such as avoiding the likelihood of emergency operations, procuring reserves from AS rather than committing additional generation through the Reliability Unit Commitment (RUC) process, and reliance on non-obligated Resources are reflected in the analysis.

Any policy decision(s) that would increase the expectation of periodic emergency operations, the use of RUC rather than procuring AS, or the reliance on non-obligated Resources for reliability services must be considered and decided by policymakers.

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1 Introduction

Ancillary Services (AS) are an increasingly important mechanism for maintaining the reliability of the ERCOT Interconnection as variability and uncertainty of both supply resources and customer demands on the grid continue to increase. AS are "ancillary" in that they are needed to provide supplemental operational capabilities that would not otherwise be provided solely by or explicitly incented by the energy market. While there are some types of AS that are procured in advance to ensure that resources with certain characteristics are available, for example, Black Start Service, this paper will primarily discuss AS capacity products that are procured in the Day-Ahead Market (DAM). These AS provide operational capabilities that are required to satisfy two purposes:

1. Meet certain supply and demand balancing related reliability objectives defined in NERC Reliability Standards, and
2. Reduce operational risks associated with the aforementioned variability and uncertainty.

Currently, the ERCOT AS program is not intended to meet long-term resource adequacy objectives, although the quantities of AS products procured and the structure of the AS program may incrementally impact the level and type of investments in new resources. Rather, AS are designed and procured to meet real-time reliability needs.

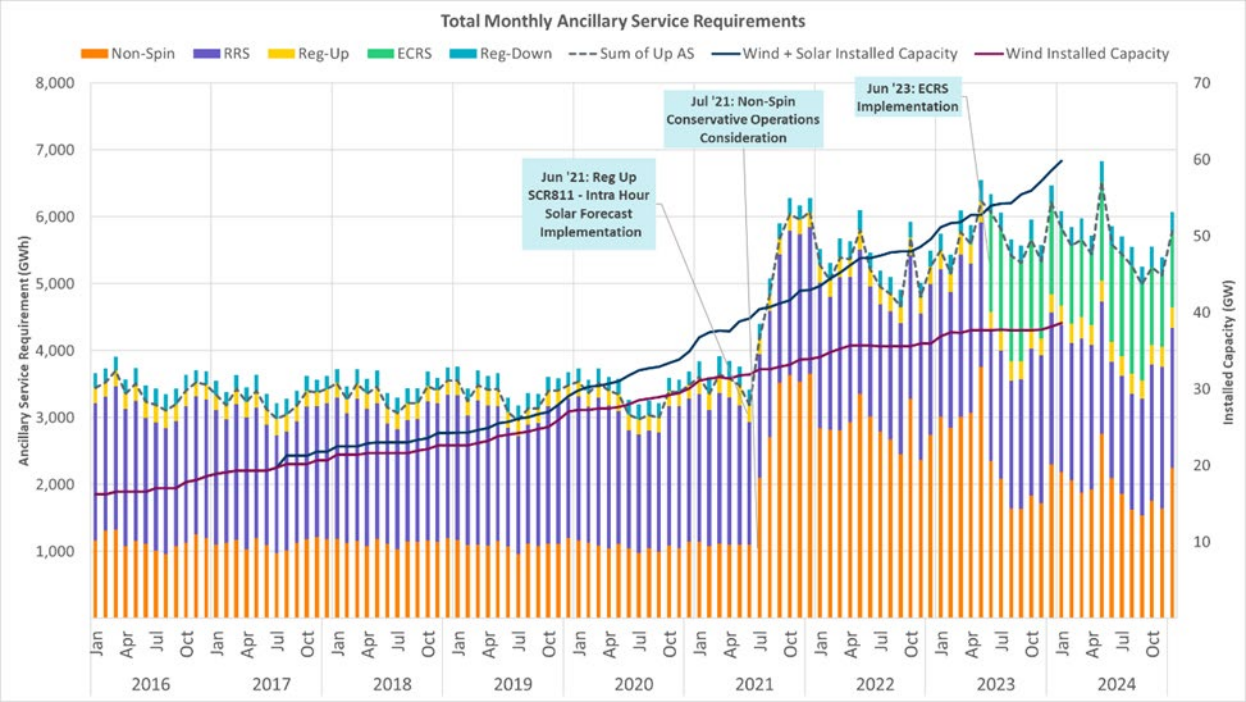
AS are generally procured in the DAM by ERCOT on an hourly basis from resources that have the appropriate, defined operating characteristics and offer to sell the AS. The ERCOT Protocols define each type of AS and the capability requirements of resources that may provide each service. The minimum quantities of each type of AS are determined on an annual basis using a methodology that includes a statistical analysis of the historical drivers for AS and factoring in expected system changes that may impact the needed quantities.

The original framework for AS was designed for the implementation of the single control area in 2001, based on the reserves that each of the 13 control areas in ERCOT had been required to maintain before the market restructuring. In the mid-2010s, ERCOT conducted an extensive evaluation with stakeholders of the AS that would be needed over the next several decades due to the fast-changing resource mix. This evaluation led ERCOT to propose a comprehensive new AS framework in Nodal Protocol Revision Request (NPRR) 667, *Ancillary Service Redesign*. While NPRR667 was ultimately rejected by stakeholders, most of the fundamental elements of that strategic AS framework, including the recent implementation of the ERCOT Contingency Reserve Service (ECRS), have been implemented in subsequent NPRRs.

2 Background

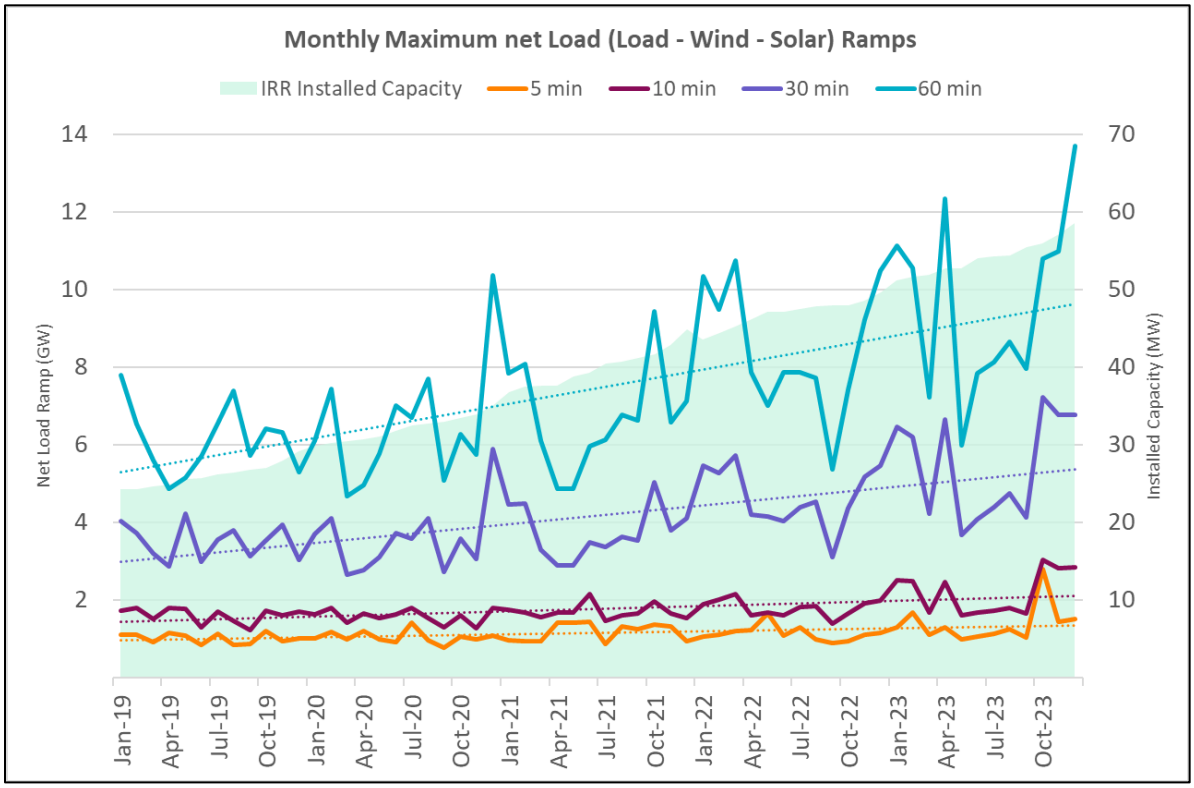
In the early 2000s, electric demand and the mix of resources were much more consistent, with few intermittent resources and little active demand response. Regulation Service (Reg-Up and Reg-Down)

(a fast-acting service to balance supply and demand and maintain frequency in between dispatch intervals) varied during certain hours where it had been historically depleted, typically during startup and shutdown times for the then recently added fleets of combined cycle units. The Response Reserve Service (RRS) (which provides fast dispatches of resources to arrest frequency deviations, such as occur when a large nuclear generator suddenly trips offline) quantity was a fixed number over the entire year and had been the same quantity since the late 1980s. Non-Spinning Reserve Service (Non-Spin) (which provides capacity that can be available within 30 minutes to cover variability in supply and demand and replace deployed reserves) was only procured during high-risk periods when self-committed reserves were less than a fixed number.



As the system has evolved to include ever-increasing amounts of intermittent resources and demand variability, the amounts of AS have necessarily increased to meet NERC Reliability Standard requirements and to maintain an acceptable level of reliability risk (see figure above). As ERCOT has sought to meet these requirements efficiently, ERCOT has differentiated the amount of each AS that is needed in different time periods, based on the variability and risk in each time period. As a result, the complexity of determining how much of each AS is needed has increased substantially. For example, rather than increasing the quantity of RRS in all hours, ERCOT began to vary the quantity by hour, based on the historic inertia in that hour, so that higher amounts of RRS were only procured when most likely to be needed and lower amounts were procured in other hours. For Non-Spin, some amount became needed in all hours, due to increasing uncertainty in both load and generation availability. And during high-risk periods, it became necessary to cover a higher level of forecast uncertainties.

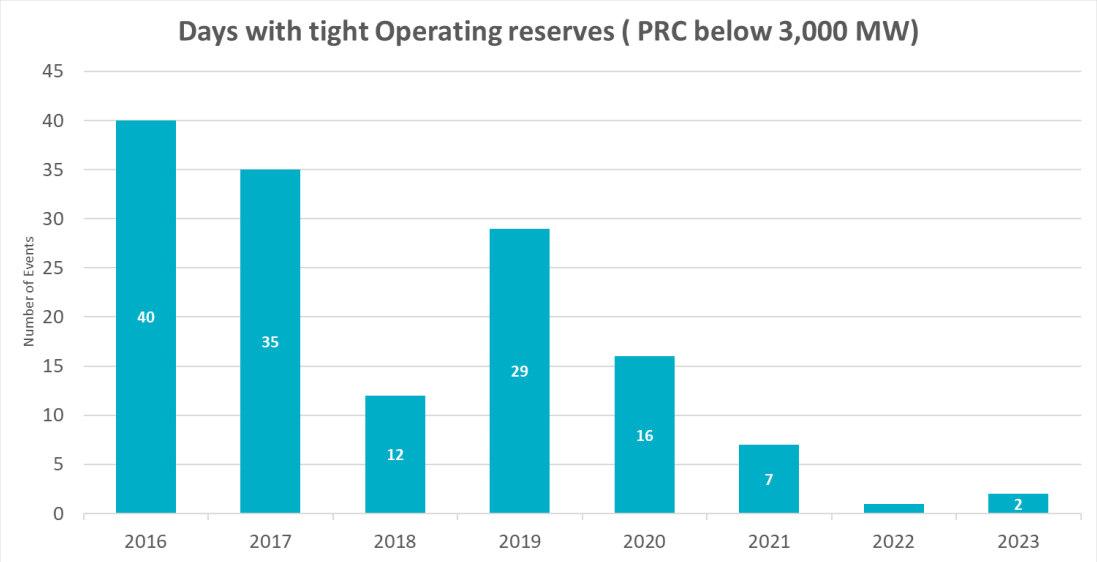
ERCOT has also added a completely new AS and modified others to take advantage of new resource types. Following the holistic review of ERCOT's AS in the mid-2010s, stakeholders adopted NPRR863, *Creation of ERCOT Contingency Reserve Service and Revisions to Responsive Reserve*, which, among other changes, created the ERCOT Contingency Reserve Service (ECRS). With the increasing amounts of intermittent resources, the potential for higher MW forecast errors, faster MW ramps, and the NERC requirement to recover frequency following a disturbance within 15 minutes, this faster-responding service was vital by the time it was implemented in 2023. Note that the intention is not to have a quantity of AS equal to the ramp; rather, it is to cover forecast uncertainties, which are magnified by large net load ramps.



2.1 2021 Operational Changes to avoid Emergency Operations

Following multiple days of high net load forecast errors and/or high generator forced outages in spring and early summer of 2021, ERCOT began operating with higher real-time reserves. The intention of this change in operating posture was to operate to a higher reliability threshold. Specifically, the goal was to have enough reserves to not only avoid the need for load shed but also to decrease the likelihood of the need for emergency operations due to insufficient reserve capacity. Previously, the goal was to have enough operating reserves to avoid load shed due to forecast errors and forced outages. Under this paradigm, if ERCOT entered emergency operations multiple times but did not shed load, the AS quantities would have been considered acceptable. Initially, this change in operating posture to avoid emergency operations was accomplished by committing additional generation through the Reliability Unit Commitment (RUC) process. However, stakeholder feedback led ERCOT

to seek the additional reserves through increased procurement of AS quantities in July 2021. Specifically, ERCOT began procuring a minimum of 2,800 MW of RRS (up from 2,300 MW) during peak hours and increased Non-Spin quantities in all hours. The chart below depicts the impact of the changes made to avoid emergency operations on the number of events where ERCOT used emergency operations procedures to declare a Watch for Physical Responsive Capability (PRC) below 3,000 MW. Effectively, since 2022, ERCOT's methodology to compute required quantities of AS uses avoiding the need for emergency operations (Watches, Energy Emergency Alerts (EEA)) as its event/criteria for determining AS procurement quantities.



Corresponding with the implementation of ECRS in June 2023, ERCOT reduced the quantity of Non-Spin procured. ERCOT also eliminated the additional 500 MW of RRS that was being procured since 2021.

2.2 AS Quantity Determination Methodology Document

The Protocols require that ERCOT shall, at least annually, review the methodology for determining the minimum required quantities for each AS. The AS Methodology document was created to describe the methodology for calculating the minimum quantity of each type of AS that is needed to meet the defined operational reliability objectives. It contains a description of how the minimum quantities for each AS will be calculated. The increasing complexity in the AS framework and quantification of requirements has been added to the AS Methodology document as it was reviewed by numerous stakeholder groups each year. Consequently, the AS Methodology document has grown in detail and serves multiple purposes, including acting as an educational document, technical reference, NERC Reliability Standard compliance record, and a description of reliability risk mitigation. Currently, the Protocols require any changes to the AS Methodology document to be reviewed by the ERCOT Board of Directors and approved by the PUCT. Appendix 4 summarizes the changes made to the AS Methodology between 2016 and 2024.

3 AS Program Elements

AS in ERCOT is an integrated program where different elements that are needed for the program are defined across numerous documents. In addition to the AS Methodology, the Protocols, Operating Procedures, and an Other Binding Document (OBD) that describes deployment processes[1] for Non-Spin, define and govern various elements of the AS program, including:

1. The **definition** of each AS and the **characteristics** that resources must meet in order to qualify to provide it,
2. The **purposes** for which different types of AS are needed, including to meet NERC requirements and limit the risk of load shed due to insufficient commitment,
3. The **criteria** used to determine the extent to which different types of risks should be mitigated by using AS,
4. A description of the **calculations** of how much of each AS will be procured to meet the criteria described in #2,
5. The **flexibility tradeoff** between the certainty of determining the AS quantities in advance (so the cost of these AS can be hedged by Market Participants) and the efficiency of the quantity procured (which could be lower in many hours if determined within the time frame for which actual forecasts are available), and
6. The criteria and timing for **deployment** of each type of AS.

Many of these elements are comingled in the way the quantities are determined in the AS Methodology document. For example:

- The criteria for determining how much of each type of risk should be mitigated is not defined separately; instead, it is decided inherently in determining the minimum quantities of each AS.
- The AS Methodology defines some, but not all, of the purposes for which each AS is needed. Each year, ERCOT includes in its methodology document and presentations a discussion of the purpose for each AS, but only to the extent that purpose is the critical factor in determining the minimum quantity of that AS for the year; there may be other purposes for which that AS is needed but in a similar or smaller quantity. For example, ECRS is partially quantified based on replacing RRS following a large unit trip and with net load forecast errors, but it may also be used when multiple units trip even if there is no forecast error.
- Based on input over several years by stakeholders, especially the Retail Electric Providers (REPs), the AS Methodology currently sets the minimum quantities for each AS to be equal to the full quantity that is expected to be needed for each time period. While ERCOT has the authority under the Protocols to procure AS in addition to those minimum quantities, it has increased AS quantities near real time only in a handful of circumstances. Therefore, the AS Methodology inherently determines the tradeoff between potential efficiency improvements and certainty in the quantities procured, leaning much more on the side of certainty.

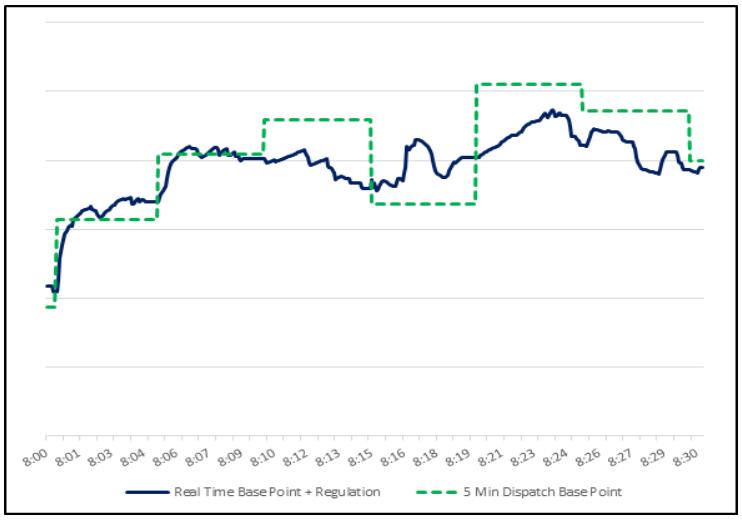
[1] There is currently an initiative at ERCOT to migrate the contents of Other Binding Documents to the ERCOT Protocols and Guides.

- The next several sections of this paper will describe how each of the six elements of the AS program are addressed.

4 Definition and Characteristics of Each AS

There are currently four types of AS, making up five distinct AS products: Regulation (Up and Down) Service, RRS, ECRS, and Non-Spin. The definition of each of these AS, including description of any AS sub-types and qualification criteria including duration requirements, for the Resources that provide it are contained in the Protocols (and included in Appendix 1 for ease of reference).

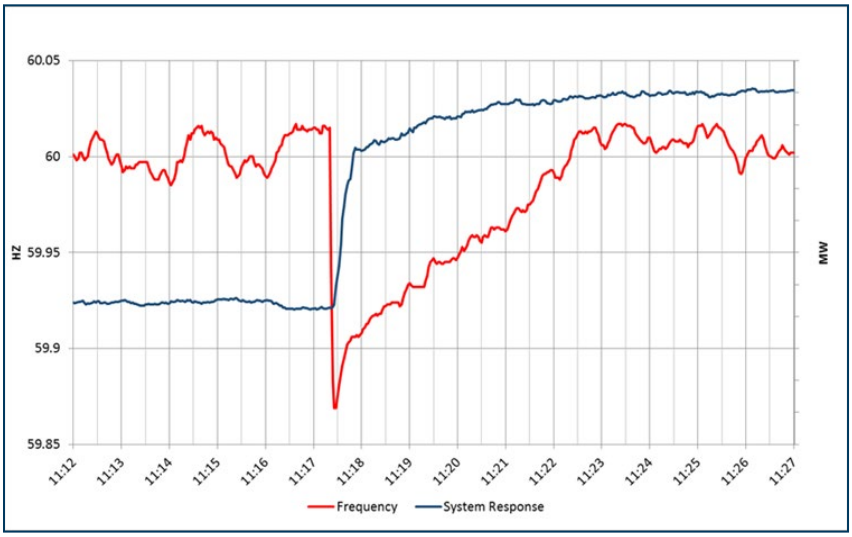
- Regulation Service is capacity that can be deployed by ERCOT systems every 4 seconds to balance supply with demand in between the 5-min Security-Constrained Economic Dispatch (SCED) intervals and maintain frequency close to 60 Hz. Regulation Service can be provided by qualified generation resources, including batteries, and load that can follow a SCED instruction. Currently, Regulation quantities are set using historic load, wind, and solar variability and adjusted for projected increases in variability due to growth in utility-scale wind and solar capacity. Up and Down Regulation are procured as distinct products as the directional needs for a given hour are typically not symmetrical.



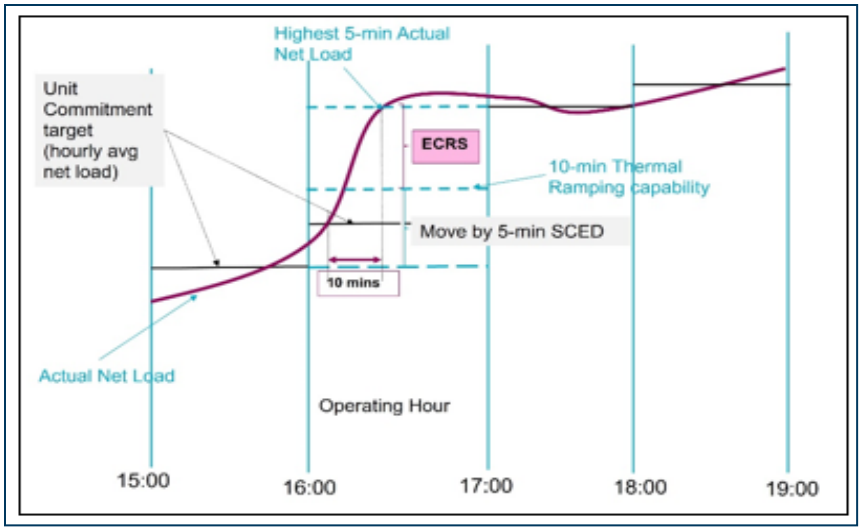
- RRS is reserved frequency responsive capacity that can respond autonomously almost immediately (within seconds) to low frequency events typically triggered by generating unit trips. RRS has three subtypes, namely, RRS from resources providing primary frequency response (RRS-PFR), RRS from resources providing Fast Frequency Response (RRS-FFR), and RRS from load with high-set under frequency relays (RRS-UFR). RRS-PFR is a continuous response to frequency (when it deviates outside a dead-band) and can be provided by generation resources including hydro resources[2], batteries, and load that can follow SCED instruction. RRS-FFR is (full) response when frequency is below 59.85 Hz within 250 ms and

[2] Hydro resources typically provide RRS in synchronous condenser fast response mode. Under this mode these Hydro resources provide (full) response when frequency is below 59.80 Hz within 20 seconds.

can be provided by batteries and “blocky” Load Resources. RRS-UFR is (full) response when frequency Is below 59.7 Hz and can be provided exclusively by “blocky” Load resources. RRS quantities are set based on historic inertia and the MW quantity needed to arrest frequency such that NERC requirements can be met. Typically, higher quantities of RRS are procured during periods with lower net load.

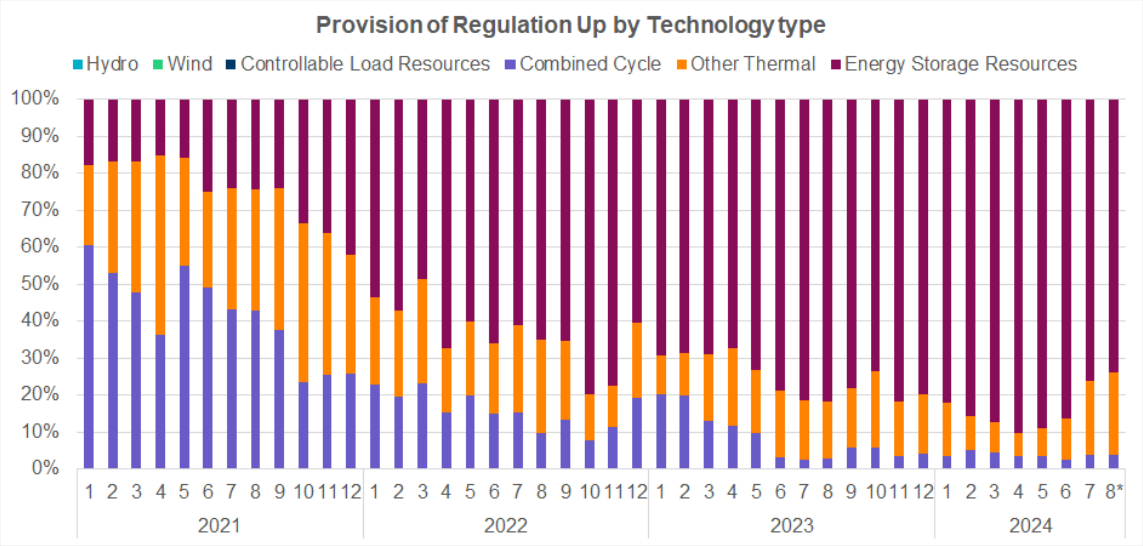


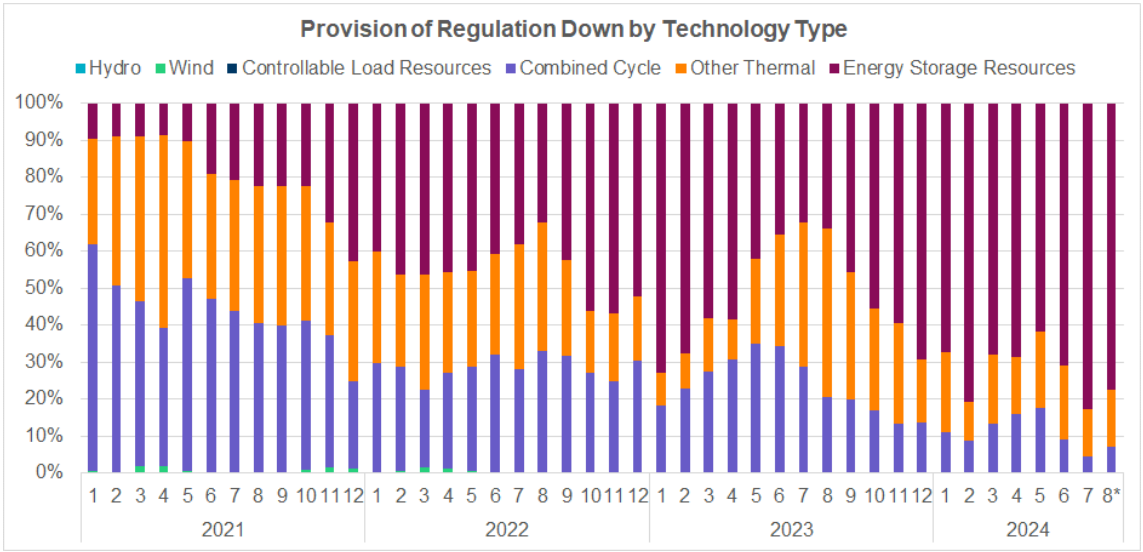
- ECRS is capacity that can respond in 10 minutes and is used to recover frequency; cover intra-hour forecast uncertainties; address load, wind, and solar variability/ramps; and replace deployed reserves. ECRS can be provided by generation resources, including batteries, and load (both SCED following and blocky) which are qualified based on capability that can be sustained for 2 hours. ECRS quantities are set (for 2024) using 30-minute ahead historic forecast error and adjusted for projected over-forecast error increases due to growth in utility-scale wind and solar capacity and capacity needed to recover frequency close to 60 Hz. During historic periods with higher reliability risk, such as near-peak load or net peak load (where net load is defined as: load – wind – solar) when other available capacity is not likely to be available, a higher risk coverage is used when determining ECRS quantities.



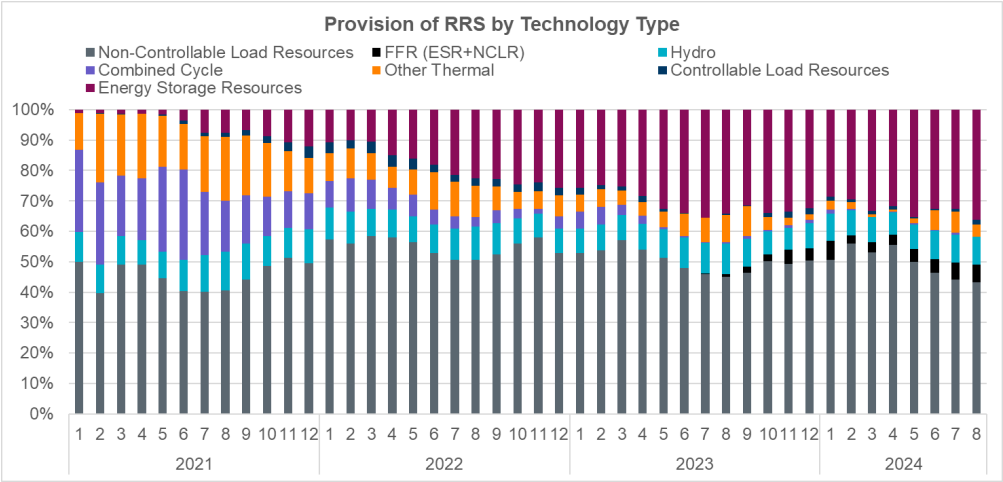
- Non-Spin is capacity that can be available within 30 minutes to cover forecast errors; load, wind, and solar variability/ramps; forced outages; and replacement of deployed reserves until additional resources can be committed. Non-Spin can be provided by generation resources, including batteries, and load (both SCED following and blocky) which are qualified based on capability that can be sustained for four hours. Non-Spin quantities are set (for 2024) using 6 hours ahead historic forecast error and adjusted for projected over-forecast error increases due to growth in wind and solar capacity. Like ECRS, during periods with a history of higher risk of net load up ramps, a higher risk coverage is used when determining Non-Spin quantities.

It is worth noting that any technology type that can meet the qualification criteria specified in ERCOT Protocols and Operating Guide can provide AS. The images below show the various technology types that have provided Regulation service between January 1, 2021 and August 26, 2024.

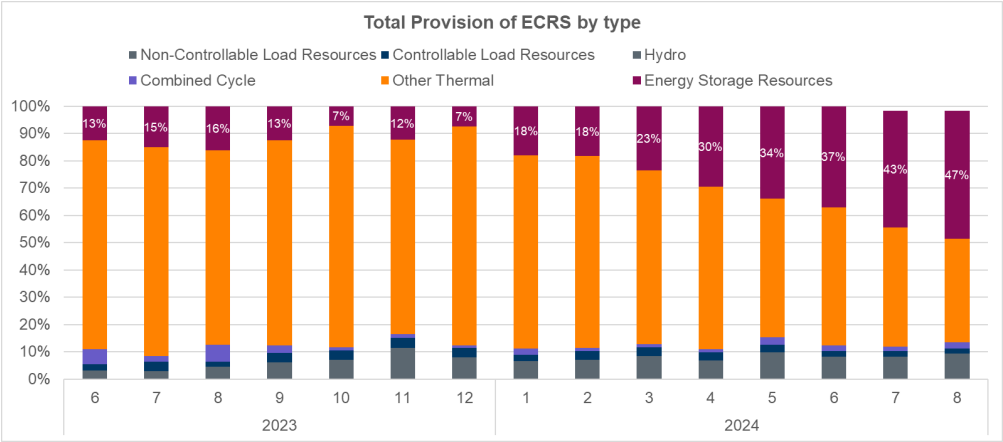




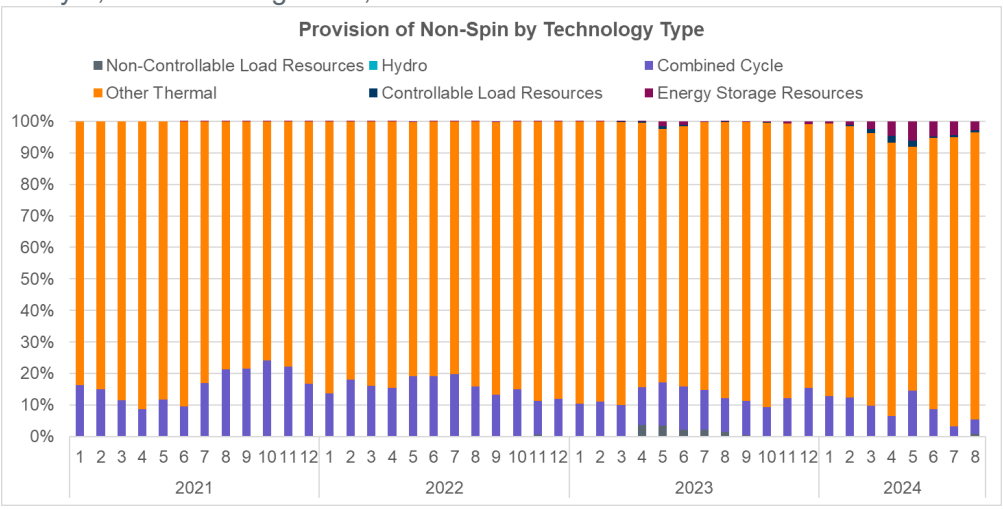
The image below shows the various technology types that have provided RRS between January 1, 2021 and August 26, 2024.



The image below shows the various technology types that have provided ECRS between January 1, 2021 and August 26, 2024.



The image below shows the various technology types that have provided Non-Spin between January 1, 2021 and August 26, 2024.



As installed capacities of Energy Storage Resources increase, the volumes of Regulation Service, RRS and ECRS being provided by these duration limited Resources also increase.

5 The Purposes of AS

As stated earlier, AS are required to satisfy two purposes:

1. Meet certain NERC Reliability Standard defined supply and demand balancing related reliability objectives; and
2. To reduce operational risks associated with variability and uncertainty.

The first purpose necessitates that ERCOT procure certain types and sufficient quantities of AS to meet balancing (i.e., generation and load must be "balanced", or near equal, at all times) requirements specified in the NERC Resource and Demand Balancing (BAL) Reliability Standards applicable to ERCOT as the sole NERC-registered Balancing Authority (BA) for the ERCOT Region. Compared to other regions in North America, meeting these balancing requirements is more based on the physical characteristics and limitations of the ERCOT Region than equitable reserve sharing since ERCOT is a single BA interconnection as opposed to one BA within a large, multi-BA interconnection.

ERCOT has developed a compliance program for meeting various BAL standards requirements. Note that NERC Reliability Standards do not specify how a BA's AS program or other reserves must be designed. Instead, the NERC Reliability Standards set several performance requirements that the BA must meet. ERCOT has designed its AS to be used, in addition to the 5-minute dispatch of energy through SCED, to meet those performance requirements. This program must be flexible enough to meet a variety of conditions: unit trips, load/wind/solar/thermal unit ramps, load variations, etc. In some cases, Regulation plus SCED may be sufficient. In other cases, RRS may be autonomously deployed with ECRS deployed by the Energy Management System (EMS) to restore frequency, followed by SCED. Most uses of AS are not "one and done;" for example, when a unit trips and AS are deployed, the risk exists that another unit could trip, so there is a need to timely restore reserves to prepare for the next possible unit trip without leaving the system exposed without sufficient reserves for an unacceptable period.

The table below summarizes ERCOT's NERC balancing requirements and how ERCOT uses SCED, Regulation, RRS, and ECRS (with backup from Non-Spin) to meet these requirements.

NERC RELIABILITY STANDARD	REQUIREMENT SUMMARY	EXPLANATION, OR MORE INFO, IF NEEDED	ERCOT ACTIVITY TO MEET REQUIREMENT
BAL-001-2 R1	Maintain 12 month rolling	CPS1 is a measure of how close system	Frequency control is maintained through Regulation deployment, governor response from resources providing RRS and from other available on-line

NERC RELIABILITY STANDARD	REQUIREMENT SUMMARY	EXPLANATION, OR MORE INFO, IF NEEDED	ERCOT ACTIVITY TO MEET REQUIREMENT
	average CPS1 score ≥ 100%	frequency is maintained relative to 60 Hz.	resources, and running SCED as often as needed. ERCOT monitors frequency control (both actively and *post hoc*) to ensure compliance with this requirement.
BAL-001-2 R2	Average ACE does not exceed BAAL for more than 30 minutes (including during EEA)	Clock-minute average frequency cannot stay below 59.91 Hz or above 60.09 Hz for more than 30 minutes	ERCOT relies on actions such as deployment of Regulation, governor response from on-line resources providing RRS and from other available on-line resources, and running SCED as often as necessary. If more on-line resources are needed, ERCOT may deploy Non-Spin and/or ECRS and use DC Ties (increasing import or curtailing export) to recover frequency below ERCOT's BAAL within the timeframes established by this requirement.
BAL-002-3 R2	BA shall have a plan to maintain contingency reserves to cover the most severe single contingency (MSSC)	MSSC for ERCOT is 1,430 MW	If ERCOT cannot maintain sufficient contingency reserves to withstand the MSSC, it will declare EEA3 and use load shed to restore sufficient contingency reserves, pursuant to EOP-011-2 R2.
BAL-002-3 R1.1	BA must recover frequency to pre-disturbance value within 15 minutes		Following a low-frequency event, ERCOT meets this requirement by relying on frequency response from resources carrying RRS, deploying Regulation, releasing ECRS, and running SCED as needed to restore frequency within 15 minutes.
BAL-002-3 R3	BA must restore its contingency reserve to at least its MSSC within 90 minutes		ERCOT will use ECRS, Non-Spin, and load shed to meet this requirement. While the current AS Methodology does not explicitly account for this specific requirement, procurement of ECRS and Non-Spin lessen the likelihood of needing to use load shed to meet the requirement.

NERC RELIABILITY STANDARD	REQUIREMENT SUMMARY	EXPLANATION, OR MORE INFO, IF NEEDED	ERCOT ACTIVITY TO MEET REQUIREMENT
BAL-003-2 R1	BA must maintain its annual Frequency Response Measure above its Frequency Response Obligation	Median of frequency response across all events within 12-month period greater than amount calculated by NERC as necessary to avoid UFLS for loss of two largest units (2,800MW)	ERCOT relies on RRS primarily to meet this requirement. This requirement is directly considered in determining the minimum level of RRS to be procured. At least annually, ERCOT calculates RRS required to meet this frequency response obligation (i.e., not trigger UFLS for the loss of 2,800 MW) at all times. ERCOT also monitors procured RRS in Real Time to ensure these are sufficient to meet ERCOT's obligation under this requirement.

Every AS type and their amounts play a role in meeting ERCOT's obligation under the BAL Reliability Standard requirements listed in the table above. Any reductions in quantity must be carefully considered in light of reliability and NERC compliance risks.

The second purpose of AS is fulfilled by ERCOT procuring certain types and quantities of AS to reduce the necessity of emergency operations and load shed due to insufficient resource commitment to cover unexpected variations in system conditions. Most unit-commitment decisions in the ERCOT market are made by Market Participants. In general, each Qualified Scheduling Entity (QSE) will commit or decommit resources based on their obligations and expected system and market conditions. ERCOT has the authority and tools to commit additional resources if needed to cover the expected net load on the system, to resolve any locational reliability issues, and to preserve the required AS through the RUC process.

Different thermal generation resources take varying periods of time to start up, from less than five minutes for some combustion turbine units to more than 12 hours for some gas steam units. Commitment decisions have to take this lead time into account. Additionally, various thermal generation resources have differing abilities to move from a low output level to a high output level. This is known as ramp capability and is expressed in MWs per minute. However, there is significant variability around both the supply and demand sides of system expectations during the timeframe for which commitment decisions must be made:

- Generating units can become unavailable;

- Load can vary from the forecasted values;
- Wind and solar generation can vary from forecasted values; and
- The timing of changes in load, wind, solar, and unit starts can vary from hourly values.

ERCOT must appropriately take these uncertainties into account when determining whether to start additional generation or risk not having sufficient resources that are available in a timely manner to serve the load if those events occur, in which case emergency operations or load shed (to balance the consumer demand with the available resources) might be required. To account for these uncertainties, ECRS and Non-Spin (and in the future Dispatchable Reliability Reserve Service[3], (DRRS)), which are provided by reserved on-line resources or off-line resources with relatively short lead times of 10 minutes to 30 minutes (to 2 hours in the future with DRRS in place), are relied upon to mitigate that risk as system conditions vary in real-time from the forecasted expectations at the time unit commitment decisions were made.

In theory, the risk of insufficient commitment to cover unexpected variations in system conditions can be raised or lowered by increasing or decreasing the quantities reserved through ECRS and Non-Spin beyond the quantities needed to meet NERC BAL Reliability Standards requirements. Currently, there are no objective reliability criteria by which to judge the sufficiency of AS quantities to cover these risks. As such, ERCOT procures quantities of AS to both meet NERC BAL Reliability Standard requirements and to avoid emergency operations considering historic variations/uncertainties in system conditions.

6 Criteria and Quantification for AS

The criteria used for determining the quantity of a particular AS for a given year is described in each year's AS methodology and will not be included here. However, the amount of each AS that is needed is generally based on the use of that AS that is most critical (i.e., that results in the highest quantity of that AS being needed). There may be other reasons that a particular AS is needed, but the amount of that AS that would be needed to cover any of those other needs is less than the amount needed to cover the most critical need. Unless there is a significant risk of both needs occurring at the same time, then the quantity needed to cover the critical need should be sufficient to cover the second need as well. However, in some cases where this risk is due to a problem that is frequent (e.g., unit trips and forecast errors) or where there is a significant chance that both problems occur at the same time, the different risks may have an additive impact on the quantity needed of that AS.

For some AS, the criteria are fairly stable over time, e.g. the quantity of Regulation has been based on the same basic formulation, with only updates to the numbers, for several years. For other AS, e.g., Non-Spin, the criteria tends to change more frequently as it is driven by changing regulatory and

[3] Texas House Bill 1500 includes a requirement for ERCOT to develop and implement an AS to procure dispatchable reliability reserve services on a day-ahead and real-time basis to account for market uncertainty. (H.B. 1500 § 22, 2023, R.S.) ERCOT is in the midst of developing this DRRS product.

market considerations (such as considering forecast errors further in advance of an operating hour in order to avoid triggering emergency operations and reduce the need for RUCs).

Another topic worth noting in the current AS methodology for ECRS and Non-Spin is in the context of how these use historic net load ramps to identify hours with higher risk of up ramp forecast errors. In these hours, when the risk of insufficient commitment to cover unexpected variations is higher, ECRS and Non-Spin quantities are set based on a higher percentile of applicable net load forecast errors using a sliding scale; hours with lowest risk of up ramps are assigned the lowest percentile (85th in case of ECRS and 68th in case of Non-Spin) and hours with highest risk of up ramp are assigned the highest percentile (95th for both ECRS and Non-Spin). The selections of the start and end values in the sliding scale are based on engineering and operational judgement of "excess" on-line/off-line generation that historically has been available during the timeframe. For example, on typical summer afternoons, there is not a plethora of excess generation capacity beyond what is committed to serve the forecasted peak demand, so ERCOT procures an amount of Non-Spin that is based on the 95th percentile of calculated historic risk for those hours. Conversely, in overnight hours, when demand is lower, there may be many generators that are operating below their maximum output or off-line but with a fast startup time that can help mitigate net load under forecast errors, so ERCOT procures an amount of Non-Spin that is based on the 68th percentile of calculated historic risk for those hours.

7 Tradeoff between Certainty and Efficiency of AS Quantities

The AS methodology document describes the methodology that ERCOT uses, updated annually, to quantify the ***minimum*** requirements for each AS. ERCOT determines the quantity it expects to need to cover the critical need for each AS for each hour, based on system conditions for that hour over some historic period. Based on feedback from stakeholders over many years, once ERCOT determines those expected required hourly quantities, those expected quantities are treated as the minimum quantities for the year and are "locked in" in December as the minimum for each hour of the year. ERCOT has the authority to procure more than the expected quantity if needed based on actual forecasted conditions, but very rarely does so because the minimum quantities generally tend to be enough to cover most of the conditions that arise. The reason these historically expected quantities are locked in to be the minimum quantity for each hour is that it allows REPs to hedge against the costs of AS.

Actual system conditions in a particular hour may vary greatly from what was expected based on historic conditions for that hour of the year. In many cases, those actual conditions may result in less AS being required for a particular hour than what was determined in December of the previous year. But because the minimum amount is already "locked-in," that full amount will be procured.

There is a tradeoff inherent in this process between certainty and efficiency. Back when the AS methodology approach was changed to set quantities annually, the difference between the quantities

determined in December and the quantities that would be needed based on real-time conditions was relatively small. At that time, the improved ability for REPs to hedge their AS obligations made certainty more important than efficiency. As the sources of variability and uncertainty on the grid increase with growth in solar, Large Flexible Loads (LFLs), electric vehicles, *et al*, the difference between an AS methodology that determines quantities a year ahead in December and an AS methodology that determines some portion of the quantities that would be needed based on conditions forecasted closer to the operating day is expected to continue to grow.

8 AS Deployment

In general, AS capacity is reserved and not used to provide energy unless it is needed to serve the purpose for which it is procured. For some AS, like Regulation, that may happen continuously. For other AS, like ECRS, that may only happen a few times per month.

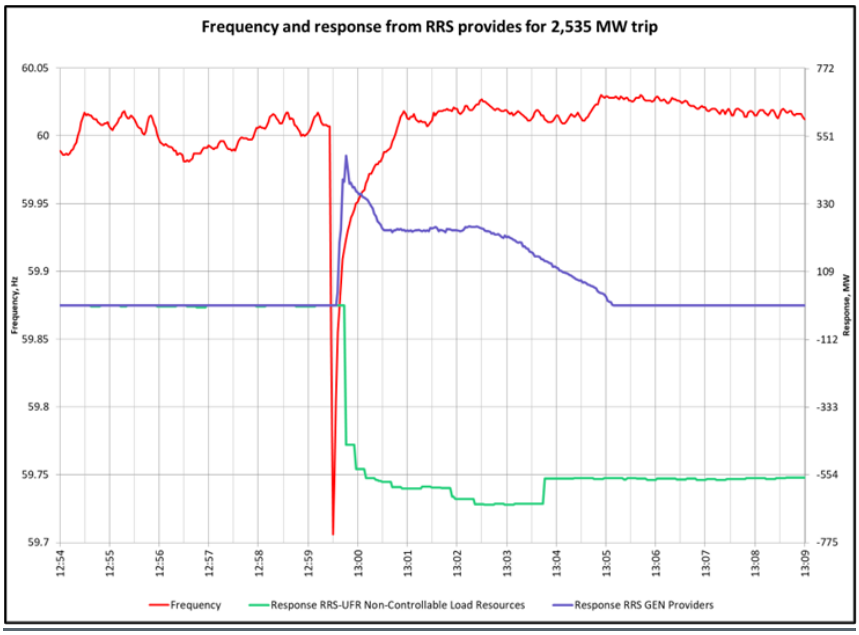
There is a distinction between the "deployment" of AS and the "release" of AS. A "deployment" happens when resources providing AS are directed – either automatically or through an ERCOT dispatch instruction – to deliver energy through an increase in output or reduction in consumption. A "release" happens when the capacity from resources providing AS is no longer held in reserve and the full capacity is allowed to be optimized through dispatch by SCED. Following a release, a resource may or may not change their output or consumption depending on the resource's energy offer price relative to other resources. During scarcity conditions it may become more supportive of reliability to release the AS capacity to be used to serve energy needs rather than to continue to hold it in reserve to cover the potential need for which it was procured (see Nodal Protocols Section 6.5.9.4.1). The deployment or release as applicable in case of each type of AS (or sub-type) will be discussed in the following subsections.

Regulation

As outlined in Nodal Protocol Section 6.5.7.6.2.1, Regulation Service is deployed by the Load Frequency Control (LFC) program within the EMS every 4 seconds as needed to maintain frequency around 60 Hz.

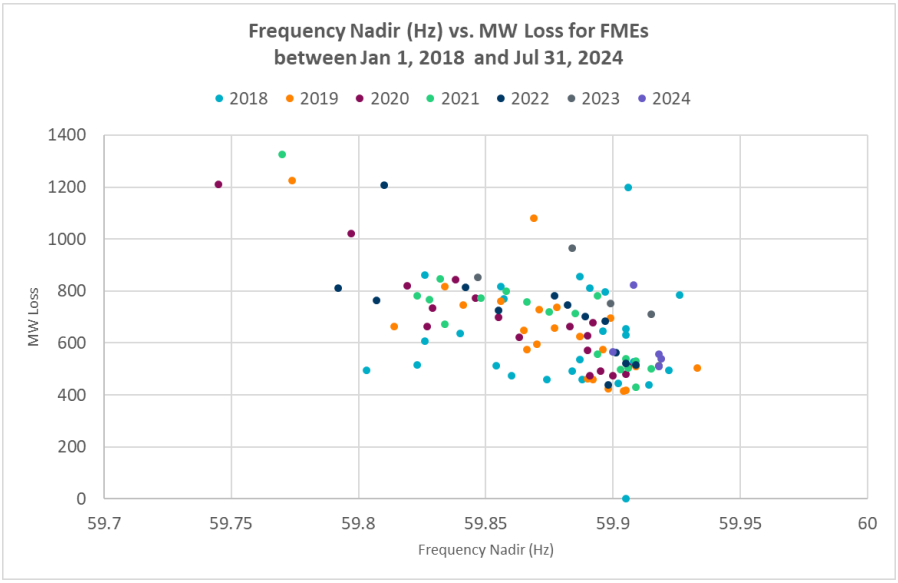
RRS

RRS from primary frequency response (RRS-PFR) is deployed automatically by resources when the resource senses a frequency deviation greater than the established dead-band (which is defined in NERC Reliability Standard BAL-001-TRE). RRS-PFR may also be released manually during scarcity conditions per Nodal Operating Guide Section 4.8 (more on this below). RRS from Fast Frequency Response resources (RRS-FFR) and RRS from high-set under frequency relays (RRS-UFR) deploy automatically when associated frequency triggers are met. More details on deployment of RRS are in Nodal Protocol Section 6.5.7.6.2.2.



The image above demonstrates response from both RRS-PFR providers (labeled as RRS-Gen) and RRS-UFR providers during a frequency event that was triggered by trip of 2,535 MW of supply. As is visible in this event due to the frequency response available at the time, frequency decline was arrested well above the first stage Under Frequency Load Shed (triggered at 59.3 Hz) and frequency nadir (i.e. lowest point of frequency was just above 59.7 Hz.)

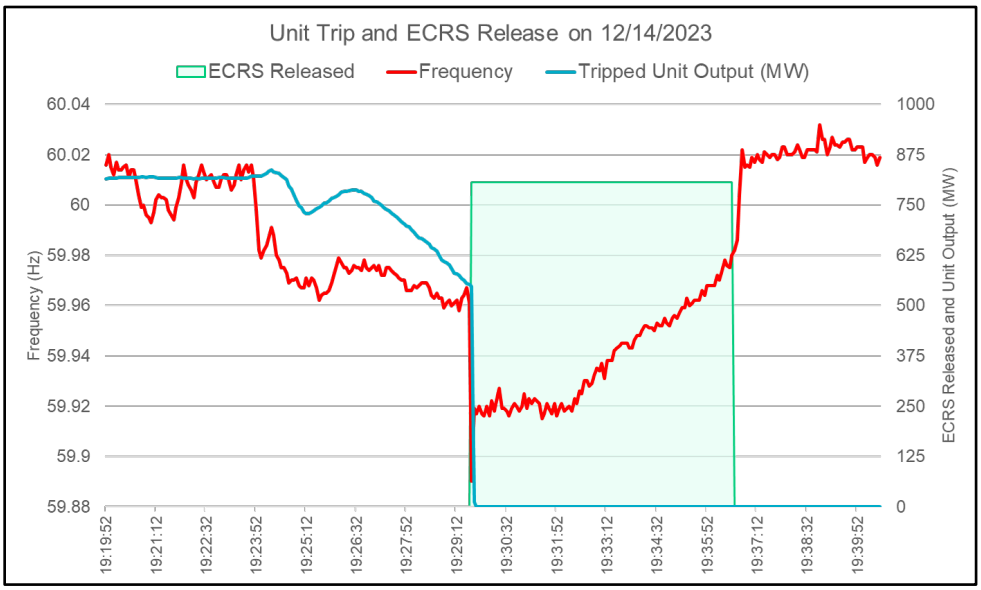
The image below demonstrates time taken to frequency nadir (lowest point of frequency) during Frequency Measurable Events (FMEs) that occurred between January 1, 2018 and July 31, 2024. In all cases, the lowest point of frequency stayed well above the first stage of Under Frequency Load Shed (triggered at 59.3 Hz). Appendix 2 contains a list of events wherein RRS was released between January 1, 2018 and July 31, 2024.



ECRS

As outlined in Nodal Protocol Section 6.5.7.6.2.4, ECRS provided by SCED-dispatchable resources may be released by LFC or manually to restore Regulation and/or RRS. ECRS may also be released when the expected net load ramp exceeds the capability of on-line resources to follow. ECRS may also be released manually during scarcity conditions (more on this below).

The image below demonstrates an event wherein a unit started experiencing operation issues and eventually tripped offline. During the event, grid frequency dropped below 59.91 Hz and ECRS was released. Frequency recovered back to 60 Hz within 10 minutes after the release of ECRS.

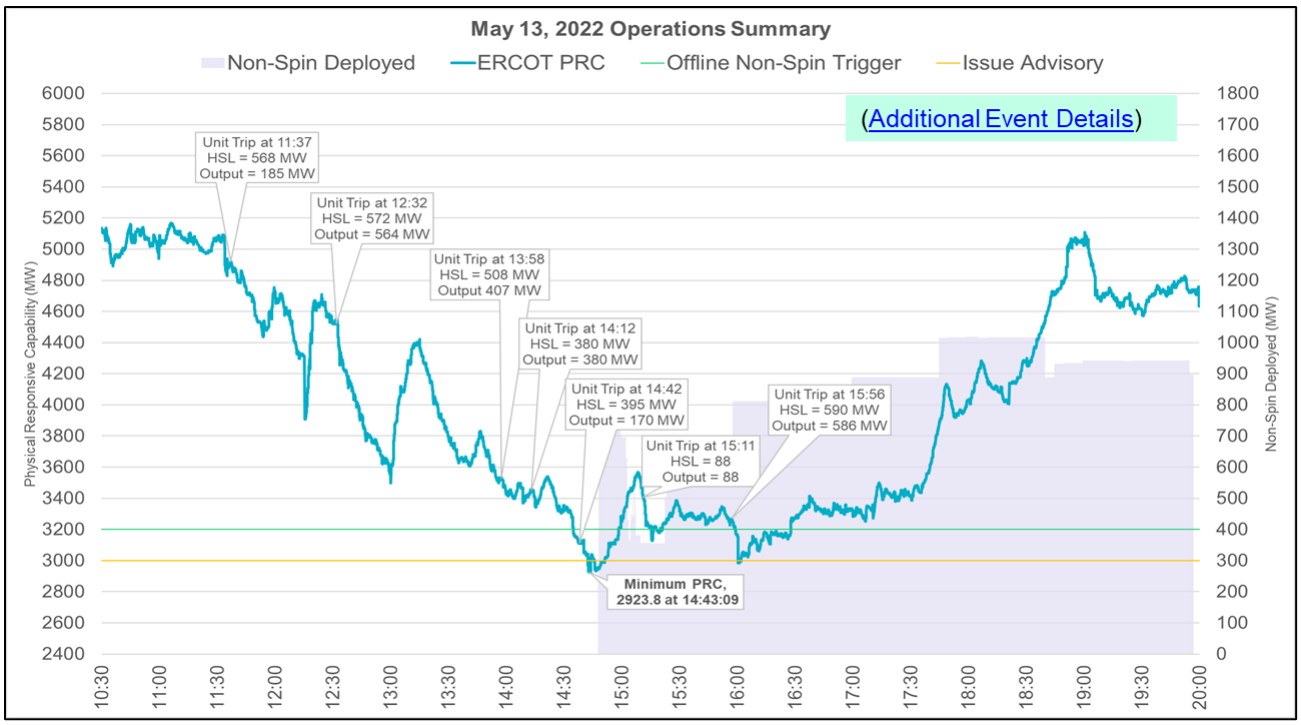


Appendix 2 contains a list of events wherein ECRS was released between June 10, 2023 and July 31, 2024.

Non-Spin

For Non-Spin provided by on-line resources, or resources that are considered to be on-line like Quick Start Generation Resources (QSGRs), the capacity reserved for Non-Spin is continuously released to SCED behind a $75 offer floor. The reason that the Non-Spin resources are released behind an offer floor is to allow for a continuous release once a pre-established value threshold is crossed where the market values having the energy now over continuing to hold this capacity in reserve. Thus, Non-Spin is automatically deployed by SCED any time this offer is cleared in the SCED solution (see Nodal Protocols Section 6.4.4.1). The deployment of Non-Spin from off-line resources is governed by the PUC-approved Nodal Protocol Section 6.5.7.6.2.3 and the OBD titled, Non-Spinning Reserve Deployment and Recall Procedure. These describe how off-line Generation Resources or Load Resources providing Non-Spin will be deployed to cover ramping needs, mitigate low system operating reserves, or resolve local reliability issues.

The image below demonstrates an event that occurred on May 13, 2022. Entering this Operating Day, ERCOT was already expecting tighter-than-normal operating conditions and had taken actions to bring additional capacity online to avoid entering emergency conditions. Between 11:30 a.m. and 2:43 p.m., approximately five generators with a cumulative generation capacity of 2,423 MW tripped offline. ERCOT's PRC dropped to a minimum value of 2,923 MW. RUC instructions and offline Non-Spin were relied upon to recover PRC and avoid emergency operations while continuing reliable grid operations.



Appendix 2 contains a list of events wherein off-line Non-Spin was deployed between January 1, 2018 and July 31, 2024.

AS Deployment During Scarcity

Scarcity conditions occur when demand approaches the available capacity on the system, including the capacity that is held in reserve to provide AS. Other than Regulation, AS are intended to protect the system against future risks, such as unit trips and forecast errors. During scarcity conditions, the immediate need to provide energy to meet demand and avoid load shed becomes a more critical issue than protecting the system against future risks, to the extent that those future risks would not result in a widespread system collapse. Thus, during scarcity conditions, ERCOT procedures include the release of capacity reserved for AS to allow it to be used by SCED to provide energy to avoid, or during, EEAs under Section 3.17.4 of the Protocols.

AS that is used to mitigate relatively longer-term risks are released first during scarcity conditions, with the AS that are used for frequency control released last. If the scarcity becomes severe enough to

approach the need for load shed, at least a subset of all AS types other than Regulation are released, and the remaining frequency-responsive capacity on the system is tracked using the calculated PRC.

However, such a release may result in energy being provided by the relatively faster-ramping, frequency responsive resources that were providing the AS and headroom being created on slower-ramping resources that may not be frequency responsive. This would mean that the system is less able to respond to fast-occurring system variations and frequency disturbances. For this reason, the release of AS capacity to serve energy needs should be done with care to recognize the reliability tradeoffs.

Individual AS are released during scarcity as follows. As noted above, on-line Non-Spin is continuously released to SCED behind a $75/MWh offer floor. If system conditions are tight enough that a resource providing Non-Spin is needed even with an offer of $75/MWh, the capacity from that Non-Spin resource is used to serve load. Resources providing off-line NSRS are deployed when available dispatchable capacity is not sufficient to cover forecasted 30 minutes ahead net load or PRC drops below 3,200 MW. ECRS capacity provided by SCED-dispatchable resources is released under scarcity conditions, if not already released due to system ramp limitations when the available dispatchable capacity is not sufficient to cover forecasted 10 minutes ahead net load. Following deployment of Non-Spin and SCED dispatchable ECRS, in accordance with Nodal Operating Guide Section 4.8, RRS from resources providing primary frequency response may be released manually during scarcity conditions to avoid EEA. ECRS and RRS capacity from non-controllable load resources is deployed in accordance with Nodal Protocol Section 6.5.9.4, during EEA2.

On August 1, 2024, ERCOT implemented an additional trigger for releasing ECRS during times of high system prices, which may be an indicator of scarcity. The current ERCOT market design (prior to the implementation of the Real-Time Co-optimization (RTC) project) has a feature whereby SCED will dispatch less generation than load when system prices are high. For example, when system prices reach $1,000/MWh (or higher), SCED will dispatch 40 MW less generation than load. When this “undergen” occurs, it is assumed that Regulation Up will be deployed to balance generation and load so that the frequency is maintained at approximately 60 Hz.

The new ECRS release trigger that was implemented on August 1, 2024, uses the undergen value as an indicator that the system is nearing scarcity conditions and ECRS should be released. Specifically, when the system has experienced an undergen of 40 MW for 10 consecutive minutes, ERCOT may release a portion of ECRS reserves.

9 Pending Changes

Two pending changes are expected to have significant impacts on AS in ERCOT; namely, the market changes associated with the RTC project and the implementation of DRRS, a new type of AS.

ERCOT and stakeholders are in the midst of a multi-year effort to implement RTC in the ERCOT market. Once the RTC project is implemented, AS will no longer be procured only in the DAM. Under RTC, AS will be co-optimized with energy every five minutes in the real-time market. This is expected to bring a number of positive benefits to the market and grid operations, including a more efficient overall procurement of AS since the optimization engine will be able to determine the most cost-effective division of resources providing energy versus resource capability being held in reserve for AS.

In addition to procurement changes, RTC will result in deployment changes to AS. In an RTC market, on-line capacity from SCED Dispatchable resources providing RRS, ECRS, and Non-Spin will be deployed automatically by the optimization engine if not autonomously deployed based on frequency. Deployment of these AS will occur when scarcity drives system prices above certain AS penalty thresholds as expressed along a demand curve. These AS penalty thresholds, or AS demand curves, are intended to reflect some of the reliability tradeoffs previously discussed. At some point, it is more important for reliability to have the energy now and forgo some amount of AS procurement.

RTC is expected to be implemented in late 2025 or early 2026.

DRRS is a new type of AS introduced in House Bill 1500 from the 88th Texas Legislature. DRRS is intended to cover risks associated with historical variations in generation variability, including intermittency of non-dispatchable generation resources and forced outages. Resources providing DRRS must be capable of being on-line and dispatchable within two hours of being called on for deployment, must have dispatchable flexibility, and must be capable of running for at least four hours at the resource's high sustained limit.

ERCOT filed NPRR1235, *Dispatchable Reliability Reserve Service as a Stand-Alone Ancillary Service*, to implement the framework and requirements for DRRS in the ERCOT market. At the time of this paper, NPRR1235 is proceeding through the ERCOT stakeholder process. DRRS is expected to be implemented sometime after the RTC project. ERCOT will begin discussions with stakeholders regarding the methodology to determine procurement quantities of DRRS after NPRR1235 has been approved by the PUC.

10 Recommendations

Overall, ERCOT finds that the existing AS products and the forthcoming DRRS are sufficient for meeting the system's frequency control and uncertainty risk mitigation needs. ERCOT does not recommend additional AS products at this time. However, as the ERCOT Region continues to transform and as technology continues to evolve, the AS methodology needs to also transform and evolve. Specifically, ERCOT recommends exploring the following two potential improvements in the near term:

1. Revamp the methodology used to calculate the non-frequency responsive portion of ECRS and Non-Spin quantities to use a probabilistic framework for quantifying reliability risks that these reserves are required to cover; and
2. Examine the benefits of determining some portion of AS quantities closer to the operating day based on days-ahead forecast conditions rather than strictly through an annual calculation.

10.1 Probabilistic Framework ("Full Statistical") for AS quantity determination

The current AS methodology for calculating minimum ECRS, and Non-Spin quantities utilizes an approach that considers the historic risk drivers from a statistical perspective. As the ERCOT grid is evolving, the combination of risks that drive the need for Ancillary Services can differ significantly on different days and hours within the same week or month. Furthermore, there are two possible shortcomings of the approach that the current AS methodology uses.

First, the methodology does not incorporate all possible risk factors into a single stochastic calculation. For example, while the Non-Spin methodology accounts for the risk of net load under forecast error and unplanned generation trips, it uses a sliding percentile scale based on risk of net load up ramps to indirectly account for availability of other on-line/off-line capacity. Thus, the methodology does not indicate the true probability that a reserve shortage caused by insufficient Non-Spin quantities will lead to an adverse reliability outcome.

Second, there are not objective criteria by which to determine if the procured quantities of each AS will be sufficient or insufficient. Instead, the quantities are set based on percentiles of risk that are determined by ERCOT operating experience and judgment to prevent entering emergency operations.

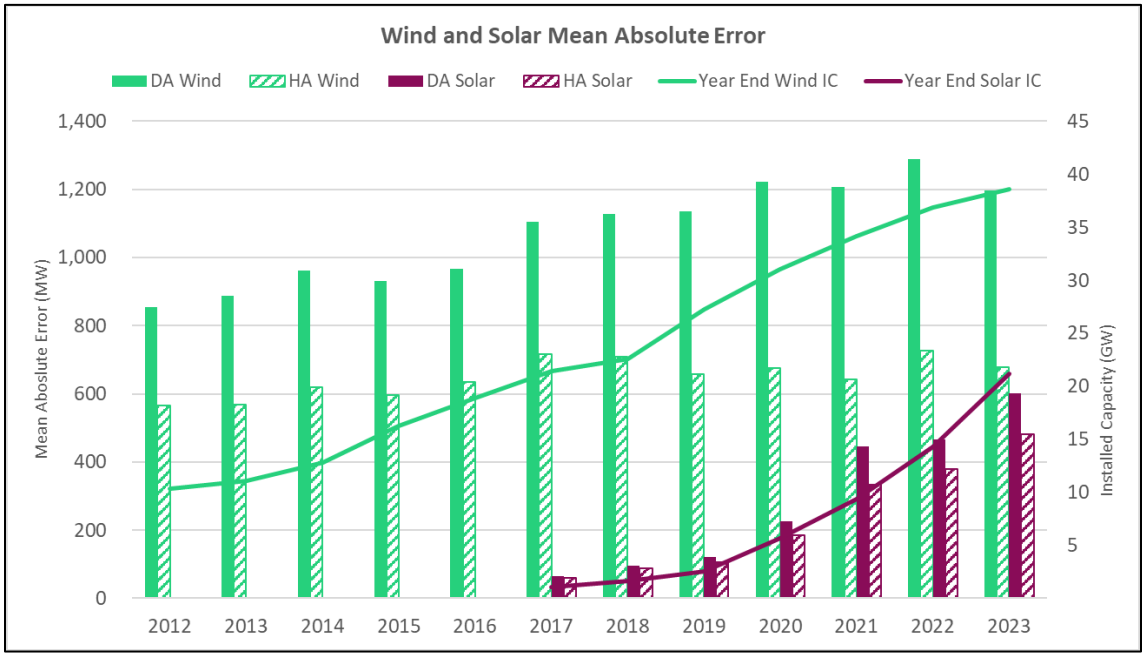
ERCOT recommends that a methodology be developed that will produce statistical reliability indexes that can be measured against objective criteria to determine quantity sufficiency or insufficiency. Recent improvements in data science may make such a methodology possible, whereas it may not have been feasible just a few years ago. However, to develop a robust, fully statistical framework to AS quantification will require much work and stakeholder discussion since the analysis of operational reserve needs is significantly more complex than the statistical analysis of planning reserve needs, historically performed as part of a loss of load probability (LOLP) study.

To develop a fully statistical AS quantity methodology the following topics should be considered with stakeholders:

- How should the available capacity that is not providing AS be accounted? In other words, should historic available headroom that is not providing AS be counted in the probabilistic risk analysis? For example, during early morning hours there has historically been a number of generators that have headroom but are not carrying AS and could respond to forecast errors,

thereby reducing the need for Non-Spin during these hours. That said, historically, ERCOT has set AS quantities based on as estimation of the risks. This approach guarantees that Resources with the right operational characteristics will be available to cover these risks and does not rely on past actions/behavior from Market Participants which may not may not continue.

- How should increases in variability and uncertainty due to wind, solar, and load growth, as well as future changes in generator commitment patterns be accounted for in the methodology?



- What are the appropriate criteria to use for each AS type? Are the criteria simply a matter of avoiding loss of load, or should there be criteria related to avoiding entering into an EEA or a Watch due to insufficient reserves? How should avoiding the need for manual operator actions be included in the criteria?
- How should temporal constraints and cumulative factors be accounted? The possibility of multiple generator trips across multiple hours (as occurred on May 13, 2022, for example) presents a risk that needs to be covered by AS. Increasingly, AS is being provided by duration-limited resources (battery energy storage). There is some risk that battery energy storage resources providing AS deplete their storage during a multi-hour forecast error event, even if they are meeting all applicable requirements. Also, AS is needed until other generators can be started or until the conditions causing the need for the reserves from AS change. All these factors present challenges when calculating the probabilistic need for AS.
- How much can other types of AS reserves be counted on to address risks for a given AS product? For example, should some or all of ECRS be counted towards meeting the reserve needs covered by Non-Spin?

Responses to these questions directly impact the volume of reserves procured and operational actions needed to continue operations. As an example, setting reserves too low could result in lower self-commitment and tools like RUC may be necessary to cover the overall expected operational risk on such days. For proper balance, stakeholder and potentially policymaker input on these issues is essential.

10.2 Dynamic AS quantity determination

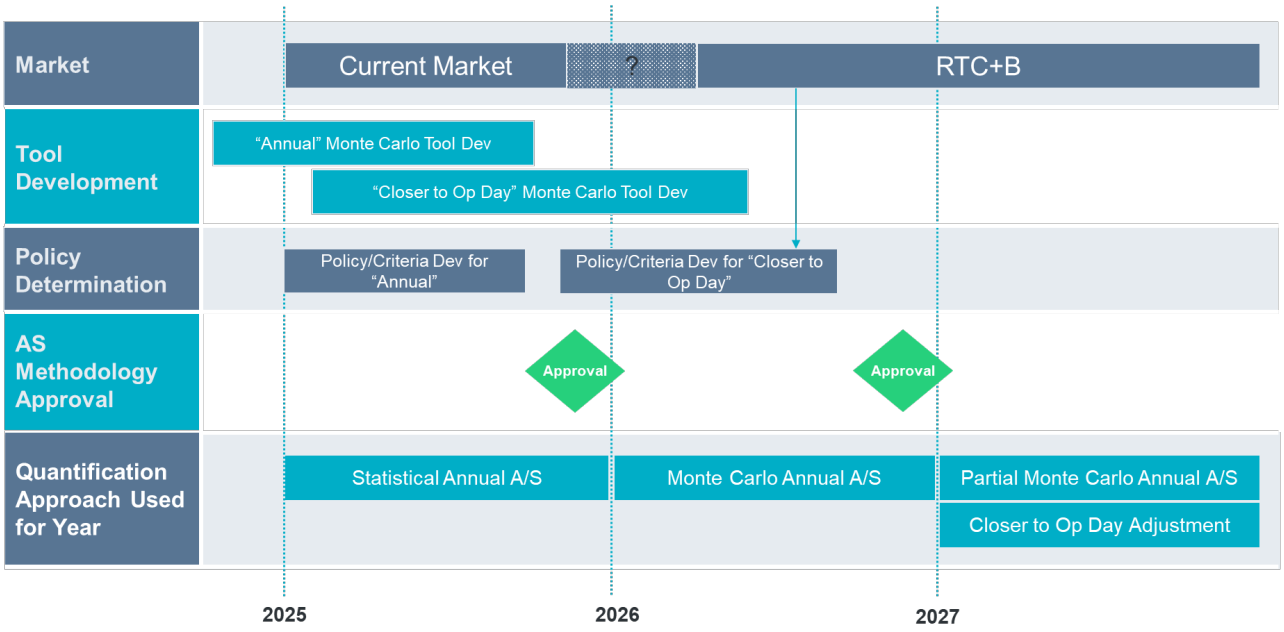
Several of the AS products are used to cover risks associated with load and generation variabilities. Those variabilities are expected to increase substantially in the future and can also differ significantly on different operating days and hours. The quantities of each AS product have increased in recent years to cover the most severe risks and this trend is expected to continue with the anticipated increases in passive response from demand, including LFLs, wind generation, solar generation, and resources on the distribution system, all of which can increase operational variability and uncertainty. Further, the difference between true minimum quantities or typical quantities of some AS products and the quantity needed to meet reliability risk objectives for worst-case or near worst-case conditions will be greater in the future.

Based on this, ERCOT should work with stakeholders to reexamine the tradeoffs between the certainty of calculating AS quantities on an annual basis and the efficiency of calculating at least some portion of AS quantities closer to the operating day. A possible framework could involve setting minimum, “expected,” and maximum AS quantities in an annual study, and then setting the actual quantity for an Operating Day before the DAM runs. The actual quantity would be within the minimum and maximum range.

11 Implementation of Recommended Changes

Both changes that ERCOT recommends constitute methodology changes. Accordingly, ERCOT could implement these changes by updating the AS Methodology, which includes stakeholder review, ERCOT Board of Directors endorsement, and PUC approval. However, implementing both changes will require the development of new software tools and stakeholder discussion on key decisions. ERCOT proposes the tentative implementation timeline shown in the table and graphic below but notes that the timeline could expand if answering the technical or policy questions related to the key decisions prove to be difficult.

RECOMMENDATION	Revamp the methodology used to calculate the non-frequency responsive portion of ECRS and Non-Spin quantities to use a probabilistic framework for quantifying reliability risks that these reserves are required to cover	Examine the benefits of determining some portion of AS quantities closer to the operating day based on days-ahead forecast conditions rather than strictly through an annual calculation
Software tool and model development	Q3-Q4 2024	Q3-Q4 2025
Key decisions	• What are the operational reliability criteria for determining AS quantities? • How should the available capacity that is not providing AS be accounted? • How much can other types of AS reserves be counted on to address risks for a given AS product? • How should forward looking changes be accounted? • How should temporal constraints and cumulative factors be accounted?	• What are the benefits of dynamic AS procurement in terms of MWs and costs? • What methodology should be used to set annual minimums? • What methodology should be used to set daily quantities?
Stakeholder discussion	Q1-Q2 2025	Q1-Q2 2026
Finalize software tools and update AS methodology	Q3-Q4 2025	Q3-Q4 2026
Tentative implementation	January 1, 2026	January 1, 2027



12 Potential Future AS Needs

As noted above, as the ERCOT Region continues to transform and as technology continues to evolve, Ancillary Services are expected to also transform and evolve. Appendix 4 lists the significant changes to the AS Methodology since 2016. Going forward, stakeholders should expect similar advancements.

Two topics that have elicited stakeholder discussions regarding possible changes to AS but have not yet been shown to be needed as new AS products are inertia and the impacts of the addition of new Large Loads.

Inertia

Inertia is the physical measurement of a power system's potential energy that is stored in the mass of rotating machines, primarily generators. Inertia levels, typically expressed in terms of GW-seconds, indicate a power system's ability to resist a change in frequency due to an imbalance in generation and load. As an example, when a generator trips offline suddenly, the inertia in a system prevents the frequency from dropping below 60 Hz too much and too quickly.

Inertia is inherently provided by synchronous generators, such as gas, coal, nuclear, and hydro resources. However, inverter-based resources (IBRs), namely wind, solar, and battery resources, do not provide inertia. It has been generally understood that as the resource mix changes to include a greater portion of IBRs and lesser amounts of synchronous generators inertia will decrease.

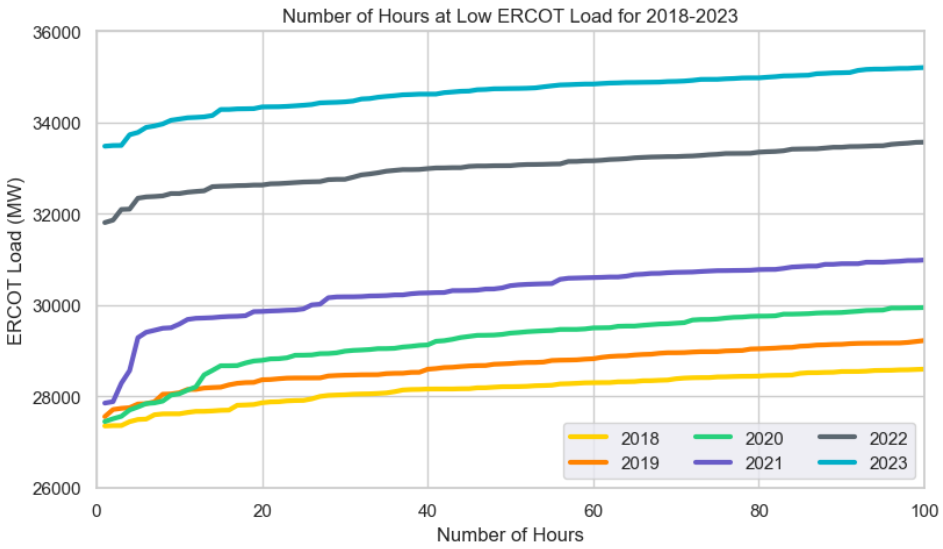
ERCOT has calculated a minimum inertia level (known as "critical inertia") of 100 GW-s, which is the amount of inertia needed to maintain stability. In ERCOT, inertia is typically between 200 GW-s and

400 GW-s depending on the number and size of synchronous generators that are online. Low inertia levels occur during times of low net load when the load is low, IBR generation is relatively high, and very few synchronous generators are online. These conditions usually occur in the spring and fall. The lowest inertia that ERCOT has experienced in the last ten years has been 115 GW-s, which occurred in March 2022.

ERCOT monitors inertia in real-time, and if inertia levels were to approach the critical inertia level, operators would use the RUC process to commit additional synchronous generation, thereby increasing inertia. This process ensures that reliability is maintained, but if ERCOT were to take this action on a regular basis, it may be more efficient to procure the inertia through a new or modified AS product.

ERCOT has not yet needed to use the RUC process to maintain inertia. Additionally, there are several developments that may lessen the chance that ERCOT would experience inertia levels near the critical inertia threshold. These developments include:

1. Minimum load levels have been and are expected to continue to increase due to increasing amounts of data center and oil and gas loads. The higher the minimum load levels, the more likely it is for synchronous generators to remain online, which results in higher inertia on the system.



2. The expected adoption of grid forming inverters is expected to lower the critical inertia level required by synchronous generators in ERCOT. Grid forming inverters are a new type of inverter that has advanced capabilities compared to the inverters on existing IBRs. While grid forming inverters do not provide inertia, they do provide stability when there is an imbalance between load and generation when a generator trips. Grid forming inverters are commercially available for battery energy storage resources, and ERCOT plans to propose grid forming inverter grid code specifications by the end of 2024 to provide guidance to stakeholders.

3. The planned addition of synchronous condensers in ERCOT will increase inertia on the system. Like synchronous generators, synchronous condensers inherently provide inertia. Synchronous condensers are planned to be added at six locations in w\est Texas by 2027. These synchronous condensers are expected to provide a total of at least 12 GW-s of inertia and are planned to be operated continuously, except for maintenance periods.

Because of these developments, at this time, ERCOT does not see a need to pursue AS product changes to address low inertia levels.

Large Load Related AS Changes

Recently, ERCOT has experienced a notable increase in new loads that are greater than 75 MW in size. These “Large Loads” present some unique challenges that may need to be addressed by changes to AS. Specifically, there are two challenges that could potentially be mitigated by AS changes and that, if not addressed, may cause reliability issues on the ERCOT system.

1. Some Large Loads, for example crypto-mining data centers, can quickly change consumption based on changes in ERCOT wholesale prices. If many Large Loads change their consumption at the same time and in a manner not coordinated with ERCOT, it could cause a significant imbalance between load and generation, which could cause frequency instability on the ERCOT system. This issue could be addressed by mandating those that are able to follow SCED must register as Controllable Load Resources (CLRs) and by establishing ramp rate limitations for Large Loads that cannot be CLRs, i.e., how fast a Large Load can change their consumption, or by increasing the amounts of AS that are procured to cover consumption changes by Large Loads. However, through mid-2024, ERCOT has not observed reliability problems due to Large Load consumption ramps. Based on this, ERCOT is not planning to make any related changes but will continue to monitor the issue.
2. The second challenge is related to how Large Load equipment responds to system faults, such as lightning strikes. When a fault occurs somewhere on the transmission system, the voltage of the equipment in the immediate vicinity of the fault will spike below normal levels. When this happens, certain voltage sensitive equipment, such as the power supplies of data center servers, will temporarily cease consuming power. This sudden reduction in consumption can cause an imbalance between load and generation, which could cause sudden frequency instability on the ERCOT system. Such an event occurred on the ERCOT system in December 2022 when multiple faults in west Texas caused the loss of 1,600 MW of consumption. In this case, frequency rose to 60.235 Hz, which is relatively high, but it did not cause any significant reliability problems on the ERCOT system. There are several ways this issue could be mitigated, including limiting the amount of load that can be connected to the transmission system at any single location, constructing transmission system improvements, establishing “voltage ride-through” requirements for Large Loads, or by creating a new type of AS to preserve “floor room” on generators so that the generators can respond to sudden load-generation imbalances and maintain frequency stability. At this time, ERCOT is not pursing a

new type of AS but is proposing to create a planning criteria that could help limit the maximum load loss that occurs during system faults. As the system and ERCOT Market Rules evolve, the need for a new type of AS should be assessed based on ERCOT's ability to maintain frequency below the levels that trigger NERC compliance issues or generation trips during actual system faults.

Appendix

Appendix 1: Excerpts from Nodal Protocol Section 3.17, Ancillary Service Capacity Products

Regulation Service

1. Regulation Up Service (Reg-Up) is a service that provides capacity that can respond to signals from ERCOT within five seconds to respond to changes from scheduled system frequency. The amount of Reg-Up capacity is the amount of capacity available from a Resource that may be called on to change output as necessary to maintain proper system frequency. A Generation Resource providing Reg-Up must be able to increase energy output when deployed and decrease energy output when recalled. A Load Resource providing Reg-Up must be able to decrease Load when deployed and increase Load when recalled. Fast Responding Regulation Up Service (FRRS-Up) is a subset of Reg-Up Service in which the participating Resource provides Reg-Up capacity to ERCOT within 60 cycles of either its receipt of an ERCOT Dispatch Instruction or the detection of a trigger frequency independent of an ERCOT Dispatch Instruction. ERCOT dispatches Reg-Up by a Load Frequency Control (LFC) signal. The LFC signal for FRRS-Up is separate from the LFC signal for other Reg-Up.
2. Regulation Down Service (Reg-Down) is a service that provides capacity that can respond to signals from ERCOT within five seconds to respond to changes from scheduled system frequency. The amount of Reg-Down capacity is the amount of capacity available from a Resource that may be called on to change output as necessary to maintain proper system frequency. A Generation Resource providing Reg-Down must be able to decrease energy output when deployed and increase energy output when recalled. A Load Resource providing Reg-Down must be able to increase Load when deployed and decrease Load when recalled. Fast Responding Regulation Down Service (FRRS-Down) is a subset of Reg-Down Service in which a participating Resource provides Reg-Down capacity to ERCOT within 60 cycles of either its receipt of an ERCOT Dispatch Instruction or the detection of a trigger frequency independent of an ERCOT Dispatch Instruction. ERCOT dispatches Reg-Down by an LFC signal. The LFC signal for FRRS-Down is separate from the LFC signal for other Reg-Down.

Responsive Reserve Service

1. Responsive Reserve (RRS) is a service used to restore or maintain the frequency of the ERCOT System in response to a significant frequency deviation.
2. RRS is automatically self-deployed by Resources in a manner that results in real power increases or decreases.
3. RRS may be provided by:
    a. On-Line Generation Resource capable of providing Primary Frequency Response with the capacity excluding Non-Frequency Responsive Capacity (NFRC);

b. Resources capable of providing Fast Frequency Response (FFR) and sustaining their response for up to 15 minutes;
c. Load Resources controlled by high-set under-frequency relays; and
d. Generation Resources operating in synchronous condenser fast-response mode as defined in the Operating Guides.

Non-Spinning Reserve Service

1. Non-Spinning Reserve (Non-Spin) is provided by using:
    a. Generation Resources, whether On-Line or Off-Line, capable of:
        i. Being synchronized and ramped to a specified output level within 30 minutes; and
        ii. Running at a specified output level for at least four consecutive hours;
    b. Controllable Load Resources qualified for Dispatch by Security-Constrained Economic Dispatch (SCED) and capable of:
        i. Ramping to an ERCOT-instructed consumption level within 30 minutes; and
        ii. Consuming at the ERCOT-instructed level for at least four consecutive hours; or
    c. Load Resources that are not Controllable Load Resources and are qualified for deployment by the operator using the Ancillary Service Deployment Manager and capable of:
        i. Reducing consumption based on an ERCOT Extensible Markup Language (XML) instruction within 30 minutes; and
        ii. Maintaining that deployment until recalled.
2. The Non-Spin may be deployed by ERCOT to increase available reserves in Real-Time Operations.

ERCOT Contingency Reserve Service

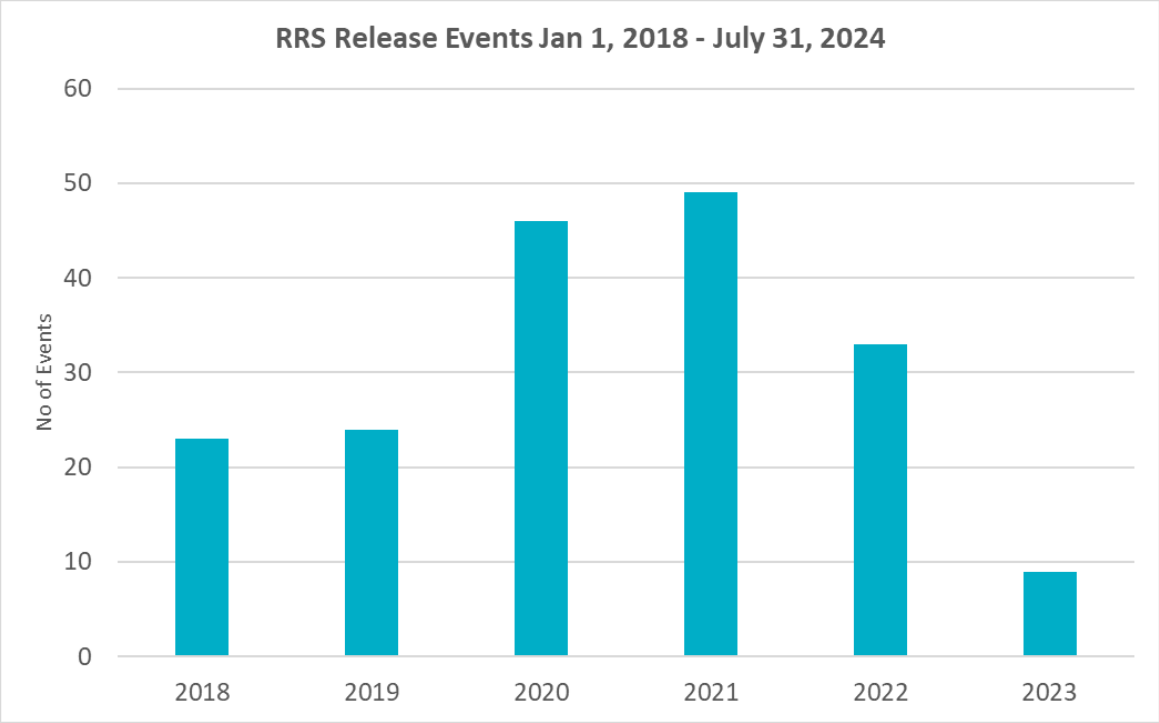
1. ERCOT Contingency Reserve Service (ECRS) is a service that is provided using capacity that can be sustained at a specified level for two consecutive hours and is used to restore or maintain the frequency of the ERCOT System:
    a. In response to significant depletion of RRS;
    b. As backup Regulation Service; and
    c. By providing energy to avoid getting into or during an Energy Emergency Alert (EEA).
2. ECRS may be provided through one or more of the following means:
    a. From On-Line or Off-Line Resources as prescribed in the Operating Guides following a significant frequency deviation in the ERCOT System; and
    b. Either manually or by using a four-second signal to provide energy on deployment by ERCOT.

3. ECRS may be used to provide energy prior to or during the implementation of an EEA. ECRS provides Resource capacity, or capacity from interruptible Load available for deployment on ten minutes' notice.
4. ECRS may be provided by:
    a. Unloaded, On-Line Generation Resource capacity;
    b. Quick Start Generation Resources (QSGRs);
    c. Load Resources that may or may not be controlled by high-set, under-frequency relays;
    d. Controllable Load Resources; and
    e. Generation Resources operating in synchronous condenser fast-response mode as defined in the Operating Guides.

Appendix 2: Historical Use of AS

The chart below summarizes the number of events when RRS was released between January 1, 2018 and July 31, 2024; the table below contains further details of each event.

It is worth noting that prior to implementation of ECRS (around June 10, 2023), RRS was manually released both during FMEs and during scarcity conditions using the approach outlined in Nodal Operating Guide Section 4.8. After implementation of ECRS, RRS is only released scarcity conditions, hence there is a stark reduction in RRS release events, post Jun 10, 2023.



RRS Event Start	RRS Event End	RRS Event Duration	Max RRS Released (MW)
2/2/2018 23:46	2/2/2018 23:49	0:03:16	680
2/5/2018 14:04	2/5/2018 14:10	0:05:04	939
2/6/2018 18:19	2/6/2018 18:21	0:01:32	271
2/14/2018 6:30	2/14/2018 6:33	0:02:44	273
4/15/2018 1:11	4/15/2018 1:14	0:02:44	308
4/21/2018 17:11	4/21/2018 17:15	0:03:40	1548
4/28/2018 9:50	4/28/2018 9:51	0:00:56	287
8/4/2018 8:20	8/4/2018 8:24	0:03:24	554

RRS Event Start	RRS Event End	RRS Event Duration	Max RRS Released (MW)
8/13/2018 23:00	8/13/2018 23:03	0:03:36	1103
8/15/2018 18:10	8/15/2018 18:14	0:03:36	745
8/16/2018 12:44	8/16/2018 12:48	0:04:08	393
8/18/2018 16:12	8/18/2018 16:16	0:03:32	896
8/31/2018 12:04	8/31/2018 12:09	0:05:36	215
9/1/2018 10:38	9/1/2018 10:43	0:04:44	228
9/4/2018 19:30	9/4/2018 19:34	0:03:43	756
9/19/2018 20:43	9/19/2018 20:47	0:04:15	1011
9/24/2018 1:39	9/24/2018 1:42	0:03:32	641
9/26/2018 13:54	9/26/2018 13:59	0:05:32	579
9/28/2018 1:12	9/28/2018 1:17	0:05:00	727
9/28/2018 12:00	9/28/2018 12:03	0:03:12	747
10/6/2018 1:30	10/6/2018 1:36	0:05:44	1039
10/15/2018 6:29	10/15/2018 6:32	0:02:40	228
10/19/2018 15:23	10/19/2018 15:27	0:04:00	756
3/2/2019 3:19	3/2/2019 3:24	0:05:36	1211
3/11/2019 21:24	3/11/2019 21:28	0:04:16	955
3/21/2019 13:40	3/21/2019 13:44	0:04:03	513
4/11/2019 3:38	4/11/2019 3:42	0:04:48	1034
4/18/2019 17:04	4/18/2019 17:09	0:04:24	775
4/19/2019 8:01	4/19/2019 8:05	0:04:36	638
4/25/2019 11:20	4/25/2019 11:23	0:03:04	1011
4/30/2019 9:37	4/30/2019 9:40	0:03:36	741
4/30/2019 21:11	4/30/2019 21:15	0:03:19	715
5/1/2019 10:17	5/1/2019 10:20	0:02:28	144
5/12/2019 8:57	5/12/2019 8:58	0:01:16	180
5/18/2019 15:25	5/18/2019 15:27	0:02:28	593

RRS Event Start	RRS Event End	RRS Event Duration	Max RRS Released (MW)
5/23/2019 16:41	5/23/2019 16:45	0:03:47	664
5/30/2019 2:56	5/30/2019 3:00	0:04:24	723
5/31/2019 11:56	5/31/2019 12:00	0:03:08	733
5/31/2019 21:06	5/31/2019 21:12	0:05:24	1138
7/15/2019 14:37	7/15/2019 14:41	0:04:36	564
7/22/2019 10:34	7/22/2019 10:38	0:03:44	332
7/23/2019 9:10	7/23/2019 9:14	0:04:00	271
7/29/2019 17:59	7/29/2019 18:04	0:05:47	1157
10/14/2019 15:31	10/14/2019 15:35	0:03:52	457
10/30/2019 21:29	10/30/2019 21:33	0:03:28	933
11/18/2019 16:20	11/18/2019 16:26	0:06:08	486
12/29/2019 22:27	12/29/2019 22:31	0:04:12	689
1/1/2020 12:53	1/1/2020 12:58	0:05:01	1150
1/10/2020 20:54	1/10/2020 20:58	0:04:12	1002
1/16/2020 18:04	1/16/2020 18:09	0:04:55	600
1/17/2020 10:01	1/17/2020 10:05	0:03:54	1099
2/6/2020 1:16	2/6/2020 1:20	0:03:52	429
2/6/2020 21:22	2/6/2020 21:29	0:06:32	845
2/10/2020 16:07	2/10/2020 16:13	0:06:32	854
3/1/2020 17:43	3/1/2020 17:47	0:03:52	520
3/2/2020 13:13	3/2/2020 13:18	0:05:08	506
3/18/2020 19:15	3/18/2020 19:20	0:04:32	958
3/22/2020 8:10	3/22/2020 8:14	0:04:12	852
3/26/2020 13:05	3/26/2020 13:10	0:05:16	671
4/8/2020 15:37	4/8/2020 15:42	0:05:39	635
4/22/2020 12:44	4/22/2020 12:49	0:05:29	679
5/6/2020 5:57	5/6/2020 6:01	0:03:32	423

RRS Event Start	RRS Event End	RRS Event Duration	Max RRS Released (MW)
5/7/2020 23:29	5/7/2020 23:33	0:03:32	595
5/12/2020 1:14	5/12/2020 1:20	0:06:12	707
5/31/2020 10:45	5/31/2020 10:53	0:07:52	1153
6/1/2020 9:48	6/1/2020 9:51	0:03:00	214
6/13/2020 12:00	6/13/2020 12:05	0:04:44	396
6/15/2020 17:22	6/15/2020 17:29	0:06:52	529
6/23/2020 16:54	6/23/2020 16:58	0:04:44	665
7/1/2020 18:28	7/1/2020 18:33	0:05:28	1162
7/6/2020 15:09	7/6/2020 15:15	0:06:08	1164
7/9/2020 20:14	7/9/2020 20:20	0:05:43	1163
7/16/2020 15:13	7/16/2020 15:20	0:06:44	794
7/20/2020 11:47	7/20/2020 11:54	0:06:08	1163
8/2/2020 15:17	8/2/2020 15:22	0:04:23	725
8/22/2020 23:47	8/22/2020 23:51	0:04:28	587
9/19/2020 16:02	9/19/2020 16:08	0:05:50	559
9/22/2020 21:04	9/22/2020 21:09	0:04:48	779
10/10/2020 14:18	10/10/2020 14:25	0:06:36	975
10/10/2020 16:44	10/10/2020 16:50	0:05:24	1150
10/13/2020 17:13	10/13/2020 17:20	0:06:24	620
10/19/2020 14:30	10/19/2020 14:36	0:05:24	598
10/26/2020 13:23	10/26/2020 13:26	0:03:20	606
10/27/2020 8:41	10/27/2020 8:46	0:04:44	1151
11/7/2020 18:05	11/7/2020 18:08	0:03:24	596
11/16/2020 9:51	11/16/2020 9:57	0:05:28	1163
11/21/2020 0:20	11/21/2020 0:25	0:05:12	1235
11/22/2020 1:22	11/22/2020 1:26	0:04:04	626
11/22/2020 12:35	11/22/2020 12:39	0:04:12	506

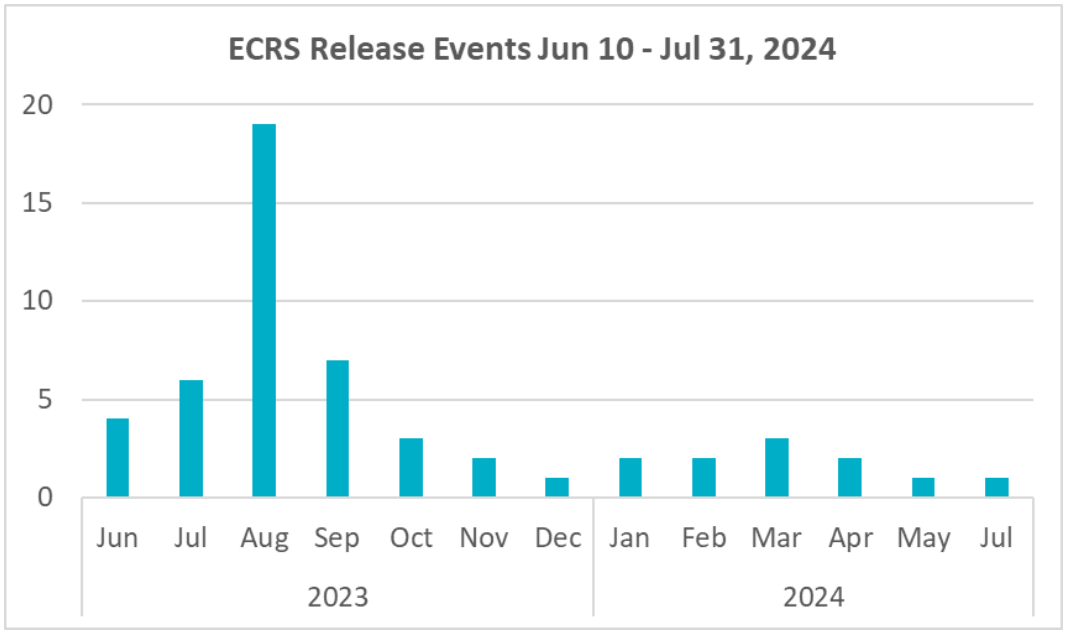
RRS Event Start	RRS Event End	RRS Event Duration	Max RRS Released (MW)
12/4/2020 7:44	12/4/2020 7:50	0:05:24	753
12/10/2020 14:34	12/10/2020 14:39	0:04:28	582
12/22/2020 15:46	12/22/2020 15:51	0:05:08	564
12/26/2020 20:49	12/26/2020 20:51	0:01:08	662
1/3/2021 11:34	1/3/2021 11:38	0:04:13	999
1/6/2021 18:20	1/6/2021 18:25	0:04:50	796
1/11/2021 13:03	1/11/2021 13:08	0:04:31	756
1/16/2021 21:35	1/16/2021 21:39	0:04:17	568
1/28/2021 14:21	1/28/2021 14:25	0:04:18	656
2/13/2021 8:36	2/13/2021 8:44	0:08:00	725
2/14/2021 23:19	2/15/2021 2:03	2:43:48	2000
2/15/2021 3:43	2/15/2021 11:56	8:13:08	1879
2/15/2021 17:08	2/15/2021 17:42	0:34:40	1000
2/15/2021 18:16	2/15/2021 19:28	1:12:20	1000
2/15/2021 21:42	2/15/2021 22:35	0:53:04	1000
2/16/2021 3:23	2/16/2021 9:31	6:08:04	1560
2/16/2021 12:49	2/16/2021 13:01	0:12:04	400
2/16/2021 14:27	2/16/2021 15:09	0:41:16	300
2/16/2021 17:29	2/16/2021 18:23	0:54:20	500
2/17/2021 6:05	2/17/2021 9:18	3:12:32	650
2/22/2021 5:39	2/22/2021 5:41	0:02:56	338
3/9/2021 16:33	3/9/2021 16:52	0:18:50	716
3/25/2021 0:59	3/25/2021 1:06	0:06:29	644
3/26/2021 23:10	3/26/2021 23:15	0:04:44	662
3/30/2021 18:01	3/30/2021 18:04	0:03:24	821
4/11/2021 19:20	4/11/2021 19:35	0:14:51	1350
4/11/2021 19:56	4/11/2021 20:20	0:23:13	500

RRS Event Start	RRS Event End	RRS Event Duration	Max RRS Released (MW)
4/13/2021 15:58	4/13/2021 18:40	2:42:40	1000
4/30/2021 22:14	4/30/2021 22:18	0:03:20	1277
5/9/2021 11:21	5/9/2021 11:24	0:02:26	859
5/19/2021 12:06	5/19/2021 12:10	0:03:32	514
5/24/2021 20:03	5/24/2021 20:08	0:05:08	913
5/25/2021 7:02	5/25/2021 7:06	0:04:40	1146
5/26/2021 23:14	5/26/2021 23:17	0:03:04	955
6/7/2021 15:26	6/7/2021 15:32	0:05:25	1420
6/20/2021 22:53	6/20/2021 22:58	0:05:19	588
7/20/2021 8:46	7/20/2021 8:50	0:04:22	696
8/10/2021 13:34	8/10/2021 13:37	0:02:53	624
8/16/2021 13:37	8/16/2021 13:44	0:07:12	797
9/9/2021 17:11	9/9/2021 17:18	0:06:44	644
9/12/2021 23:17	9/12/2021 23:21	0:03:44	1187
9/22/2021 9:15	9/22/2021 9:17	0:02:44	359
9/25/2021 15:39	9/25/2021 15:42	0:02:52	374
10/1/2021 11:11	10/1/2021 11:15	0:04:52	809
10/2/2021 5:51	10/2/2021 5:56	0:04:48	908
10/27/2021 1:11	10/27/2021 1:18	0:06:34	650
11/1/2021 4:57	11/1/2021 5:05	0:07:43	403
11/10/2021 11:23	11/10/2021 11:38	0:15:00	70
11/15/2021 17:53	11/15/2021 17:56	0:02:44	722
11/17/2021 14:32	11/17/2021 14:35	0:03:00	768
12/23/2021 9:33	12/23/2021 9:37	0:04:16	823
12/27/2021 9:57	12/27/2021 10:00	0:02:44	653
12/30/2021 12:41	12/30/2021 12:44	0:03:00	635
1/11/2022 9:15	1/11/2022 9:18	0:03:08	635

RRS Event Start	RRS Event End	RRS Event Duration	Max RRS Released (MW)
1/13/2022 18:06	1/13/2022 18:10	0:03:28	742
1/16/2022 19:03	1/16/2022 19:09	0:06:04	619
1/26/2022 2:28	1/26/2022 2:33	0:05:48	1053
2/4/2022 18:21	2/4/2022 18:27	0:05:52	822
2/22/2022 6:18	2/22/2022 6:20	0:01:48	786
3/12/2022 10:21	3/12/2022 10:25	0:04:12	469
3/14/2022 21:41	3/14/2022 21:45	0:03:56	543
3/21/2022 13:50	3/21/2022 13:52	0:01:25	620
3/22/2022 4:16	3/22/2022 4:19	0:02:44	524
3/29/2022 23:58	3/30/2022 0:01	0:02:33	743
4/13/2022 7:28	4/13/2022 7:34	0:05:12	1040
4/19/2022 15:16	4/19/2022 15:20	0:04:28	1159
4/20/2022 19:31	4/20/2022 19:36	0:05:04	671
5/8/2022 23:37	5/8/2022 23:42	0:04:20	555
5/13/2022 12:32	5/13/2022 12:36	0:04:16	553
5/24/2022 7:05	5/24/2022 7:07	0:02:48	662
6/4/2022 12:59	6/4/2022 13:00	0:01:19	1227
6/20/2022 19:26	6/20/2022 19:30	0:04:28	671
6/28/2022 16:18	6/28/2022 16:23	0:04:20	680
7/13/2022 15:16	7/13/2022 16:42	1:26:00	500
8/21/2022 19:27	8/21/2022 19:31	0:04:44	763
9/5/2022 23:48	9/5/2022 23:52	0:04:28	1219
10/6/2022 2:24	10/6/2022 2:30	0:06:12	941
10/6/2022 11:54	10/6/2022 11:57	0:02:24	558
10/8/2022 6:47	10/8/2022 6:51	0:04:08	252
10/16/2022 18:41	10/16/2022 18:45	0:03:36	576
10/20/2022 5:05	10/20/2022 5:11	0:06:36	849

RRS Event Start	RRS Event End	RRS Event Duration	Max RRS Released (MW)
10/21/2022 16:45	10/21/2022 16:49	0:03:04	769
10/26/2022 0:21	10/26/2022 0:25	0:04:04	540
10/27/2022 23:15	10/27/2022 23:20	0:04:48	704
12/8/2022 3:39	12/8/2022 3:43	0:03:32	484
12/17/2022 18:54	12/17/2022 18:59	0:04:56	648
1/24/2023 14:27	1/24/2023 14:31	0:04:16	570
4/12/2023 20:46	4/12/2023 20:49	0:02:38	382
5/1/2023 13:32	5/1/2023 13:35	0:02:56	664
5/23/2023 11:21	5/23/2023 11:24	0:03:20	263
5/24/2023 20:39	5/24/2023 20:42	0:03:32	455
8/17/2023 19:09	8/17/2023 20:06	0:57:00	893
8/25/2023 19:21	8/25/2023 20:11	0:50:00	1000
8/30/2023 19:25	8/30/2023 20:24	0:59:00	700
9/6/2023 18:59	9/6/2023 19:55	0:55:52	1100

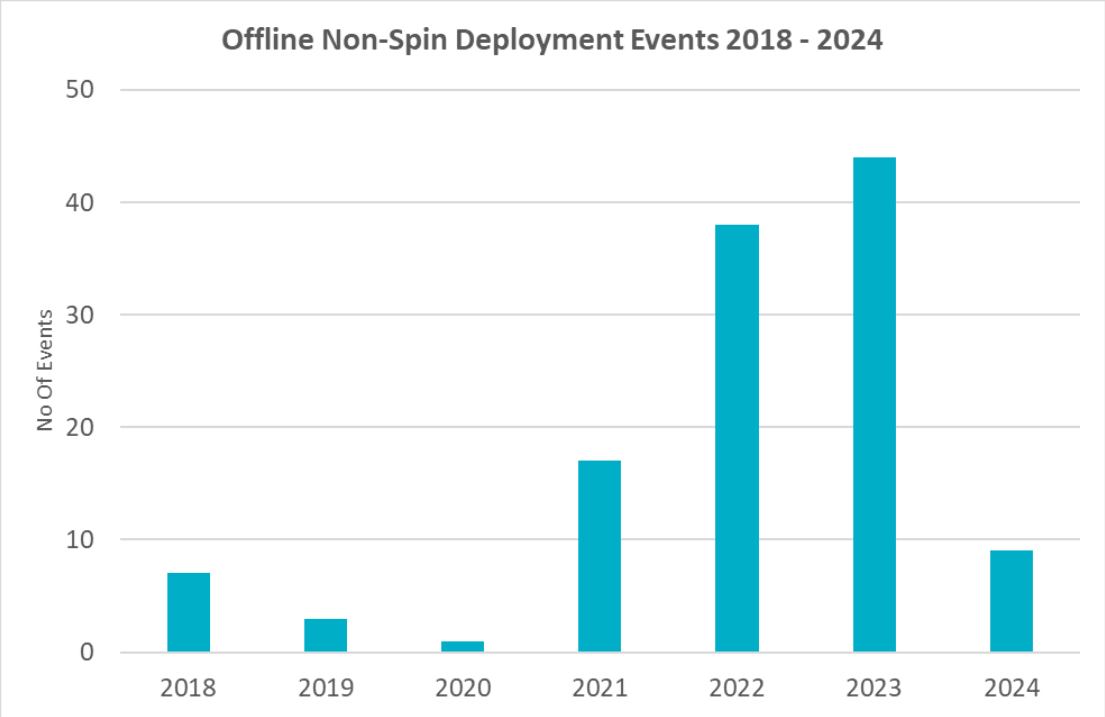
The chart below summarizes the events when ECRS was released between June 10, 2023 and July 31, 2024; the table below contains further details of each event.



ECRS Event Start	ECRS Event End	ECRS Event Duration	Max ECRS Released (MW)
6/14/2023 19:20	6/14/2023 19:33	0:13:00	600
6/16/2023 18:31	6/16/2023 18:36	0:05:00	430
6/18/2023 19:20	6/18/2023 19:45	0:25:00	200
6/20/2023 16:21	6/20/2023 21:01	4:40:00	1900
7/6/2023 21:05	7/6/2023 21:12	0:07:00	724
7/8/2023 19:57	7/8/2023 20:04	0:07:00	500
7/10/2023 19:21	7/10/2023 19:43	0:22:00	700
7/16/2023 10:41	7/16/2023 10:45	0:04:00	133
7/31/2023 18:35	7/31/2023 18:44	0:09:00	809
7/31/2023 19:35	7/31/2023 20:32	0:57:00	400
8/4/2023 17:03	8/4/2023 18:14	1:10:48	800
8/4/2023 18:52	8/4/2023 20:41	1:49:12	2472
8/6/2023 19:46	8/6/2023 20:26	0:39:20	1500
8/7/2023 16:42	8/7/2023 18:06	1:24:32	500
8/7/2023 18:57	8/7/2023 20:16	1:19:36	1500
8/8/2023 19:31	8/8/2023 20:27	0:56:16	1500
8/10/2023 15:29	8/10/2023 17:19	1:49:52	1500
8/10/2023 17:20	8/10/2023 20:18	2:58:32	1250
8/11/2023 18:31	8/11/2023 20:06	1:34:56	1750
8/12/2023 19:37	8/12/2023 20:12	0:34:40	500
8/15/2023 19:25	8/15/2023 20:31	1:05:44	500
8/17/2023 14:41	8/17/2023 20:46	6:04:40	2620
8/20/2023 19:11	8/20/2023 21:11	1:59:44	2000
8/22/2023 1:27	8/22/2023 1:35	0:08:00	674
8/24/2023 15:55	8/24/2023 20:41	4:45:48	2342
8/25/2023 18:21	8/25/2023 20:44	2:23:04	2579
8/26/2023 19:38	8/26/2023 20:46	1:07:56	500

ECRS Event Start	ECRS Event End	ECRS Event Duration	Max ECRS Released (MW)
8/29/2023 19:26	8/29/2023 20:01	0:35:08	700
8/30/2023 18:27	8/30/2023 20:41	2:13:32	2749
9/5/2023 19:20	9/5/2023 20:02	0:42:08	500
9/6/2023 14:57	9/6/2023 20:56	5:58:48	2600
9/7/2023 18:34	9/7/2023 20:03	1:29:04	1964
9/8/2023 16:06	9/8/2023 17:44	1:37:12	1000
9/8/2023 18:56	9/8/2023 19:32	0:36:00	750
9/17/2023 18:56	9/17/2023 19:27	0:31:00	500
9/22/2023 10:09	9/22/2023 10:13	0:04:00	232
10/5/2023 19:50	10/5/2023 19:56	0:06:12	498
10/19/2023 18:17	10/19/2023 18:44	0:27:08	500
10/25/2023 22:30	10/25/2023 22:31	0:00:12	651
11/13/2023 6:21	11/13/2023 6:25	0:03:36	149
11/13/2023 10:28	11/13/2023 10:33	0:04:56	546
12/14/2023 19:29	12/14/2023 19:36	0:07:00	805
1/1/2024 20:13	1/1/2024 20:19	0:06:00	549
1/16/2024 18:25	1/16/2024 19:07	0:42:00	400
2/27/2024 9:21	2/27/2024 9:28	0:07:00	779
2/28/2024 10:16	2/28/2024 10:19	0:03:00	329
3/4/2024 18:31	3/4/2024 19:20	0:49:00	550
3/12/2024 8:16	3/12/2024 8:24	0:08:00	852
3/17/2024 15:16	3/17/2024 15:19	0:03:00	820
4/16/2024 19:58	4/16/2024 20:32	0:34:00	200
4/28/2024 19:47	4/28/2024 21:10	1:23:00	1200
5/8/2024 19:07	5/8/2024 20:48	1:41:00	1827
7/24/2024 7:02	7/24/2024 7:08	0:06:00	884

The chart below summarizes the events when off-line Non-Spin was deployed between January 1, 2018 and July 31, 2024; the table below contains further details of each event.



NSRS Event Start	NSRS Event End	NSRS Event Duration	Max Off-Line NSRS Deployed (MW)
1/23/2018 6:43	1/23/2018 7:29	00:46:52	1005
4/11/2018 15:16	4/11/2018 23:59	08:42:04	50
4/12/2018 13:25	4/12/2018 23:59	10:33:43	203
4/25/2018 12:11	4/25/2018 17:18	05:06:56	140
5/1/2018 17:46	5/2/2018 8:00	14:13:46	86
5/2/2018 9:41	5/2/2018 22:00	12:19:43	66
5/3/2018 1:33	5/3/2018 16:01	14:28:09	14
9/22/2019 16:33	9/22/2019 16:35	00:01:49	74
10/5/2019 15:52	10/5/2019 17:05	01:12:55	305
12/22/2019 8:27	12/22/2019 12:00	03:32:37	115
2/3/2020 8:55	2/3/2020 13:58	05:02:46	145

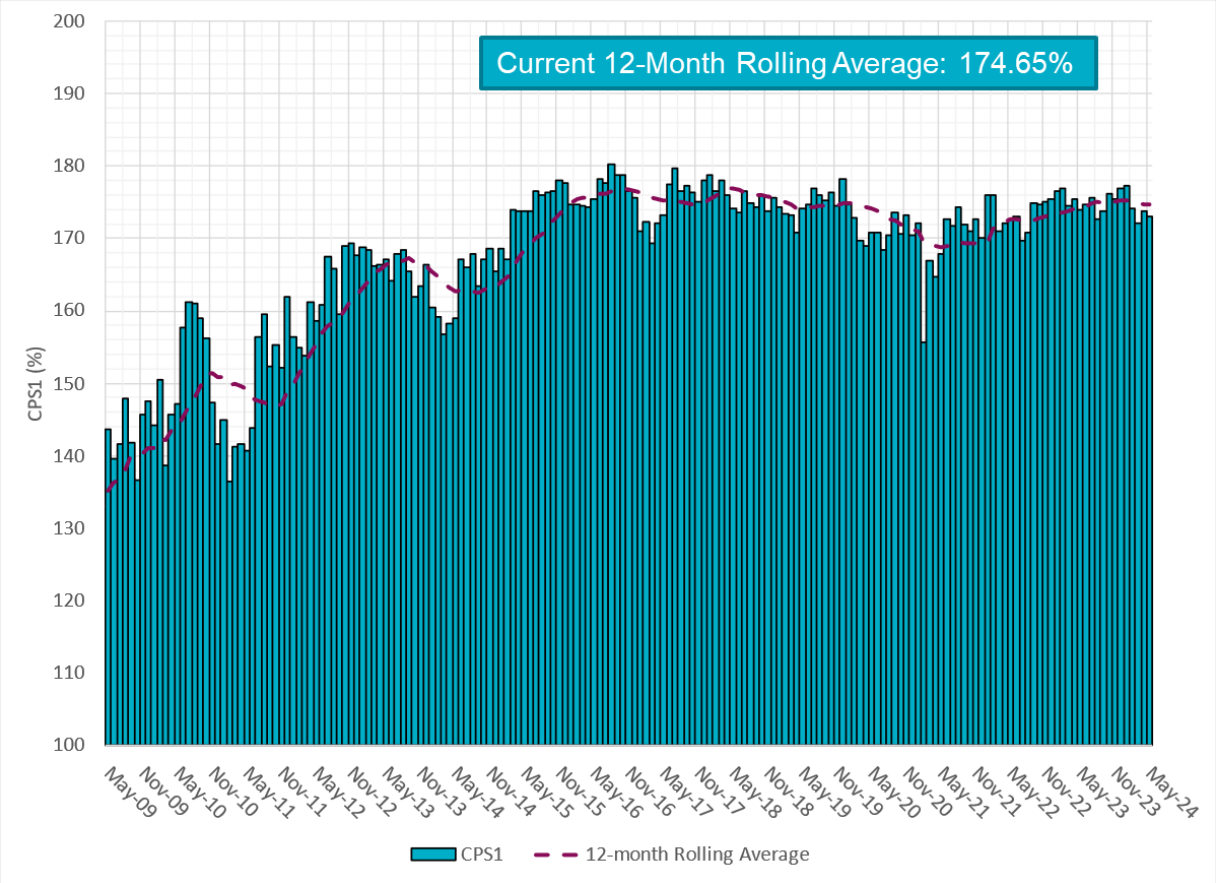
2/13/2021 8:46	2/13/2021 12:35	03:48:50	324
2/14/2021 23:17	2/19/2021 10:08	10:51:53	537
4/11/2021 19:21	4/11/2021 20:35	01:13:56	497
4/13/2021 15:47	4/13/2021 19:20	03:32:53	375
6/13/2021 15:37	6/13/2021 20:15	04:38:00	696
6/14/2021 14:13	6/14/2021 16:17	02:03:52	512
9/13/2021 19:07	9/13/2021 20:34	01:26:35	295
9/24/2021 16:18	9/24/2021 19:44	03:26:12	400
9/25/2021 15:46	9/25/2021 19:14	03:27:58	433
9/26/2021 19:06	9/26/2021 20:05	00:58:58	424
10/20/2021 12:57	10/20/2021 15:00	02:02:39	53
10/22/2021 14:00	10/22/2021 18:39	04:39:29	49
10/24/2021 18:44	10/24/2021 21:23	02:39:15	140
10/30/2021 17:51	10/30/2021 18:50	00:59:08	582
12/22/2021 7:14	12/22/2021 8:12	00:58:15	493
12/28/2021 17:53	12/28/2021 20:00	02:06:03	494
12/29/2021 7:54	12/29/2021 9:12	01:17:37	504
4/2/2022 16:05	4/2/2022 20:51	04:46:00	529
4/5/2022 15:48	4/5/2022 19:26	03:38:00	50
4/15/2022 15:18	4/15/2022 19:55	04:37:00	49
5/3/2022 1:03	5/3/2022 6:59	05:56:59	47
5/9/2022 13:23	5/10/2022 0:00	10:37:00	568
5/10/2022 14:32	5/11/2022 0:00	09:28:00	253
5/11/2022 14:45	5/11/2022 18:28	03:43:00	46
5/11/2022 14:45	5/11/2022 18:28	03:43:00	46
5/13/2022 14:48	5/13/2022 19:56	05:08:00	1018
5/26/2022 16:34	5/26/2022 20:08	03:34:00	840
6/14/2022 11:35	6/14/2022 20:31	08:56:00	158

6/15/2022 12:25	6/15/2022 20:08	07:43:00	157
7/8/2022 13:06	7/8/2022 18:24	05:18:00	939
7/9/2022 13:56	7/9/2022 21:16	07:20:00	891
7/10/2022 13:47	7/10/2022 20:23	06:36:00	897
7/11/2022 12:49	7/11/2022 16:38	03:49:00	611
7/13/2022 12:39	7/13/2022 19:01	06:22:00	877
8/9/2022 12:33	8/9/2022 16:43	04:10:00	592
8/23/2022 13:15	8/23/2022 22:15	09:00:00	617
8/28/2022 13:01	8/28/2022 18:28	05:27:00	2745
8/31/2022 10:46	8/31/2022 16:16	05:30:00	1157
9/3/2022 12:37	9/3/2022 21:52	09:15:00	1592
9/4/2022 13:38	9/4/2022 15:18	01:40:00	941
9/5/2022 13:40	9/5/2022 21:35	07:55:00	1869
9/9/2022 13:33	9/9/2022 20:13	06:40:00	722
9/11/2022 18:42	9/11/2022 21:15	02:33:00	784
9/13/2022 16:11	9/13/2022 19:55	03:44:00	905
9/28/2022 18:46	9/28/2022 21:04	02:18:00	1049
10/1/2022 18:55	10/1/2022 19:56	01:01:00	574
10/2/2022 16:46	10/2/2022 19:55	03:09:00	1726
10/4/2022 17:39	10/4/2022 19:47	02:08:00	1118
10/5/2022 15:50	10/5/2022 18:56	03:06:00	612
10/6/2022 18:01	10/6/2022 19:05	01:04:00	557
11/26/2022 16:45	11/26/2022 18:12	01:27:00	3988
12/13/2022 17:40	12/13/2022 19:30	01:50:00	2965
12/14/2022 18:43	12/14/2022 19:01	00:18:00	485
12/16/2022 17:42	12/16/2022 19:17	01:35:00	967
12/23/2022 6:52	12/23/2022 10:01	03:09:00	3222
1/3/2023 17:21	1/3/2023 18:30	01:09:00	1135

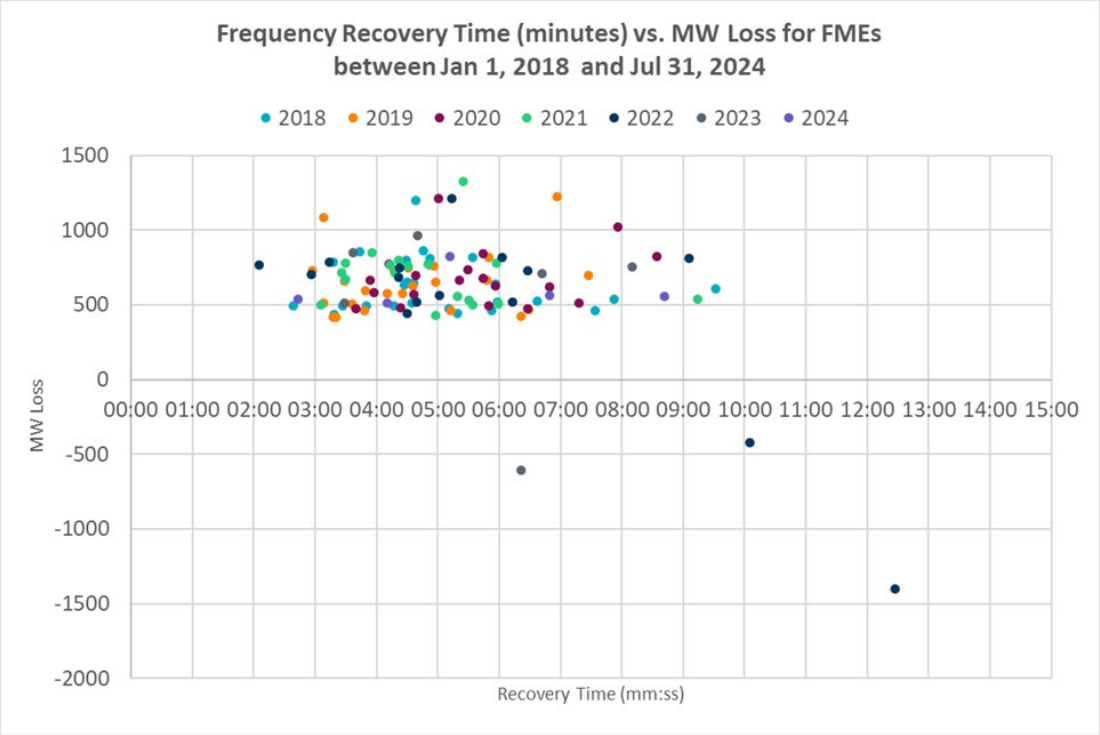
1/6/2023 16:53	1/6/2023 18:15	01:22:00	1215
1/9/2023 17:26	1/9/2023 17:56	00:30:00	514
1/17/2023 5:46	1/17/2023 7:25	01:39:00	468
2/8/2023 18:07	2/8/2023 18:40	00:33:00	544
3/21/2023 19:01	3/21/2023 19:50	00:49:00	545
3/22/2023 19:01	3/22/2023 19:51	00:50:00	525
3/24/2023 5:55	3/24/2023 7:19	01:24:00	1832
3/24/2023 18:55	3/24/2023 19:33	00:38:00	976
3/25/2023 18:44	3/25/2023 20:48	02:04:00	1829
3/26/2023 18:35	3/26/2023 20:03	01:28:00	2241
3/27/2023 18:32	3/27/2023 21:05	02:33:00	731
4/14/2023 19:15	4/14/2023 20:14	00:59:00	622
4/21/2023 18:54	4/21/2023 20:56	02:02:00	690
4/29/2023 19:39	4/29/2023 21:11	01:32:00	1183
5/4/2023 19:50	5/4/2023 20:25	00:35:00	447
5/11/2023 19:18	5/11/2023 21:18	02:00:00	1049
6/10/2023 19:16	6/10/2023 20:32	01:16:00	328
6/18/2023 19:36	6/18/2023 20:22	00:46:00	448
6/20/2023 16:24	6/20/2023 21:09	04:45:00	379
7/10/2023 19:21	7/10/2023 20:23	01:02:00	1081
8/4/2023 17:04	8/4/2023 20:43	03:39:22	123
8/7/2023 16:58	8/7/2023 20:19	03:21:27	129
8/10/2023 15:29	8/10/2023 20:23	04:53:33	117
8/11/2023 18:34	8/11/2023 20:09	01:34:37	112
8/12/2023 18:57	8/12/2023 20:13	01:16:18	244
8/13/2023 19:02	8/13/2023 20:06	01:03:24	199

Appendix 3: Effectiveness of AS

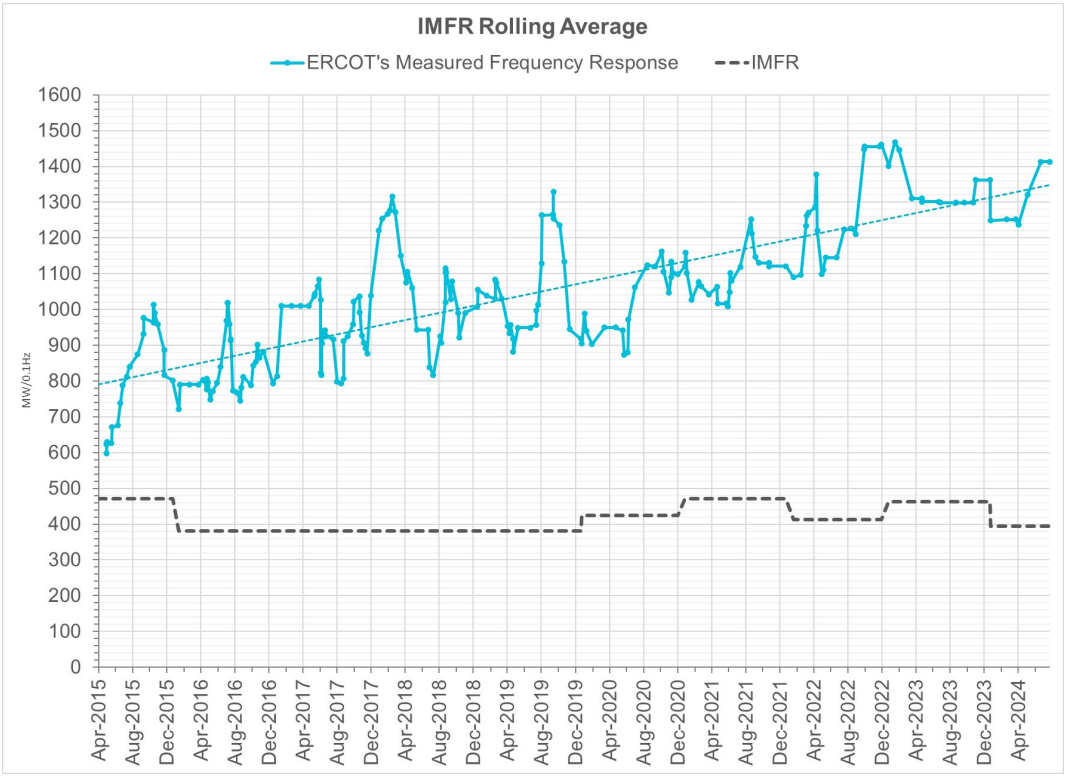
The efficacy of ERCOT's AS program with respect to frequency control is demonstrated through ERCOT's CPS1 performance, time taken to recover frequency back to pre-event value or 60Hz following a Frequency Measurable Event (FME) and ERCOT's Frequency Response Measure (FRM) performance. The chart below shows ERCOT's 12-month rolling average CPS1 score. ERCOT's CPS1 performance is one of the best in North America and is well above 100%, the minimum threshold for performance.



The image below demonstrates time taken to recover frequency during FMEs that occurred between January 1, 2018 and July 31, 2024. ERCOT was able to recover frequency in under 15 minutes in all the events during this timeframe.



The image below demonstrates measured frequency response (FRM) during FMEs that occurred between April 1, 2015 and July 31, 2024. ERCOT's FRM stayed well above ERCOT's Interconnection Minimum Frequency Response (IMFR) obligation.



Appendix 4: Changes to AS Methodology between 2016 and 2024

The table below summarizes the changes that were made to the AS Methodology between 2016 and 2024 to account for the reliability risks for which these AS quantities were being procured.

YEAR	AS METHODOLOGY CHANGE DESCRIPTION
2016	• Remove consideration of the last 30 days from Regulation analysis and instead use the Regulation data using same month of the previous two years; Use 95th percentile of 5-minute netload/deployments instead of 98.8th percentile in Regulation methodology. • Remove last 30 days from NSRS analysis and instead use the same month for previous three years; Use the 3-hour ahead net forecast error instead of 6-hour ahead; Use net forecast error only on the under-forecast; and use dynamic percentile between 70th and 95th percentile based on the risk of net load ramp in NSRS methodology
2017	• Remove Regulation exhaustion feedback and include solar into netload variability calculation in Regulation methodology
2018	• Include effects of solar in Net Load Forecast error & Net Load up-ramp risk calculations and include an adjustment to account for additional over-forecast uncertainty from projected increase in installed wind capacity in NSRS methodology
2019	• Remove 1,375 MW floor on NSRS quantities during On-Peak Hours (HE 7 thru 22)
2020	• No Changes.
2021	• Create and incorporate Solar adjustment tables into the Regulation Service methodology similar to the Wind adjustment tables. • Create and incorporate a Solar over-forecast error adjustment table in NSRS methodology.
2022	• A floor of 2800 MW applied to RRS quantities during the peak hours. • Use the highest 5-min net load within the hour and 6-HA netload forecast to calculate netload forecast uncertainty; change percentile coverage to vary between 85th and 95th; build a table that tracks historical intra-day variations in thermal resource availabilities due to Forced Outages to compute NSRS quantities.
2023	• Introduced ECRS beginning June 10, 2023. • NSRS methodology was changed such that prior to ECRS implementation, update the hourly net load forecast uncertainty calculation to use ten hours ahead net load forecast. Upon ECRS implementation, update the hourly net load forecast uncertainty calculation to use six hours ahead net load forecast and the average net load. Change in the percentile coverage for off-peak hours such that NSRS requirements for these hours is determined using 75th percentile of historical hourly net load forecast uncertainty.
2024	• Remove 2,800 MW floor for RRS during the peak hours. • A floor on the percentile coverage for sunset hours such that the ECRS requirements for these hours are determined using at least 90th percentile of historical intra-hour net load uncertainty. Change the frequency recovery related computations such that ECRS requirements are determined using 2 years of historic information, cover 60% of historic net load and inertia conditions and account for Regulation requirement in the hour.

- Change the percentile coverage for HE23 to HE02 in Winter and HE23 to HE06 rest of the year such that NSRS requirements for these hours is determined using 68th percentile of historical hourly net load forecast uncertainty.
- Change approval process for the AS Methodology so that the PUC is the final approver rather than the ERCOT Board of Directors.

Appendix 5: Reserve Product Comparison

Product Type	Outside of U.S.			United States						
	AEMO	Eirgrid (Ireland)	National Grid (United Kingdom)	ISO-NE	NYISO	PJM	MISO	SPP	ERCOT	CAISO
Region Facts	Max Demand 35,796 MW Min Demand 11,892 MW Wind Capacity 11,392 MW Solar Capacity 9,644 MW Rooftop Solar Capacity 19,642 MW	Max Demand 5,577 MW Wind Capacity Solar Capacity Rooftop Solar Capacity	Max Demand 55 GW Min Demand 15 GW Wind and Solar Capacity 35 GW (Includes 2.9 GW of Rooftop solar capacity)	Max Demand 28,130 MW (Aug 2006) Wind Capacity as of Dec 2023: 1,400 MW Solar Capacity mostly Rooftop as of Dec 2023: 6,500 MW	Max Demand 33,956 MW (July 2013) Wind Capacity as of Dec 2023: 2,736 MW Solar Capacity as of Dec 2023: 194.4 MW Rooftop Solar Capacity as of Dec 2023: 5,227 MW	Max Demand 165,563 MW (Summer 2006) Wind Capacity as of Jun 2022: 1,570 MW Solar Capacity as of Jun 2022: 2,665 MW	Max Demand 127.1 GW (7/20/2011) Wind Capacity as of Dec 2023: 30.56 GW Solar Capacity as of Dec 2023: 7.6 GW	Max Demand 56,184 MW (8/21/2023) Wind Capacity as of Jun 2024: 5.4 GW Solar Capacity as of Jun 2024: 396 MW	Max Demand 85,559 MW (8/20/2024) Wind Capacity as of Jun 2024: 39,450 MW Solar Capacity as of Jun 2024: 25,333 MW	Max Demand 44,534 MW (8/16/2023) Wind Capacity as of Aug 2024: 8,352 MW Solar Capacity as of Aug 2024: 19,638 MW Rooftop Solar Capacity as of Aug 2024: 10,000 MW

Product Type	Outside of U.S.			United States						
	AEMO	EirGrid (Ireland)	National Grid (United Kingdom)	ISO-NE	NYISO	PJM	MISO	SPP	ERCOT	CAISO
Total AS Products Procured Using Pre-Day Ahead or Day Ahead or Real Time Markets	10[4]	(Current) 10 (AS product suite is in active transition. Products and counts may change in future)	(Current) 20 (AS product suite is in active transition. Products and counts may change in future)	4	3	4	5 or 6	6	5	6 or 7
Regulation Service	Regulation raise and Regulation lower	Primary Frequency Control Secondary Frequency Control	Regulating Reserve changing to Dynamic Regulation and Dynamic Moderation	Regulation	Regulation	Regulation	Regulation	Regulation Up Regulation Down	Regulation Up Regulation Down	Regulation Up Regulation Down
Frequency Response		Fast Frequency Response Primary Operating Reserve Secondary Operating Reserve	Dynamic Containment, Static Firm Frequency Response and Dynamic Firm Frequency Response	-	-	-	-	-	Responsive Reserve Service	-

[4] For AEMO, SPP, ERCOT, and CAISO, it's relevant to note that these numbers include the fact that these markets have separate Regulation Up and Regulation Down AS products. The other regions also have Regulation Up and Regulation Down (i.e., Regulation to address frequency deviations in either direction), but they are part of one singular Regulation product.

Product Type		Outside of U.S.			United States						
		AEMO	Eirgrid (Ireland)	National Grid (United Kingdom)	ISO-NE	NYISO	PJM	MISO	SPP	ERCOT	CAISO
Contingency Reserve	**Spinning**	Very fast raise & lower (1 second raise & lower) Fast raise & lower (6 second raise & lower) Slow raise & lower (60 second raise & lower) Delayed raise & lower (5 minute raise & lower)		(Proposed) Quick Reserve (Proposed) Slow Reserve	Ten-Minute Spinning Reserve (TMSR)	Spinning Reserve	Synchronized Reserve (SR)	Spinning Reserve	Spinning Reserve	ECRS	Spinning Reserve
	Non-spinning reserves and supplemental reserves	-	Tertiary Primary Operating Reserve Band 1 Tertiary Operating Reserve Band 2 Replacement Reserve Substitute Reserve	Short term operating reserve	Ten-Minute Non-Spinning Reserve (TMNSR) Thirty-Minute Operating Reserve (TMOR)	Non-spinning reserve	Non-Synchronized Reserve (NSR) Secondary Reserve	Supplemental reserve	Supplemental Reserves	Non-spin reserve	Non-spinning Reserve

Product Type		Outside of U.S.			United States						
		AEMO	Eirgrid (Ireland)	National Grid (United Kingdom)	ISO-NE	NYISO	PJM	MISO	SPP	ERCOT	CAISO
			Contingency Reserve								
Ramp Products	**Short Horizon**	-	(Proposed) Ramping Margin 1 Hour (Proposed) Ramping Margin 3 Hour (Proposed) Ramping Margin 8 Hour	Start up and Hot standby	-	-	-	Up and down Ramp Capability	Ramp Capability Product	ECRS	Flexible Ramping Product– upward and downward reserves
	Longer Horizon							Short-Term Reserve	Uncertainty Product	Non-Spin Reserve	Imbalance Reserve