

### **Filing Receipt**

Filing Date - 2024-04-04 03:42:56 PM

Control Number - 54584

Item Number - 55



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ercot.com

April 4, 2024

Public Utility Commission of Texas Chairman, Thomas J. Gleeson Commissioner Kathleen Jackson Commissioner Lori Cobos Commissioner Jimmy Glotfelty 1701 N. Congress Avenue Austin, TX 78711

Re: PUC Project No. 54584, Reliability Standard for the ERCOT Market

Dear Chairman and Commissioners:

Electric Reliability Council of Texas, Inc. (ERCOT) submits this update regarding the Reliability Standard for the ERCOT Market. Since the last update, ERCOT has completed the modeling of the final proposed reliability standard study scenarios and completed the initial steps in the Cost of New Entry (CONE) study. Presentations regarding the reliability standard study results and CONE reference technology are included for your review.

#### **Reliability Standard Study Modeling**

ERCOT has completed the modeling of the phase four reliability standard study scenarios (included here as Attachment C). As proposed at the Public Utility Commission of Texas' (Commission) January 18, 2024 Open Meeting, this phase of work further limited the range of Loss-of-Load Expectation (LOLE) frequency scenarios, simulated smaller LOLE increments within that range, and updated the scenario portfolios based on the December 2023 Capacity, Demand, and Reserves (CDR) Report. The attached presentation provides an overview of the system cost analysis for phase four, including background on the study design and comparison of high system cost years (Attachment B). Also provided is an analysis of the seasonal solar and wind capacity equivalents that would be necessary to replace the combustion turbine capabilities simulated in the Strategic Energy & Risk Valuation Model (SERVM).

During the analysis of the additional reliability standard study runs, ERCOT discovered a bug impacting battery scheduling simulations in SERVM. The issue produced erroneous negative market prices during negative net load hours, thereby resulting in the over-curtailment of solar resources and depressed market costs. Astrape corrected the bug in SERVM and ERCOT reran the previous 76 scenarios simulated for phase three that were previously filed with the Commission in January. The revised scenarios are included in the attached reliability standard study results tables. Overall, there was a substantial increase in market costs and a general increase in portfolio reliability.

#### CONE Study Update

ERCOT has engaged The Brattle Group (Brattle) to conduct a study to determine one or more CONE values. These values may be used for various market and reliability-related purposes, including calculating the value of Performance Credits under the Performance Credit Mechanism (PCM) and the Peaker Net Margin.

ERCOT formalized its study engagement with Brattle in December 2023. Brattle has now completed the first two steps of the engagement—specifically, identifying a primary and alternative reference generation technology. The primary reference technology is intended to be an example of a thermal, dispatchable generation plant that is likely to be developed in the next few years. Based on recently built and planned thermal dispatchable generation, the primary reference technology identified by Brattle is a ProEnergy GE LM6000 combustion turbine operating in a 6 x 0 configuration, providing an aggregate capacity of 484 MW, and located in Harris County.

The alternative reference technology is intended to be an example of a dispatchable renewable plant that is most likely to be developed in the ERCOT Region in the next few years and that may be used as a basis for sensitivity analysis of the primary case. Based on recently built and planned projects, the alternative reference technology identified by Brattle is a hybrid solar-storage facility consisting of 200 MW of photovoltaic capacity and 100 MW of battery energy storage capacity located in Brazoria County.

Brattle is now developing cost estimates for these technologies. At the Supply Analysis Working Group (SAWG) meeting on March 22, 2024, Brattle and ERCOT invited stakeholder to provide comments on the reference technologies as well as the after-tax Weighted Average Cost of Capital (WACC), a key financial parameter for the CONE calculations (Attachment D). Brattle is compiling a summary and response document based on provided comments. The final calculated CONE values, an Excel spreadsheet model for CONE sensitivity analysis, and a draft CONE study report are expected to be filed by late April 2024. The final CONE study report is expected to be filed by end of May 2024.

#### Next Steps

ERCOT is seeking confirmation from the Commission on next steps in the reliability standard study. This delivery of the phase four scenarios completes the final modeling recommended by ERCOT at this time. To help the Commission interpret the analysis and begin to narrow the scope for stakeholder feedback, ERCOT has developed a white paper (included as Attachment A) with recommendations on certain input parameters. ERCOT representatives will be available at the April 11, 2024 Open Meeting to present this information and answer any questions that you may have regarding the reliability standard study phase four results, recommendations, and the CONE study update.

Respectfully submitted,

/s/ Woody Rickerson\_\_\_\_\_

Woody Rickerson, P.E. Vice President, System Planning and Weatherization

#### Reliability Standard: Potential Methodology for Interpreting the ERCOT Analysis

#### Background

Senate Bill 3 from the 88<sup>th</sup> Legislative Session required the Public Utility Commission of Texas (Commission or PUC) to ensure that ERCOT establishes requirements to meet the reliability needs of the power region. The Commission initiated PUC Project 54584 to establish a Reliability Standard for the ERCOT Region. The new standard would replace the 13.75% Reserve Margin previously approved by the ERCOT Board of Directors, which does not have a regulatory requirement to maintain.

Beginning in 2023 and after consultation with PUC Staff, ERCOT proposed a framework for this new Reliability Standard that was based on three criteria: Frequency, Magnitude, and Duration. Frequency is a measure of how often a loss-of-load (LOL) event occurs and is measured as an expected value (i.e., a probability-weighted average of LOL events over a given period for many Monte Carlo simulation outcomes). This frequency measure is called the Loss of Load Expectation, or LOLE. Magnitude considers the maximum hourly MW of all LOL events across many simulation outcomes, while Duration accounts for the maximum hours experienced for a single LOL event across the simulation outcomes.

ERCOT used the November 2022 Capacity and Demand Report (CDR) as the basis for the load and Resource information. The analysis focused on results for 2026 and used the Strategic Energy & Risk Valuation Model (SERVM) to perform a Monte Carlo probabilistic analysis of potential reliability outcomes based on a range of scenario variables. In total, ERCOT reported results for 76 different scenarios prior to the latest scenario set, referred to as Phase 4 scenarios. Each scenario and the corresponding results were based on 5,250 individual runs that capture a range of load, wind, solar, and thermal unit outage values.

Weatherization Effectiveness	Varied from 70% – 90% effectiveness at preventing weather-related thermal outages tied to low winter wind chill temperatures
Number of Historic Weather Years	42 weather years or a subset of the most recent 15 years
Retired Thermal Unit Capacity	Either 900 MW or 3300 MW
Type of New Units Added to Scenarios Requiring Additional Generation Beyond the 2026 Expected Portfolio	Gas combustion turbines (CTs) or a proportional mix of planned wind, gas, and battery storage capacity reflected in different CDR reports

In addition to the three reliability criteria proposed for the Reliability Standard, ERCOT used four secondary scenario variables to provide a larger set of unique scenarios:

The first of the secondary variables consisted of the effectiveness of new weatherization standards and the associated ERCOT inspection process in preventing weather-related Forced Outages on

thermal units. The second variable considered the number of historic weather years used in the analysis. For the 5,250 Monte Carlo runs for each scenario, SERVM randomly selects one of the historic weather years. Each weather year is associated with hourly 2026 forecasted loads (based on the historical weather conditions) and intermittent renewable generation amounts, also based on historical weather conditions. ERCOT started the analysis with a 42-year weather set and also considered a smaller set comprising the most recent 15 weather years. Use of this smaller set puts larger weight on the more recent winter storm events. The analysis used a third variable to modify the number and type of units that would retire before 2026. Finally, a fourth variable considered the types of new generation that were added for some scenarios.

Altogether, the primary variables (Magnitude, Frequency, and Duration) along with the secondary variables (weatherization effectiveness, weather years, retirements, different combinations of new generation) resulted in 98 different scenarios.

In addition to the three primary criteria and four secondary variables, there are also several important scenario outcomes to consider in determining a new Reliability Standard. These are listed in the table below:

Summer and Winter Reserve Margins	Traditional Reserve Margin for the scenario during Summer Peak or Winter Peak provides a comparison to conditions ERCOT has traditionally seen.
Expected Unserved Energy (EUE)	EUE is the amount of energy (MWh) not served resulting from LOL events. Like LOLE, it is a probability-weighted average of amounts across all runs for a scenario. For a given hour, EUE is equivalent to the product of the Magnitude and Duration for that hour. It is a more common metric used in other markets and useful for comparisons.
Total System Cost (Market Cost + Customer Load Shed Damages + New Generation Fixed Cost)	Useful number that quantifies the annual ratepayer cost for electricity in ERCOT. It incorporates energy and Ancillary Services costs to serve load, customer load shed damage costs (EUE multiplied by the Value of Lost Load (VOLL)), and the fixed cost of new generation. (Note that for this analysis, the Market Cost is equivalent to the Customer Cost—the latter reflecting what ratepayers actually pay for electricity.)
Exceedance Probability for Duration and Magnitude	Exceedance Probability is the probability that a LOL event will exceed the maximum Duration or maximum Magnitude standards for any given scenario. A 3% Exceedance Probability indicates that 3 out of 100 LOL events will exceed either the maximum Magnitude or maximum Duration threshold.

MWs of Additional (New) Dispatchable Generation	This is a measure of additional generation capacity that must be added for the three primary criteria to be met. Additional information is also included in the analysis to examine the variable costs and market costs associated with the additional amounts of generation
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#### Methodology

What follows is a potential approach for parsing the 98 different scenarios. The methodology uses all the primary criteria as well as the secondary variables.

- **Magnitude** In the fall of 2023, ERCOT surveyed the Transmission Service Providers (TSPs) responsible for administering rotating outages during a load shed event. An ERCOT Request for Information determined that the total load that is not critical or transmission-connected while reserving the 25% Under Frequency Load Shed (UFLS) is 31.7 GW at a 75 GW system load. Taking roughly 60% of the 31.7 GW provides an estimated amount of load (19 GW) that could be effectively rotated. A load shed amount exceeding 19 GW could result in some portion of the total required load shed amount not being rotated. This upper limit of 19 GW sets a boundary for considering how high the Magnitude variable can currently be set while maintaining rotation of all the outaged loads. Further investment in the distribution system or changes to the number or treatment of critical loads could raise the Magnitude variable to a value greater than 19 GW. This number will also change as new load is added to the system. The addition of future transmission-connected load is not included in the load shed plan.
- **Duration** The Duration criteria is closely correlated to the Magnitude in the scenario results. When maximum Magnitude is restricted to values less than 19 GW, the maximum Duration results never exceed 14 hours. If you assume the Magnitude limitation of 19 GW allows all the load outaged during a LOL event to be rotated, 14 hours, even in a winter event, could be considered an acceptable LOL event duration. It is also relevant to remember that the ERCOT analysis of risk for the Reliability Standard indicates the LOL event risk is dominated by winter events.
- Frequency For Frequency, a 1-in-5 value indicates that a LOL event is expected to occur once every five years. A Frequency of 1-in-20 would result in an expectation that a LOL event would occur once every 20 years. The lower the Frequency ratio the more often a LOL event is expected. If the Frequency of the LOL events are allowed to be as low as 1-in-5 years or 1-in-8 years, the resulting Magnitude exceeds the 19 GW Magnitude threshold when utilizing the 42-year weather set. Once the Frequency is set to 1-in-10, 15, or 20 years, approximately a third of the subset of scenario outcomes result in maximum Magnitude (19 GW) and maximum Duration (14 hour) values that meet the Magnitude and Duration criteria discussed previously. Historically, the LOLE frequency of 1-in-10 years has been a widely accepted industry standard.

**ERCOT recommendation** – Maximum Magnitude should not exceed 19 GW, Frequency should be no more frequent than 1-in-10 years (e.g., 1-in-20 years), and the maximum Duration should not exceed 14 hours.

The following is an examination of the four secondary variables and how their variability affects the overall results.

• Weatherization Effectiveness – ERCOT, based on field inspections of actual preparations, number of cure periods required, and a limited number of winter storm experiences (Winter Storms Elliot in 2022 and Mara in 2023), estimated that the weatherization effectiveness variable should be set at least as high as 85%. At the PUC Staff's request, the weatherization effectiveness variable was also tested at 70% and 90%. Using EUE as a measure, an increase of 1% in weatherization effectiveness resulted in an average 0.4% decrease in EUE. Using new CT capacity as a measure, a 1% increase in weatherization effectiveness resulted in an approximately 3% decrease in new CT capacity. Therefore, the overall effect of changing the measurement from 85% to 90% does not dramatically alter the overall results.

**ERCOT's recommendation** – For studies supporting the Reliability Standard, the weatherization effectiveness should be set at 85% or 90% until metrics are available to make more precise effectiveness estimates.

• Number of Historic Weather Years – ERCOT has access to 42 years of weather data along with power conversion models that account for temperature, wind speed, solar irradiance, and other variables. These probabilistic variables, along with probabilistic Forced Outage modeling, was the basis for SERVM simulations. ERCOT was also asked to consider only the most recent 15 years of weather data. This approach gave a heavier weighting to Winter Storm Uri making it like a 1-in-15-year storm. Most analysis agrees that, for Texas, Winter Storm Uri was closer to a 1-in-100-year storm. The move to a 15-year weather set instead of 42 years dramatically worsens reliability outcomes. For a Frequency of 1-in-10 years, the 15-year weather set resulted in a 25% increase in maximum LOL event durations, a 53% increase in maximum LOL event magnitudes, and a 188% increase in the amount of new dispatchable generation needed compared to the 42-year weather set.

**ERCOT's recommendation**–Use at least the full 42 years of weather data for Reliability Standard studies.

• Number of Retirements – ERCOT used both 900 MW and 3300 MW of retirements for the 2026 modeled year. The 900 MW figure came from facilities that have provided a public intent to retire. The 3300 MW number was based on an analysis that considered thermal units at risk of retirement by 2026 because of proposed Environmental Protection Agency (EPA) emission rules. The upcoming changes in the market structure, projected load growth, and existing and potential litigation over the EPA's proposed rules, make it difficult to predict the number of retirements that could eventually occur. The Commission could choose the lower of the two numbers and then track the MW amount of retirements

that exceed 900 MW. The excess can be translated by ERCOT into additional amount of new generation.

#### **ERCOT's recommendation** – Use the 900 MW retirement amount.

• **Type of New Capacity** – The ERCOT analysis used several different combinations of new generation, including only CTs, the mix of new resource types found in the 2022 November CDR, and finally the mix of new Resource types found in the 2023 November CDR (which included proportionally more solar and batteries). The upcoming changes in the market design and new incentives make choosing a Resource mix difficult. It is likely that the mix of generation that is eventually built will not be what is currently in the interconnection queue. For establishing the Reliability Standard, it is simpler to use the CT assumption as a standard of comparison for all the scenarios. Subsequently, the amount of new CT generation can be translated into any mix of Resource types using average Effective Load Carrying Capability (ELCC) estimates and outage rate assumptions for dispatchable thermal resources.

**ERCOT's recommendation** *Use the combustion turbine as the Resource type for comparing scenarios.* 

#### **Final Results**

ERCOT submitted an additional 22 scenarios as Phase 4 results. Phase 4 results use an 85% weatherization effectiveness factor, 900 MW of retirements, 42 years of historical weather, and incrementally add just CT generation to the December 2023 CDR's base resource portfolio.

The analysis includes all future generation capacity known at the time of the December 2023 CDR that is expected to be available by 2026. Hourly load is a probabilistic variable in SERVM, but the average summer peak value is 86 GW and the average winter peak value is 75 GW. Load that exceeds these average peak forecasts would require additional MWs of incremental capacity to maintain the equivalent scenario outcomes.

Using the Phase 4 results, if no additional generation (generation not included in the December 2023 CDR) is added, ERCOT would have a Reliability Standard with the following measurements. This scenario can be considered a baseline for comparison.

Incremental MWs	0 MW
Added	
Frequency	1-in-8.3
	years
Duration	14 hours
Magnitude	25,652 MW

Adding 1,113 MW of new CT capacity produces the following results that fall just outside the suggested maximum Magnitude criterion. The analysis estimates a 98.57% chance the maximum Magnitude does not exceed 14,000 MW.

Incremental MWs	1,113 MW
Added	
Frequency	1-in-10
	years
Duration	13 hours
Magnitude	22,375 MW

Adding 4,452 MW of new CT capacity produces the following results that are close to the suggested maximum Magnitude criterion. The Exceedance Probability should be considered when evaluating the Magnitude of 19,771 MW. The analysis estimates a 99.3% chance the maximum Magnitude does not exceed 14,000 MW.

Incremental MWs	4,452 MW
Added	
Frequency	1-in-15.7 years
Duration	13 hours
Magnitude	19,771 MW

Similarly, adding 5,936 MW of new CT capacity produces the following results that are close to the suggested maximum Magnitude criterion. The Exceedance Probability should be considered when evaluating the Magnitude of 19,164 MW. The analysis estimates a 99.64% chance the maximum Magnitude does not exceed 14,000 MW.

Incremental MWs	5,936 MW
Added	
Frequency	1-in-20.5 years
Duration	13 hours
Magnitude	19,614 MW

A scenario representing a more conservative Reliability Standard adds 8,904 MW of new CT capacity, producing the following results that all fall well within suggested parameters:

Incremental MWs	8,904 MW
Added	
Frequency	1-in-35.8
	years
Duration	11 hours
Magnitude	16,124 MW

The complete data set results for the Phase 4 scenarios can provide more details on some of the key outcomes for each scenario.



Reliability Standard Study: System Cost Impact Analysis (Phase 4), Updated Phase 3 Simulation Results, and Technology Type Capacity Equivalencies

April 4, 2024

# Modeling Study Design, Phase 4

Ran SERVM for a wider and more granular range of combustion turbine (CT) additions, using the 2026 resource portfolio from the December 2023 Capacity, Demand and Reserves (CDR) report and adding incremental CT capacity:

- 22 Monte Carlo simulations are reported for which no additional coal capacity is removed beyond the 900 MW scenario assumption
- Total CT capacity for the 22 simulations range from 0 to 20,776 MW (56 units @ 371 MW each)
- Range of expected frequencies (LOLEs) is 0.12 to 0 events/year; 0.12 is equivalent to a day with at least one LOL event every 8.3 years
- All simulations include 900 MW of unit retirements, 42 weather-years of hourly wind, solar and load data, and a weatherization success rate of 85% (i.e., 85% reduction in weather-related outages due to weatherization efforts)
- SERVM bug discovered and fixed by Astrape prior to Phase 4 study runs



# Cost Analysis Approach

- Calculated the system (or societal) average cost, per year, for each resource portfolio; system cost is the sum of three cost components:
  - Market cost = Load x market price
  - Customer Load Shed Damages (Expected Unserved Energy x \$25,000/MWh Interim VOLL)
  - Fixed cost of incremental CT additions @ \$119,000/MW-year
- Calculated the incremental system cost needed to avoid a MWh of Expected Unserved Energy for each CT addition scenario
- Developed cost curves intended to help identify the expected frequency that minimizes system costs and meets maximum loss-of-load magnitude and duration criteria
- Evaluated the cost impact of adding sufficient CT capacity to avoid extreme market cost outcomes



Frequency, Magnitude and Duration Criteria

- Frequency:
  - The modeled system in 2026 is expected to yield a LOLE of close to 0.1 loss-of-load events per year (or one day with at least one loss-ofload event every 10 years).
  - This is in line with the industry LOLE standard and is therefore a reasonable benchmark with which to compare alternative values.
- Maximum Magnitude:
  - Based on TSP information, ERCOT estimates that a load shed amount exceeding 19 GW may not be capable of being fully rotated.
- Maximum Duration:
  - There are no ERCOT operational considerations that suggest a specific max duration criterion.
  - Assuming that all load can be shed on a rotating basis, a 14-hour maximum duration (which is the highest realized amount for the Phase 4 simulations) could be considered acceptable given improved customer lead-time communications since WS Uri.



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# **Simulation Results Summary**

CTs Added	CT Capacity MW (Non- summer Rating)	Frequency (Expected Loss of Load Events/Year, LOLE)	Max Magnitude (MW/hr)	Max Duration (Hrs)	EUE (MWh)	System Cost (Million \$/Year)
0		0.120	25,652	14	4,213.6	12,264.71
1	371	0.111	22,901	14	3,825.6	12,250.39
2	742	0.107	24,566	14	3,672.8	12,256.09
3	1,113	0.100	22,375	13	3,331.1	12,259.85
4	1,484	0.096	21,669	13	3,075.2	12,264.68
5	1,855	0.090	22,388	13	2,743.9	12,263.77
6	2,226	0.085	22,176	13	2,637.8	12,285.76
7	2,597	0.078	22,013	13	2,418.3	12,290.71
8	2,968	0.080	21,028	14	2,263.2	12,316.17
9	3,339	0.073	21,583	13	2,073.8	12,327.72
12	4,452	0.064	19,771	13	1,744.9	12,387.93
16	5,936	0.049	19,614	13	1,222.9	12,459.16
20	7,420	0.037	18,674	12	731.9	12,535.27
24	8,904	0.028	16,124	11	500.1	12,634.39
28	10,388	0.020	13,418	10	279.2	12,735.21
32	11,872	0.016	12,807	10	188.8	12,865.08
36	13,356	0.008	12,666	9	60.5	12,986.74
40	14,840	0.005	7,903	8	31.1	13,137.44
44	16,324	0.001	5,085	3	3.6	13,293.08
48	17,808	0.000	5,097	3	1.9	13,458.18
52	19,292	0.000	0	0		13,628.20
56	20,776	0.000	0	0		13,797.07

CT addition scenarios start at the LOLE level (0.12) where no portfolio capacity needs to be removed or added.

### Key Takeaways:

- A 0.1 expected frequency (LOLE) is not sufficient to constrain the max magnitude to 19 GW; a LOLE of approximately 0.04 is needed to achieve that. The incremental system cost to achieve this increased reliability is between \$195 and \$271 million per year above the amount that supports a 0.1 LOLE.
- A 0.02 LOLE would be needed to reduce the max duration to 10 hours. This lower frequency increases the annual system cost by \$471 million above the amount that supports an approximate 0.1 LOLE.



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# Incremental System Cost for Avoiding one MWh of Expected Unserved Energy (EUE)



Key Takeaway: Incremental system costs for avoiding a MWh of EUE start escalating as expected loss-of-load frequency (LOLE) goes below ~0.04 events/year.

# Comparison of High System Cost Years

- Market costs are highly variable from year to year; the SERVM runs reflect average costs across all simulation outcomes.
- How much additional CT capacity would be needed to fully hedge against a year with higher-than-average system costs?
- For a "1-in-100" weather year, system costs would be lowest with CT additions sufficient to yield a zero LOLE:
  - Requires ~17.1 GW of additional capacity above that needed for a 0.1 LOLE
  - Expected annual cost, in addition to the cost to get to 0.1 LOLE, is \$2.03b
- For a 1-in-20 weather year, system costs would be lowest with CT additions sufficient to yield a 0.03 LOLE:
  - Requires ~5.2 GW additional capacity above that needed for a 0.1 LOLE
  - Expected annual cost, in addition to the cost to get to 0.1 LOLE, is \$618m
- For a 1-in-10 weather year, system costs would be lowest with CT additions sufficient to yield a 0.16 LOLE:
  - Expected cost is less than a portfolio designed to achieve 0.1 LOLE (\$441m annual savings)
  - However, reliability criteria suggested on Slide 4 will not be met with this LOLE\_level.

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# **Comparison of Years with High System Costs**





# Updated Phase 3 Simulation Results

- SERVM bug discovered and fixed by Astrape prior to Phase 4 study runs; the bug affected battery scheduling and resulted in erroneous negative market prices during negative net load hours.
- Impacts of the bug:
  - Solar over-curtailment and depressed market costs
  - Battery storage scheduling was sub-optimal
- Re-ran all 76 Phase 3 scenario simulations; the main impacts include:
  - Substantial increase in market costs, on the order of \$3 to 4 billion
  - For most of the resource portfolios, an increase in reliability; for example, across the Base Case portfolios, EUE decreased, on average, by ~10%, while Max Magnitude decreased, on average, by ~850 MW.
- Phase 1 simulations were not re-run because that modeling was an exploratory effort.
- Phase 2 simulations were not re-run because many portfolio scenarios are replicated in the Phase 3 and 4 simulations, while other scenarios were dropped for further consideration (e.g., 3,300 MW retirement scenario).



# CT vs. Wind/Solar Capacity Equivalencies

- The following table shows how much solar, wind, and standalone battery storage capacity is needed to displace the CT capacities used in the SERVM simulations assuming a system that meets a 0.1 events/year LOLE. The solar and wind capacity conversions are based on Effective Load Carrying Capabilities (ELCCs) published in ERCOT's 2022 ELCC study.
- The ELCCs are based on a reference combustion turbine with perfect reliability, so the wind, solar, and battery storage capacities are grossed down by 1.98% to reflect the assumed CT effective forced outage rate (EFOR) used in the reliability study modeling.

	Megawatts (MW)												
	Combustion												
	Turbine	Equivalent	Equivalent			Equivalent							
CTs	Maximum	West Solar,	Non-West	Equivalent	Equivalent	2-hour							
Added	Capacity	Summer	Solar, Summer	Wind, Summer	Wind, Winter	Battery							
[1]	[2]	[3]	[4]	[5]	[6]	[7]							
1	371	1, <b>081</b>	1 <b>,351</b>	2,226	1,991	430							
2	742	<b>2</b> ,16 <b>2</b>	2,702	4,451	3,983	860							
3	1,113	3,243	4,054	6,677	5,974	1,290							
4	1,484	4,324	5,405	8,902	7,965	1,720							
5	1,855	5,405	6,756	11, <b>128</b>	9,956	2,150							
6	2,226	6,486	8,107	13,353	11,948	2,580							
7	2,597	7,567	9,459	15,579	13,939	3,010							
8	2,968	8,648	10,810	17,805	15,930	3,440							
9	3,339	9,729	12,161	20,030	17,922	3,869							
12	4,452	12,972	16,215	26,707	23,896	5,159							
16	5,936	17,296	21,620	35,609	3 <b>1,86</b> 1	6,879							
20	7,420	21,620	27,025	44,511	39,826	8,599							
24	8,904	25,944	32,430	53,414	47,791	10,319							
28	10,388	30,268	37,835	62,316	55,756	1 <b>2,038</b>							
32	11,872	34,592	43,240	<b>7</b> 1, <b>21</b> 8	<b>63,72</b> 1	13,758							
36	13,356	38,916	48,644	80,120	71,687	15,478							
40	14,840	43,240	54,049	89,023	79,652	17,198							
44	16,324	47,563	59,454	97,925	87,617	18,917							
48	17,808	51,887	64,859	106,827	95,582	20,637							
52	19,292	56,211	70,264	115,729	103,547	22,357							
56	20,776	60,535	75,669	124,632	<b>1</b> 1 <b>1,512</b>	24,077							

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na. FRE	FREQUENCY	MWRation	Capacity Mix to Advisor Frequency Target: 100% CT vs. May CDH proportional mix of planned Mind, Lolar, 199, San	Pentidia Reserv Magin far Sammer*	Partfalls Rasaros Margin far Wintar*	Experied United Control Coll. (Millet)	Load Shed (herages (BU)) W(R) ( politice 5/91)	Coll Capacity Reduction (1999)	MMs of Additional (seed) (Repair hable Generation	Hand God al AddRinn & Cl Gameration (million (291)	Tutal Variable Costs (million; 5/yr)	Variable Conto - ELE al VELI St. ant, March Indian U/pr)	CT and Validate East Jostfloor S/yr	ET and Wathdate Cont a Loand United Demografi (million Shyr)	Marinet Cost (million S/w]**	Tantamen Carl a LondShed Damagers a CT Carl (offlice S71)	Max (buridium	Convectories Productable p Despring for Daration 15 lunars	Eponodiason Producting Naropine of for Distribution 30 focum	Excendiance Probability throaster for futuration 5 hours	tras Magnituris	Encondument Produktilley Reconductor Magnificatio S.R.mice Matter	Proceedians Probability Respired for Magnitude Stand Mill	Formstanse Probability Respired for Magediads Catto Mill	Annual becommental Final Cost of EUE Reduction (EF Conf./year per MRTs of avoided EUE)	Annual Incommune CE and Variable Co of DUE Reduction (Total SJycor per NUML of availability
- 2	1915	800	1078 CT	2.7%	1976	5,029	-	345		¢.	15,285	15,259	115.000	15,299	11.515	32,945	- 15	3.029	4.199	4,578	25,942	2.526	4.678	3.276	-	
2.	110	905	100% CT	44796	205	3,381	-18		1,853	721	15,128	15,157	13,311	15,343	11,354	12,342	- 15	0.02%	3.12%	3.35%	31,194	1,378	2,70%	1,774	90,211	40,91
Ť	10.10	900	100% CT	LPh .	2293	2,679	12		5,825	257	11,117	11,194	13,501	15,514	12,404	12,625	24	0.00%	2.82%	2.85%	23,117	0.37%	2.21%	4,40%	185,700	185,13
- 21	38.15	900	100% CT	23%	326	1,368	1		3,576	- 255	15,295	25,298	11,000	15,800	12,167	12,364	13	8.00%	1,179	1.51%	18,517	0.25%	1.124	2.574	503,354	291,45
- 5	19-20	805	100% CT	21%	30%	7(8)		2 4	6,533	LOIS	13,100	11,045	16,300	16,500	17,581	11370	12	11.00%	3.6%	1.05%	14,863	1.34%	0.486	1,8%	167,649	361,57
. 8	165	900	COLMA	1.7%	1814	5,548	- 15	3,100	- ÷ .	0.	15,300	15,252	12,115	15,200	15,205	13,544	15	10.02%	4.13%	5.34%	26,489	2.84%	3.689	10.48%		
2	1118	900	228 Adv	35%	20%	4,255	100		242	14	15,304	15,362	15,171	15.172	12.553	12,452	15	1.02%	3.58%	3,77%	.24.355	1.58%	5.324	6.22%	32,794	2,85
1	1.0-10	900	CORMA	176	7274	3,176	16	16	1,236	363	15.178	15,057	11.TTF	15341	12,435	12,716	15	0.07%	2.179	1.03%	21.307	1.38%	7.578	1.379	145,511	144,64
- B-	10.15	900	CDRAGE	22%	229	1,812		- 6	1,345	642	15,000	12,049	13,713	25,719	12,290	1,5,500	1.9	0.00%	£.24%	1.75%	17,819	0.52%	1.90%	2,884	299,131	311,04
10	18.20	836	228.66	27%	30%	897	4		6425	- 685	16.548	23,045	CLUBS.	15,511	1231F	133,394		E.00%	3.1.91	11124	26,225	0.129	0.8%	2.094	118,527	345,78
11.	183	1,300	100% CT	176	174	5,714		26	1,488	1m	15,107	15,15#	1.1.1.110.	15,364	12,945	1774	15	0.074	4.125	4.37%	34,503	3,004	4.574	82.76	-	
12	1010	8,300	100% CT	11%	- 22%	3,211	129	- 6	5,710	441	13,140	11,139	1.1.100	15,507	12,617	11,172	15	0.02%	3,34%	3.42%	23,499	1,128	3.0.24	6.176	112,298	116,73
18	10.55	1,350	1094-07	174	22%	2,518	128.1		1,885	- 185	15,178	25,235	11.778	15,700	12454	113,500	15	0.52%	2.38%	2.53%	21,068	0.85%	1.364	4.33%	185,554	175,75
3.0	10.12	3.306	100% CT	21%	274	1,308			8,533	1.015	15,113	12,177	16129	16,129	12,170	112300	: 14	E.00%	1.32%	1934	16,648	0.25%	1,12%	2.574	291,001	296,44
15	\$ HH 20	3,300	IDEN CT.	22%	2004	308			10,012	1,193 -	-13,100	\$5,35#	14,299	36,300	12,084	11,389	12	12.00%	0.83%	1.22%	10.008	DULEN.	0.769	2,226	440,289	433,33
- 18	1818	1,350	COLUMN	12%	1854	2.317		1			15,768	25,138	1182,128	15,100	12,347	11111	16	1.89%	4.89%	3,826	27,348	2.554	1.54%	22.68%		
17	100	8,200	COR Mile	16%	209	4,063	365		2,968	102	18,122	18,122	13,475	15,075	12,645	13.516	15	8.02%	3,375	3,529	22,554	1.699	1,009	6.324	118,517	25,27
12	19(12)	3,305	100 Mis	2001	224	2,834	34.1	- 4	-4,822	134	13,0mi	15,025	13,649	25068	112,409	13,547	1942	11.00%	2,42%	2.00%	24,085	0.59%	2.5/54	4,20%	129,041	195,00
18	1.4.25	1,800	LDBMS	23%	2994	1.300		10	6,62	521	15.373	11,04	LARSE	16.043	12394	733.5ad	18	E.00%	1.30%	LAPE	12,932	0.04%	1.388	2.826	208485	265.82
- 20	110.20	1,338	CDHMa	278	10%	905			3,640	1,148	13,068	13,065	14,308	36,213	15.110	13,271	13	E.00%	3.80%	1.10%	16.6%	0.294	6.72%	2.546	390,648	182,25

#### Table 2. Filteen Weather Years Sensitivity

	Raticiality Standard Transmith Inputs		Scenario Parar	matars											Scenario (	Nitcomes				~					
34	FREQUENCY (LOUI)	MWRatinud	Capacity Mix to Advisor Frequency Target: 540% CF vs. May CH proportional role of places Wind, Lolar, 1141, Gas	Pertidia Rasara Magin lar Barmar*	Partfalia Rasaron Margin far Wintar <sup>a</sup>	Expected Securities for the engrand TEX (security)	inself-Sites Demogra (SER + MORC) (selfine S291)	Mills of Additional Intent Departure Generation	Fixed God of Additional CT Generation (nation, 5/yr)	Sonal Vaciation Contto (million 5/yr)	belad Vanishin Contra Utita Vitit States Media Indian Media	(Land Variable: Corr (million S/yr)	ET and Variable God + Load Shed Dan ages (selfice S/ye)	Mater Col Indian Myrj**	- Continuer Cont + Lond Unit Damager + CT Cost (publics S7#1	Mer Derstine	DU Investigant Investigant Investigant Investigant Investigant Investigant	Careekase Possibility Required for Daration 38 hours	Emerations Postability Required for Paration 1 hours	Mar Magnitude	MAG Excentioner Probability Required for Misgoinettor Misgoinettor	NITUDE Creations PostadidBy Required for Miggshold Colline May	Excendions Probability Required for Magnificade Later MW	Annual Internet a Final Last of ELS Backetter EFT Ortf/from per ABER of availed EFT]	Annual Incomental C1 and Validate Cost of EUE Reduction (Total L/pear per ROVs of avoided EUE)
1	10.8	9.05	100% Cf	10%	- 271	4,211	21	3,565	662	15,152	-13,111	11,793	13,814	12,649	11.111	.ii	0.02%	4.35%	\$324	20,605	1.076	1,7%	4.279		
2	188-33	930	100%-CT	22%		2,598	122	8,162	.771	15,136	15,154	18,048	114,107	1228	11100	1281	1,00%	2.82%	3.54%	12,965	3.276	11.72%	1.8%	354,673	141,758
3	19.12	505	100% CT	29%	373	102	1	11.077	LATE	15,171	15.518	16,531	16.534	12.014	C TYLEN C	T	0.004	1.64%	3.80%	12,202	1.076	2.476	7,198	252,735	241,092
6	18:22	901	100% CT	281	274	357		13,381	Line	15,117	:31C133	11,708	14,707	11,800	:13,418	311	. S.00%	3.77%	3379	1/2/5	1.026	3.05%	1.324	751,352	ML290.
5	12348	936	CHAN	27%	.32%	-2,297	70	1.363	862	35,135	15,049	15,757	13,778	13,429	18,115	-55	0.026	1.79%	4.479	21,427	1.288	1.274	5.87%		
£.	1200.00	501	N	215	28%	2,079	- 38	6,533	1,015	15,095	15.381	16,108	16115	12230	TEM		0.074	1.60%	2.88%	16,994	1,10%	1.874	4,374	174,318	1751年
T	19:45	905	CDB Mix	37%	8218	73世		11,121	6,334	33,088	13,081	110407	16413	:12,342	15,830	31	. S.00%	3.32%	1.279	13,554	1,026	:0.376	2.5.74	230.272	725,090
	18.25	850	I DR Alla	275	344	402		1184	LSEL	11,040	15,045	18,382	CLASSIC.	TLAM	COLUMN .	.11.	0.02%	.0.11%	0.125	1.1.880	1.50%	0.276	1.326	MISE	ABLAM
1.	100	3,200	107N CT	22%	2014	7411	-17	6,537	1.015	15,168	15,580	15,161	15,178	12,386	TRAID	13	0.00%	3.774	4,375	18,238	1.36%	7.5%	\$.775	-	
12	1.0.12	3,301	IDDA CT	276	28%	1,002		11,121	1,334	15,549	23L342	10,408	16,61	:12,338	:12,654	(17)	. 8.00%	:1.81%	2.201	17,630	18,274	:1.23%	4,128	174,612	173,123
11	18:25	1,300	320% CT	27%	308	3.82		14,018	LSPE	11,135	15,126	18,834	14.816	12,012	11.643	:11.	0.00%	0.27%	0.479	12,638	1.00%	9.278	1.43%	334,386	115,641
12	18-20	3,200	100% CT	276	174	319		14,840	1,766	35,138	15,125	15,901	16,996	11,248	11.757	- 41	5,00%	-1.376	0.485	12,101	3.326	0.476	2,30%	1,065,133	1,656,168
18	1118	3,305	COUNS:	21.8	20%	3,452	17	8,162	.871	15,127	11.111	11,161	14,018	12,401	15,802	:13	. S.DOW	2,39%	4,32%	18,490	3.734	0.25%	1,701		
- 14	1.1 (1.10)	1,300	LINAN	2.7%		2,185	12 12 1	16.00	L182	11,118	13,395	18,257	14,808	12,293	TEAST -	1.1	0.02%	1.81%	2.88%	17,154	3.128	. 2,084	4.825	17,,436	148,193
15.	19:32	3,300	CDI Ma	30%	379	396	1	1.2,514	1.301	15,155	15,301	16,612	- IGene	:0,111	TIMIT	-11	3.00%	0.32%	1.129	14,379	3.376	0.376	1,728	243,596	233,868
10	19-25	3,300	CDH Mia	26%	171	418		14.411	1.722	15,120	125,098	14 arity	14.827	123,586	15,915	11	11.00%	3.14N	13.48%	10.114	1.074	11.1.FW	2.084	433.512	440,543

#### Table & "Increased IBP" Portfulie Servicing

	Rafishting Branderd Fryntaesek Inpuls		Scenario Parar	nafars	_									-	Scenario C	Adaamee	-								
80	FREQUENCY (LOU)	MWRatest	Copenity Mix to Advisor Proparity Target: Increased Planned Wind, Solar, ESE propertional to May 2023 CDI	Partialia Rasarva Margin far barrinas*	Perifuli & Raserva Margin for Winter*	Experied Description Exactly interference Exactly interference	Local Marel Demogra (ILM * POLL) (realized S797	Million at Addition at Joseph Dispercification Committee	Fixed Cost of Additional (T Generation (selline 5/yr)	Total Variable Codts (million 5/yr)	Satud Variadale Confis -SUE at VIII PS,ase,Matala (million S/yr)	Chand Variation Gas (million SZyr)	CT and Variable Cod + Initial Unit Data ages (million S/yr)	Bilatker Con (million 3/91)**	Galdenser Colt + Lonal Mont Damager + CT Colt: publics Silve3	Mar Develop	Excentance Probability Required for Direction 25 hours	ATION Residence Protection Response for Datafies Bill Insuit	incendance Postulativy Required for Datable 3 hours	Mac Majo Rocki	Encendaria Probability Respired for Mignitude 14,000 Sett	Exceletation Periodiality Respired for Magnitude (0,000 MW	iteredase PolisiiNy Regularita Ngolarit 1,000 MM	Assessed Internet & Flori Cost of KAK Reduction (DT Cost(/your pro AMWK of associated \$23(3)	Annual Incremental CT and Variable Cost of EDE Reduction (Total ) /pour per MWA of avoided 2003
1	1008	900	CORMAN HISTORY	18%	185	4,522		0		34,810	34,996	14,790	14,818	11,858	:11,546	.18:	0.07%	1.49%	3.54%	25,320	1.826	1.68%	6.30N		
- 2.	18.35	990	CER Mix + Incline	20%	22%	3,554	128	1		34,320	14,921	\$4,952	14,326	25,798	10.84	- 58	3.32%	2.63%	3.47%	25,195	1.476	3,129	5,715	1	15014-215
1	1.4-0.15	800	CER Mix + Inc INF	67%	8176	7,089	10	- 76 II	0.000	11,454	TEAM	11,454	12,004	0,336	3,605	310	0.024	3,476	2,48%	26.377	3,80%	3.084	4,276	- 18	(147,061)
- 6	18.20	900	COM Mix + inclusion	34%	233	1,014		0		12,713	13,211	17,253	13,715	1,246	9,154	31	0.00%	0.11%	2.12%	17,081	3,524	1,38%	1.416		1111,017
5	1358	3,500	CTR Mix + Incline	225	225	4,866		5 3 1		34,128	34,354	34,234	14,128	11.58	Materia I	-58	3.52%	2,575	4.174	NUM	2.328	4,299	2.37%		
15	18:10	3,300	COLMX 4 DOUBLE	175	2016	3,815	15		1.000	11,435	15.5 M	13,676	11,005	1,750	19,898	17	0.00%	1.629	3.68%	25,221	1.526	3,424	6.089	- 6	1407,8619
- P)	18:15	3,305	CER Mix + Inc IBE	\$25	2816	2,800	12	- 6		13,050	110,000	12,038	1,1,110	8,270	9,542	31	0.00%	- A11%	2.69%	13,000	1.076	2.635	4.399	- 10	4417,1675
	110.20	2.300	COR Mark Inc. 198	CPV	424	3.000			1.	\$3,755	12.20	12.766	13.705	Richt	10.010	10	0.07%	2.00%	2.08%	20.302	15.67%	1.776	1.374	- 10	THREET

#### Table 4. 70% Weatharization Effectiveness Serviceity

	Balalatity Storderd Fransassik Ispatz		Scenario Para	meters											Scenario C	Adrem es									
¥4.	FREQUENCY (LOU)	MWRatowl	Capacity Mis to Advisors Frequency Target DNL CT vs. May CDI proportional sale of plasmel Wind, Soling DDI, Can	Portfolio Razarva Margin for Summer*	Pertfails Reserve Margin for Winter*	Expected Descend Design Statighted	SmathAberd (Seeinger (1936) * VOLL) (million S7yr)	Millional Additional (serie) Unput challer Generation	Fixed Cost of Additional CT Generation (sellice 5/34)	fortal Martalan Conto (million 52pr)	Total Variable Conto - USE at VID2 States/Annue (relies Vyr)	CL and Variables Lost (million S/pr)	CT and Endedin Cod 4 Load Sheet Damages (million S/yr)	Masket Cod (villian S/yr)**	Sundament Cost + Local Unit Granger + CFGred (Holling S/W)	Max Dentition	DUP Excessions Period Duration S5 hours	Consultance Protocolity Response for Datable St Surgers	Incondinue Probability Respired for Datable Schoors	Max Magnitude	MAG Probability Despiration Shapirtuck Shapirtuck	Encoderation Productive Negative Magnitude States SW	formationer Fockstallity forgationitie Magnitude Supplicate	Annual Internet a Date Cost of EUC Reduction JUT CostS/prot per MRN of anoided EUC	Annual Incommutal C1 and Variable Cost of 100 Reduction (Total S/year per MINs of avoided EUR)
	3118	502	100% CT	1.7%	2004	-8,234	- 23	1,715	-441	15,120	13,101	(1,2)	11.572	1248	11,393	11.	3.22%	3.37%	3.75%	27,764	1.495	1.324	6.799	-	
2	10:10	950	100% CT.	12%	22%	3,534	100	3,194	10.00	15,217	18,381	15,718	13,735	\$2,394	14,937	18-	0.029	2.84%	3.12%	32,480	1.124	2.435	3.501	135,495	133,645
- 8-	19.55	900	100% CT	378	265	1.317		3,545	1,348	15,5%	15,349	55,237	14,348	13,555	11,254	38	3,02%	1.15%	1.59%	20,557	1.369	0.2%	2.578	276,035	270,295
4	18:20	900	100% CT	178	20%	134		\$1,131	L504	13,091	15,067	15,412	16,416	111.5.90	31,305	33	9.00%	0.874	1.23%	16,101	3,124	0.851	2.0ms	90fJM45	494,463
- 3	.168	956	CDII Mix	124	225	4,700	34	2,966	353	35,829	15,599	13,432	13,436	13,391	17,598	141	3.00K	3.52%	4,195	23,683	2.078	7,368	7.431		
- 6	19.35	900	128466	19%	279	3,596	18	4,457	536	15,097	15,345	23,599	15,617	12,411	12,345	34	3,076	3.039	3.41%	21,678	3.578	3128	LEN	547,578	135,751
1	10.15	900	CD9.66x	201	22%	1,338		8,504	1,040	13,067	15,094	15,115	16,123	12,893	123,538	31	0.00%	1.22%	LARK	25,101	3,076	1.234	2.84%	754,603	228,542
- E	18:20	900	COLMA	22%	20%	1,158	18	1,646	LMB	15,000	12,554	10,362	11,208	11,053	15,206	11	0.00%	1.00%	1.185	17,537	3.294	1,194	2,001	491,295	-483,011
- 61	1818	1,80	300% CT	176	2019	4,065	- 20	3,236	Tim	35,347	15,111	15,878	11,000	12,400	16,331	58.	3.579	3.77%	3.70%	21,215	1486	2,455	4.99%		-
12	18.10	1,300	100% CT	17%		2,399	.15	7,420	mt)	35,137	-11.117	15,000	14.015	12,341	35,795	- 13	0.02%	2.76%	3.27%	25,140	1.25%	2.54%	1.24%	313,534	181,015
11	10.15	1,300	100% CT	2/11	201	1,119	1.0	11,893	1,413	15,111	11,107	14,830	16,525	12,000	15,418	33	0.00%	1.129	1.174	19,000	1.251	1.13%	2.594	201,000	28,48
1.2	18.25	3,300	100% CT	275	309	205		13,355	1,585	15,125	15,315	15,575	14,638	11,571	15.564	52	3.32%	1.775	0.69%	35,254	11.06%	0.65%	1.324	\$25,195	-A21,508
11	110	3,300	-CDR Mis	176	203	4,286	E	1,194		15,111	18,295	11,708	13,778	13,534	13,344	-15	0.03%	3.11%	3,724	34,689	1.30%	1.101	6.374		
18	18:10	1,000	COLMU	19%	225	3,388	397	1,10%	211	15,152	13,081	11,875	13,000	13,354	:15,396	18	0.07%	2.81%	3.28%	24,310	1.494	2,33%	5.584	116,673	191,000
1.5	10.15	3,300	228.66	72%	284	1,797		9,546	1,588	15,564	15,325	88,229	16,772	12,124	15.59	14	3.324	1,10%	2.27%	18,481	1.596	1.5.94	1.584	775,653	254,845
1000						and the second second		and the second se	and the second sec	and the second sec	and the second se	And a second second second	<ul> <li>A regulation of the Automatic</li> </ul>		Provide the Second State			and the second sec							

#### Table 3. NYS Weatherstation Effectiveness Sansitivity

	Ratability Standard Promanaly Injusts		Scenario Para	meters											Scanario	Outcomes									
84	FREQUENCY	Milland	Capacity Mis to Adriana Programs Target: 3401 Cf es. May CDI proportional size of planned Misel, Solar, DSP, Gan	Portfolio Reserv Margin for Summer*	e Partfall a Rasaro Margin For Wintar*	Expected Universed Every EUX (Inhib)	South State	Max of Additional Addi	Time Cost of Additional CT Generation (sellion S/pt)	Const Variable Constitu (million SJyr)	Total Variable Louis - 652 al VOIs 51,000 Artes (robbin Mys)	CT and Variable Cost Indiline Myr	CT and Validate Cost +12xed Sheet Damager Joillion S/ye	Maker Coll (selline C/m) <sup>24</sup>	Fundament Coll + Local Hand Domoge + CT Coll ( polition S/pr)	She fignation	Exceedance Probability Required for Decation 25 hours	Kannelance Hotaddity Required for Deather 38 hours	incentions foot-dailing foot-dailing foot-dailing foot-dailing foot-dailing foot-dailing	Nut Magnitude	MAG Terrelate Induktiky Repaireda Magettek Magettek	Eccentricianese Productionally Recyclicities Magnification Magnification Strategistication	Taxeniana Isokaliliy Impaintito Alapolisie Canit Alar	Annual Incommut a Faced Cost of EUC Restortion (CT CostLiberar pro MITS of availabil EUC)	Annual Intermenta CT and Variation East of 1330 Reduction (Total S Annu per MWh of avoided 5030]
- 11	3118	502	00% CT	3496	124	3,341	121	34,438	132	33,136	31,339	11,252	11,308	12,340	TIME-	-13	3.32%	2,99%	3.72%	25,311	1.129	2.084	1.774		
- 2	19(10	950	100k CT	33%	18%	2,811		2,226	. 265	15,228	25,593	13,875	13,394	12,441	12,895	.18	. 8.82%	2.53%	2,926	32,642	0.824	.2.00x	4,879	245,548	222,096
- 1	10.55	926	1074 CT	198	228	1,499	1	5,158	878	15,557	15.295	15,295	15,711	13,998	11,895	-18	0.076	1.58%	5.795	15,220	3.276	1.22%	1.778	257,438	211,997
- 4	10.20	900	100% CT	22%	2414	892	3	5,676	715	13,005	15,040	\$1,675	114.000	12,100	:12,906	(12)	0.00%	1.094	1.3/1	15,400	3.15%	0.824	7.0ms	154,726	344,711
- 3	2 23.0.0	900	CORMS.	34%	174	3,835	- 26	·		15,113	13,291	13,070	12/12	13,375	11,593	3.8	. 0.02%	3.25%	3.439	33,276	1.329	1,1284	6.454		
- F	19.35	900	CDI Ma	13%	18%	3,209	36	:1,318	137	15,991	15.375	15,357	12,778	12,475	TLATE	34	3,576	2,91%	3,29%	21.845	1.359	2,23%	1.389	191,300	133,257
- 7	10.15	900	CDEAG	117%	775	1,636		4,452	330	13,094	15,044	\$1,579	11.586	12,344	:13,763	-15	0.00%	1.374	1.81%	15,265	3.426	1.374	2.30%	253,605	234,371
1.0	18:20	900	CDI Mix	22%	204	904-	1 1	3,578	751	11,042	15,798	11,831	13,817	12,100	12,962	32.	0.00%	0.82%	1.15%	16,034	2.176	0.24%	1.30%	962,224	111,196
. 1	1918	3,28	100% CT	378	105	3,475	18	2,968		15,143	15,175	15,47E	15,000	12,615	12,584	38.	3.279	3.12%	3.199	32,120	1.199	2.4.76	1.875		
-18	1 == 10	1,300	100% CT	11%	125	2,600	-13	4,452	.330	15,127		25,643	13,696	52,435	112,996	-14	0.00%	2,40%	2.70%	20,045	3.899	2.194	4,576	192.613	175,872
11	10.15	1,300	1074 CT	19%	275	1,300	1	7,430	101	11,10#	15,101	11,294	100.01	12,198	11,285	-14	0.00%	1.499	1.185	18,599	2.291	1.15%	2.63%	263,871	255,943
57	1 m 20	3,300	. 100% CT	278	34	1.50		8,304	L260	13,222	15.387	18,157	116.357	152,599	115356	-52	1.076	1.09%	5.229.	35356	8.579	1.355	1.344	511,829	491,512
-13	1.918	1,300	CDIAG	34%	174	3,515	-20	-2,226	-263	15,127	15,067	11,352	11.371	12,597	11,002	-14	0.00%	1.28%	3.45%	23,615	1.374	8.204	6.295		
-18	1.8(10	1,300	2DI Mix	3.9%	. 194	2,815	24	3,713	-40.	11,085	15,374	11,138	TATIC	1,10	31,825	-14	0.00%	2,30%	2374	24,341	1.274	2.278	4.59%	110,007	140,231
15	10.35	1,309	LOR MIN	175	171	1.542		5,578	715	15,018	11,041	13,855	14,903	177355	1694	-58	1.076	1.075	1.779.	-523N	3.589	1.199	1.574	204,372	256,200
10	110.20	1.300	CDR Mix	21%	2019	640	- 4	8,864	1,060	15,058	13,894	16.134	16,119	13,294	15.141	.12	0.00%	0.92%	L084	15,320	1.194	0.34%	1.794	385414	17(27)

#### Table 6. Phese 4 Scenterie

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	Radiability Disordered Processorie Inputs		Scenario Para	maters											Scenario C	Maamee									
											and a						DUR	ATION			MAG	ITUDE	A	Annual	Annual Incompany of
80	FREQUENCY (LOUE)	MWRainel	Cape dig Mis to Addison Requiring Target Dis. 2021 (201+17)	Portfolio Reserve Margin for Barmon *	Portfull a flasor or Margin for Westur <sup>4</sup>	Expected Interved Dangy EDE (MRH)	tonell'Sheet Demogra (D.N. * VOLL) (million S/91)	Million of Additional Streamloads Generation	Final Cost of AddRived CT Generation (sollion 3/pt)	Sotul Variable Conto (million S7yr)	Validat Costs -SSE at Vite State State State State State State	CT and Variable Coat (million (Vyr)	CT and Validation Cond + Scout Share Dates ages (selfleen SV(s))	Market Crit (million S/w(**	VPDIAN COLT Market God + Lond Unter Danages + CF Cost (Juditors S <sup>1</sup> 97)	Mar Datatha	Consultance Productive Neuroscience Discretione 25 hours	Consultance Produktility Required for Caraction 38 Jonary	Encentaine Probability Respired for Decision 5 Acres	Nas Magestude	Exceedance Probability Negatived for Negativede 34,000 MW	Excertions Probability Required for Magnitude 16,000 MW	Exceediant Probability Required for Mignitude 5,400 MB	Control EUE Control EUE Reduction Bill Contil/year part Match of accident BURS	CT and Variable Cost of UAL Reduction (Yatal Silver per MIN's of anothed UAL)
1	1.14.83	900.	Des. 2023 CDR Mile	20%	219	4,234	228	2	1	34,253	3HJHH	(4,332	14,417	12,199	12,301	380	1.00%X	3.00%	3.38%	23,652	1,7489	108	6.284	-	-
2	18.20	906	Dec. 3033 CDA Mis	22%	22%	3,826	- 25	3.82		34,343	340334	14,308	LAADE	12,111	10,195	34	ULCONK	3.84%	3.50%	23,301	1.578	3.108	5.201	111.795	53,164
- 3	1054	800	Own, 2072 CDR Mile	21%	225	3,673	- 12	742	10	\$4,335	-34,364	24,408	14.400	12.536	112,254	-14	0.00%	2.876	3.42%	24,366	2.68%	3.09%	1.49x	246,816	235,777
- 6	110100	502	Des. 2023 CDR Mie	27%	- 22%	9,311	33	1,118	132	14,327	34,311	\$4,443	ASH	13,544	12,260	:13	1.00%	2.52%	3,104	22,375	17438	2,63%	3.374	121,229	111,841
3.	2.0-12.4	936	29m; 3033-238 Mik	33%	298	3.075	39	1,494	134	34,339	34,855	14,491	14.558	12.011	11198	1.2	8.00%	3.22%	3.179	31.669	1.35%	:2.40x	4,328	171478	155.003
- E	120111	800	Date 2013 CDR Mix	27%	279	2,744		1,455	221	34,313	14,301	14,520.	114.585	11.374	12,394	33	9.00%	3.024	2.705	22,388	1.376	2.34%	4.574	131.774	116144
- 2	18-11.0	900	Den 1013-108 Mik	279		2,698		2,236		34,358	14,211	14,500	TIAGN	11,935	12,300	(清景)	3.00%	1.89%	2.826	32,199	1.581	2.13%	4,361	#16,834	171.348
E	18:124	900	Dec. 2073 (208 Ma	3/6	205	2,263	32	2,968	353	34,921	SLIVE	15,642	14,639	11,968	31.595	34	1.07%	1.58%	2,51%	21,578	17,781	1.0095	4.129	285,720	221,801
	18:12#	900	Den: 3023 CDR Mia	27%	203	2,418	「「「「」	2,197	309	34,354	34,393	14,821	14.662	11.871	12,701	-15	0.00%	1.56%	2.579	22,013	1.076	1.994	4,129	294,680	268,058
10	19:117	900	Den 2023 CDR Mik	24%		2,074	_D	3,225	187	14,257	34,388	24,034	14,715	11,879	12,526	31	0.00%	1.32%	2.38%	121,385	1,001	1,879	1.574	216,296	225,634
3.2	199127	926	Dec. 2073 (208 Ma	22%	274	1,745	- 44	4,452	345	34,290	SLIVE	\$4,995	14.854	11,915	11.700	-38	1.076	1.975	2.08%	15,771	3,70%	1.2.25%	1.179	613,799	199,751
12	18:20.1	800	Den: 3023 CDR Mik	27%	224	1,223	- 羽	3,516	75	34,289	14.5%	14,943	14.018	111,722	12,488	33	0.00%	0.63%	1.12%	19,614	3.35%	1.18%	2,586	106,255	829,607
19	11=28.0	900	Oro 2023 CDR Mik	27%	3214	732	128	7,430	1011	34,270	34,394	15,157	13,175	CILEM.	12,595	32	0.00%	0.29%	1.02%	18,574	1.176	0.78%	1.000	10,706	254,755
34	5 In 15.8	900	Data 2023 CDR MW	275	379	\$20	18	8,804	L060	34,275	SOR	15,337	13,545	11342	12.534	31	3.024	0.13%	3.85%	36,124	1.526	1,764	Large	751,781	755,515
12	12:313	900	Dec. 3023 CDR Mia	2.7%	2004	279	1	10,388	1.296	34,273	34,373	23,308	11.315	11,423	12,795	-10	0.00%	0.00%	9.32%	-13.4HE	1.00%	0.13%	1,189	793,312	754,751
18	19-620	900	Ora 2023 COR Mik	3/1	374	1.00		11,892	1,413	14,271	34,373	11,084	13,100	11,448	12,965	10	0.00%	0.00%	0.27%	12,807	1.074	0.12%	0.074	1,853,277	1,351,856
17	131117.8	990	Data 2023 CDR Mile	375	379	81		13,355	1,589	\$4,272	54,377	15,811	15,801	11.39	12,567	4	3.996	8.00%	0.17%	12,565	10.00%	1.04s	0.584	1,377,008	3,377,716
10	E-81 1985-E	300-	Des 3022 CDR Mix	37%	-425	310	16	34,643	1,765	54,272	34,373	15,038	14,038	11,171	13,007		0.00%	0.00%	0.56%	7,903	3.00%	0.00%	0.276	3,196,875	5,381,012
19	1167011	800	Des 2019 CDH Mik	37%	494		1.1	16,304	1,943	34,271	34,175	15,758	16,214	31,500	11,265	1	0.00%	10.00fs	0.32%	3,261	1.00%	0.00%	0.0#s	6,430,258	6,471,831
28	19(21863	910	Date 2012 CDR Mily	878	45%	1		12,800	2,129	\$8,275	34,375	15,290	114,390	11,379	1144	1	3.324	8.00%	3.82%	3,193	10.00%	0.00N	0.084	301,355,421	331,548,917
-21	3.0xmminity	900	Dec. 3022-CDR M/s	478	485			15,262	2,296	54,771	34,371	15,367	14,567	11,333	111670	1	0.00%	0.001e	0.50%		3.00%	0.00%	0.00%	34,302,170	94,711,813
22	1 in substa	200	Des 1013 CDI Mix	A4%	375			20,88	2,000	14,271	34,353	DICTMR.	TEME -	11.325	115,997.1	1.1	1.00%	11.00%	0.079		3.00%	1,00%	0.07%		-

agins are calculated with Effective Land Carrying Capitel Has for which, salar, hattery storage, and non-PON thermal resources.

\*\* Market Contric The sum of entriesme energy contri and filocodile to serving tool, piloc Availlery Service contribution of controls of the encoded using the following model member Market Contri is and \* Market Thise is fails founded \* for Weighted Phice + Rep Lip Keepland \* Rep Lip Weighted Phice + Rep Lip Weighted

 Cast Parameters

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		Portfolio atter Belining	Capacity Changes to Attribut Chait	Capacity Changes to Refere	Capacity Changer to Actient	(Aparty Changes to Achieve 116-15	Capacity Changes to Relations 116-20	Capacity Changes to Addient	Capacity Changes to Address	Capacity Changes to Activity The M	Capacity Changes to Addient The US	Capacity Changer to Achieve
Incomer Type	Der 3077CDB	(apartry	Requiring	Request	FINISHING	Firement	Request	Firement	REALF	Request	Firement	FINISHING
Cra	13,670	13,670	(975)					(270)				
35	::.43	:453										
A11.	41.35 :	41,85 :										
ώnπ.	2. F	10,755						787	782	782	24	×2
Tamen (immyr	11.945	17,945						7,082	7,082	1.252	3082	.308.1
New CT /						7,678	5,730		742	2,736	1,977	7,121
1014	364.433	3ha/30	1M758	16.21	10.75	1/2/84	1/4.251	144.372	1/1.524	1/1.00	1/5.34	2// 2012

				1, 114	MM Refires	ient Scenario						
	ي الم الم	(Posticións			SPACE Second	iu .				COE HÁN		
			Capacity	Capitality	Capacity	Capacity	Capacity	Capitolo	Capacity	Capacity	Capacity	Capacity
			Changes to	Changes to	Change - In	Changes to	Changes to	Change to	Changes to	Changes to	Changes to	Change - In
		Portfolio arte i Berbing	1/bbm	1.180	Arbbe	Arbierer	100	Artaber	Artainer	Frither.	Arisiser	Arbbe
		The reaction	(M.S.	161	(6.36	16.15	16.4	167	18.5	16.8	1615	16.26
Incomer Type	Dec #22C04	Gac/2,400 Crails	Requesty	Requesty	Reperty	Eingenny	Requesty	Request	Frequency	Request	Fireparaty	Requesty
Lua	135.50	11.30						(400)				
22	22.425	:45/5										
'Altr	/1,857	4.87	-							-	-	
Sh#	11,775	11,75						782	782	782	72	7.
SALLYYN AB	1.96	1.96						:06.	:06.	1.8.	306.	3062
New CTV			1,82	171	5975	2,577	17,017		2,968	4555	5,162	3,611
TOTAL	166,618	161/18	10,002	107,878	100,001	17 (15)	ອນທ	106,797	C1,17	17,005	DT_114	76,378

#### <sup>1</sup> Solid BRMs ware float that the second statement is a supervised ware set of the party and other statements and the PNE is an Jackey 20 (New Worlds Teer Residing)

		900	MWRethre	ment Scenari	6			
		Birth CT Scenar	in .			CD1	: Mills	
lovers his	Capacity Change , to Activity 1 in Films wants	Capacity Champes to Relations J in 2014 converses	Capacity Classyscim Relations J in 15 Listerator	Capacity Classecon Rehiere 1 is 39 Inconcert	Capacity Altange con Actieve Dis I	(Spartyr (Joseph m Advient Jie 30 Luceward	Capacity Classycus Usings Jin 15 Licenser	(apartny Obsegvenn Adminis Die 20 Lucustan
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້ອກອງທິດກອງກ					1087	3,087	3.87	7,082
Nue Cia	5,000	:.b.	11.87.	್ಷ ೫೯	5,545	12.00	11:30	1,214
10141	1/1/2/3	1/1.00	1// 58	1/58/4	25.34	1/1115	397/12	32.2%

		3,30	I MW IMie	ment Scena	rien			
		INCOME STREET	h			CDB		
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ún <del>a</del>					77 Y	20.5	727	782
Tament (compose					1087	3087	37811	1087
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"arregión age	1.15	1,777	Y, M	2115
NUM C S	1/7.544	21.5%	A1465	2:048

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AU.	: 25,	2.09	. 43.	1148.
án <del>a</del>	V,202	36,875	19,657	81° V
Tamen (immore	11.4.4	17.107	7897	7.1%
New CT /				
101 ML	3112	2557	2/9.58	2020

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		900	MW Retires	nent Scenari	0			
		BACK OF STREET	h			CDB	: Mills	
burn br	Capacity Changes In Achieve 1 in 2 Learners	Capacity Champs to Relieve	Capacity Changy can Uchicae 1 in 15 Linearan	Capacity Classeson Refere 1 is de	Caparity Clauge cm Achiem Jimi	(apartny (Jacanyse na Adalerne Jim 30 Linearnen	Capacity Changy can Uchicue Tin 15 Linnar are	Caparity Classifyer of Addition Tim 20 Linear on
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Tameny Sciences					1082	3,082	$T_{20}$ ,	7,082
9.54 C S	5 (L.	:.24	. 19 19	- <b>1</b> 1-	-26	40.	2004	9646
1014	10.63	1/9312	1/1.344	7,744	2/2.57	2/43%	1/7.94	1/1.25

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aren kontexe					1087	.3087	3.87	7,087
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KOL ML	10.24	2/0./38	1/1.75	1/1.0/4	1/2.5/3	1/314	2/11/2	1/1.8.4

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1014	DATE:	16/344	14312	272.5%	141.572	1/1.405	1/41%	2/4.200

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incomere Type	Capacity Changes In Arisipes	Capacity Changes to Actions The M Engine act	Capachy Changes lo Relation The 15 Responsey	Capacity Changes to Redicres T is 26 Requesty	Caparity Changer in Active The I Forgunary	(aparty Changes to Adhiere The M Foregoing	Capacity Changes to Acticate The 15 Responsey	Caparity Changes to Address The Al Forgue ary
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Tamen (cmmore	-				1082	.3082	3.8.5	7,082
New CTV	2,972	4,472	7/ Y	2977	2,236	3,20	77	2,901
1014L	364.284	16/7/1	2/9/3	vim	16.47	1/1.02	1/134	2/4,841

#### Secéna or Pârme 4 Statemie

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		Portfolio arte i Berbileg	- California	Printere .	Arbiew	Arialeer	Print-me	Arbiter	Artainer	Print-m-	Artainer	Arkiew	Artaber	Artaber	Artaber	Print-m-	Arisiser	Arbiew	( takene '	1/khan	Arithmer	Arkber	i fallene	- Walter
		NO NY AT GAS	10.1.1	1614	18.91	16 8.4	16.161	16.0.1	16114	16121	16.124	16.137	16 127	16.4.5	16.7.4	1673	16 78.9	16624	1610.9	18.855	1 10 2911	162761	i in beliefer	1 in Infinity
Incomine Type	Det #23CD4	(aparter	Request	Request	Firemany.	Firement	Requirer	Firement	FINISHING	Request	FIREMANY	FINISHING	Firement	Finger sty	FINERAL BOT	Request	FINISHING	FINISHING ST	Frequency	Request	Finance	Financer	Request	Requirer
i.a	155.50	135.50																						
25	112b.	2486.																						
What has a second secon	21,971	11,971																						
6n#	17,182	7 1/82																						
CALLEY SID LAC	1.590	1.50																						
See C14				- a**	725	1 U.S.	1,62	1,275	2,236	2918	1.202	4,75	1,400	1,916	7,130	= an 1	17,768		1	12,810	16.024	1.1828	15,295	×.75
TOTAL	B2225	81/2	81/7	123,795	出入2日	1128.3	31.94	8.156	B1.611	34240	81.122	85,164	8077	2010	34.27.	141.77	H2213	191,017	192131	WL07.	196,144	112,000	201,10	262,431

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Г			and a second of the	-														00	GATION .			Muc	RIMIDE		- increased	and shows
•	PREQUENCY (cn.8)	AND Provide	Page 6 With the Advance Page 2017 to constitute 1000kd7 to constit	And and a second second	1.000	Lacost Constant Lacost	and the second	1000	inel Ineliane	And a second sec	100 4000 100 100	Time day	11 a.m. 			Cartolic Grapping		H		Constant Constant Constant Constant Constant	-				Vandinan Vite Ankonin (Ar taski fan sei Ankonin antik (Kit)	
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- 2	10.0	202	COR NN	1.75	0.05	18	1	-	18-	1.18	. 812	2012	- 11 1	- 112	118	118	6	1225	4.225	-2358	12,5%	-6.205	2.25	12.256	11.132	8.18
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	10.0		10.00	1.75	143	471		_		_				- 18		4100		1101		1.508		-1.10%		110		10.720
	10.2		100.00	1.75	1.75	110	-			-	111	242		100	1100	1100		1.176	5.00%	1.000	3,201	0.078	- 100	4.08	1.44	0.05
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#### Attachment D

# **ERCOT CONE Study**

### **REFERENCE AND ALTERNATIVE TECHNOLOGY SELECTION**

PREPARED BY The Brattle Group Sam Newell Andrew W. Thompson Rohan Janakiraman

Sargent & Lundy Sang Gang Joshua Jungé Hyojin Lee

MARCH 22, 2024



PREPARED FOR ERCOT Supply Analysis Working Group Agenda

Selection of the Reference Technology

Selection of the Alternative Reference Technology

Project Timeline and Next Steps

# **Reference Technology**



### Purpose of Reference Technology Selection

**Objective**: describe a thermal dispatchable plant that is most likely to be developed in ERCOT in the next few years, as a basis for calculating a Cost of New Entry (CONE) metric useful for resource adequacy planning and market parameters

Approach: determine "revealed preference" by reviewing plants recently built and under development

### **Characteristics included**

- Technology type, turbine model, plant size and configuration
- Typical practices for direct electrical interconnection, fuel infrastructure and supply (e.g., dual fuel or firm gas), power augmentation (e.g. turbine inlet air cooling technology), emissions controls, and weatherization

# Proposed Specifications for Reference Technology

Technology and Size		
Generation Technology	Aeroderivative Combustion Turbine	Determined from most capacity in recently built or
Turbine Model	PROENERGY GE LM6000PC	<ul> <li>planned dispatchable plants in ERCOT for CODs between 2021-2026</li> </ul>
Configuration	8 x 0	Based on planned natural gas-fired plants by
Nameplate Capacity (MW)	484	capacity with a COD between 2021-2026)
Detailed Design		
Fuel Type	Natural gas, no secondary fuel	
Combustion Controls	Selective Catalytic Reduction (SCR)	-
Power Augmentation	Spray Intercooling (SPRINT)	Based on standard plant design for WattBridge natural gas-fired plants
Water Supply	Well	
Winterization	Additional cold weather critical components	-
Other Project Details		
Location	Harris County	Determined by county with most capacity
Lifetime (Years)	20	Based on standard plant design for WattBridge
Firm Gas Contract	Yes	natural gas-fired plants

### **Technology Type and Turbine Model**

Constructed our "Primary Thermal Dataset" of recently built and planned thermal dispatchable generation with actual or planned COD between 2021 to 2026:

- Data provided by WattBridge
- Cross-referenced against data from Hitachi ABB Velocity Suite, ERCOT CDR report, Texas Commission on Environmental Quality
- Excluded small cogeneration or internal combustion generation plants

This resulted in 14 generators which were all natural gas-fired plants with a total nameplate capacity of 5.1 GW, **98% of capacity is from GE LM6000 aeroderivative combustion turbines** 

Plant Name	Notes	Technology	Turbine Type	County	Online Date	Number of	Nameplate Capacity
Existing							
Topaz	[1]	Combustion Turbine	GE LM6000	Galveston	10/31/21	10	605
HO Clarke Generating	[2]	Combustion Turbine	GE LM6000	Harris	11/11/21	8	484
Victoria Port Power II	[3]	Combustion Turbine	GE LM6000	Victoria	01/12/22	2	100
Rabbs (Braes Bayou)	[4]	Combustion Turbine	GE LM6000	Fort Bend	05/02/22	8	484
Chamon Power	[5]	Combustion Turbine	GE LM6000	Harris	06/20/22	2	100
Beachwood (Mark One	[6]	Combustion Turbine	GE LM6000	Brazoria	11/30/22	6	363
Colorado Bend	[7]	Combustion Turbine	GE Frame 6B	Wharton	05/31/23	2	78
Brotman	[8]	Combustion Turbine	GE LM6000	Brazoria	10/23/23	8	484
Planned							
Remy Jade	[9]	Combustion Turbine	GE LM6000	Harris	04/01/24	6	363
Beachwood II (Mark Or	n [10]	Combustion Turbine	GE LM6000	Brazoria	06/01/24	2	121
Remy Jade II	[11]	Combustion Turbine	GE LM6000	Harris	11/30/24	4	242
Sibyl	[12]	Combustion Turbine	GE LM6000	Fort Bend	07/01/25	6	300
Elmax	[13]	Combustion Turbine	GE LM6000	Harris	06/01/26	10	605
LongLeaf	[14]	Combustion Turbine	GE LM6000	Angelina	2026	12	726
	[15]	= SUM ([1] to [14]) if Lf	V16000 To	tal LM6000 Na	meplate Capaci	ty (MW)	4,977
	[16]	= SUM ([1] to [14])	Total Dis	patchable Ge	neration Capaci	ty (MW)	5,055
	[17]	= [15] / [16]	LM6000 S	hare of Total I	Nameplate Capa	acity (%)	98%

### Thermal Dispatchable Generation in ERCOT (COD 2021 – 2026)

Notes and Sources: [1] to [14]:

Confidential data provided by ERCOT staff.

Hitachi ABB Velocity Suite, Generating Unit Capacity Dataset, January 22, 2024.

ERCOT, Report on the Capacity, Demand, and Reserves in the ERCOT region (2024-2033), December 8, 2023. Texas Commission on Environmental Quality, Issued Air Permits for Gas Turbines 20 MW or Greater, July 1, 2023.

# **Configuration and Nameplate Capacity**

WattBridge is the developer with most of the recently built and planned thermal dispatchable capacity, which all use the same turnkey natural gas-fired plant design (PROENERGY LM6000PC with SPRINT)

Filtered Primary Thermal Dataset for planned plants by WattBridge to determine most representative configuration and plant capacity resulting in 5 plants (2.1 GW capacity)

Gas-fired plants tend to be built with even-number units, so we selected a **8 x 0 configuration resulting in nameplate capacity of 484 MW** based on the average number of units of planned WattBridge plants and Sargent & Lundy experience

### Planned Thermal Dispatchable Generation in ERCOT by WattBridge (COD 2023 – 2026)

Notes	Technology	Turbine Type	County	Online Date	Number of	Nameplate Capacity
[1]	Combustion Turbine PROE	NERGY GE LM6000PC with SPRINT	Harris	04/01/24	6	363
[2]	Combustion Turbine PROE	NERGY GE LM6000PC with SPRINT	Brazoria	06/01/24	2	121
[3]	Combustion Turbine PROE	NERGY GE LM6000PC with SPRINT	Harris	11/30/24	4	242
[4]	Combustion Turbine PROE	NERGY GE LM6000PC with SPRINT	Harris	06/01/26	10	605
[5]	Combustion Turbine PROE	NERGY GE LM6000PC with SPRINT a	Angelina	2026	12	<b>72</b> 6
[6] =	Average([1] to [5])			Average	7	411
-	[1] [2] [3] [4] [5] [6] =	NotesTechnology[1]Combustion Turbine PROE[2]Combustion Turbine PROE[3]Combustion Turbine PROE[4]Combustion Turbine PROE[5]Combustion Turbine PROE[6] = Average([1] to [5])	NotesTechnologyTurbine Type[1]Combustion Turbine PROENERGY GE LM6000PC with SPRINT[2]Combustion Turbine PROENERGY GE LM6000PC with SPRINT[3]Combustion Turbine PROENERGY GE LM6000PC with SPRINT[4]Combustion Turbine PROENERGY GE LM6000PC with SPRINT[5]Combustion Turbine PROENERGY GE LM6000PC with SPRINT[6] = Average([1] to [5])	NotesTechnologyTurbine TypeCounty[1]Combustion Turbine PROENERGY GE LM6000PC with SPRINTHarris[2]Combustion Turbine PROENERGY GE LM6000PC with SPRINTBrazoria[3]Combustion Turbine PROENERGY GE LM6000PC with SPRINTHarris[4]Combustion Turbine PROENERGY GE LM6000PC with SPRINTHarris[5]Combustion Turbine PROENERGY GE LM6000PC with SPRINTHarris[6]= Average([1] to [5])	NotesTechnologyTurbine TypeCountyOnline Date[1]Combustion Turbine PROENERGY GE LM6000PC with SPRINTHarris04/01/24[2]Combustion Turbine PROENERGY GE LM6000PC with SPRINTBrazoria06/01/24[3]Combustion Turbine PROENERGY GE LM6000PC with SPRINTHarris11/30/24[4]Combustion Turbine PROENERGY GE LM6000PC with SPRINTHarris06/01/26[5]Combustion Turbine PROENERGY GE LM6000PC with SPRINTArerise[6] = Average([1] to [5])Average	NotesTechnologyTurbine TypeCountyOnline DateNumber of[1]Combustion Turbine PROENERGY GE LM6000PC with SPRINTHarris04/01/246[2]Combustion Turbine PROENERGY GE LM6000PC with SPRINTBrazoria06/01/242[3]Combustion Turbine PROENERGY GE LM6000PC with SPRINTHarris11/30/244[4]Combustion Turbine PROENERGY GE LM6000PC with SPRINTHarris06/01/2610[5]Combustion Turbine PROENERGY GE LM6000PC with SPRINTAverage7

Notes and Sources: [1] to [5]:

Confidential data provided by ERCOT staff.

Hitachi ABB Velocity Suite, Generating Unit Capacity Dataset, January 22, 2024.

ERCOT, Report on the Capacity, Demand, and Reserves in the ERCOT region (2024-2033), December 8, 2023.

Texas Commission on Environmental Quality, Issued Air Permits for Gas Turbines with Electric Output 20 MW or Greater, July 1, 2023.

### **REFERENCE TECHNOLOGY**

### Location

All of the planned gas-fired plants are located in 5 counties in Southeast Texas

**51% of planned natural gas generation capacity is in Harris County** (highlighted in green), so Harris county was selected as the location

### Locations of Planned Thermal Dispatchable Gas Capacity in ERCOT (COD 2023-2026)

![](_page_31_Figure_5.jpeg)

Sources: Confidential data provided by ERCOT staff; Hitachi ABB Velocity Suite, Generating Unit Capacity Dataset, January 22, 2024; ERCOT, Report on the Capacity, Demand, and Reserves in the ERCOT region (2024-2033), December 8, 2023; Texas Commission on Environmental Quality, Issued Air Permits for Gas Turbines with Electric Output 20 MW or Greater, July 2, 2023.

# **Alternative Reference Technology**

# Purpose of Alternative Technology Selection

**Objective**: describe a dispatchable renewable plant that is most likely to developed in ERCOT in the next few years as a basis for sensitivity analysis of the Cost of New Entry (CONE) reliability metric

Approach: again use "revealed preference" based on developers' actual plants/plans

### **Characteristics to include:**

- Generator technology type and size
- Storage technology type, size, and duration
- Location of a representative plant
- Typical engineering design for power coupling, DC / AC ratio, battery chemistry and battery augmentation schedule

### ALTERNATIVE REFERENCE TECHNOLOGY

### Proposed Specifications for Alternative Reference Technology

Technology and Size		
Generation Technology	PV + BESS Hybrid ("Solar Hybrid")	Determined by alternative technology type with most capacity in recently built or planned plants in ERCOT for CODs 2021-2026
PV Capacity (MW)	200	
Storage Capacity (MW)	100	Determined by assessing median plant size, median solar-to- storage ratio, and median duration
Storage Duration (Hours)	2	
Detailed Design		
PV Module Technology	Monocrystalline Bifacial Panels	Determined by most prevalent characteristics in recently built
PV Tracking System	Single-axis tracker	2026
PV DC / AC Ratio	1.3	Determined by median PV DC / AC ratio
Storage Technology	Lithium-ion	Determined by most prevelent storage technology
PV-BESS Coupling	AC Coupled (separate inverters)	Determined by most prevalent coupling design
Other Project Details		
Location	Brazoria County	Determined by county with most capacity
Lifetime (Years)	20	Lifetime chosen from typical design for plant type based on Sargent & Lundy expertise
Storage Augmentation	Every 5 years	Median augmentation frequency based on Sargent & Lundy expertise and review of similar sized solar hybrid plants

# Alternative Reference Technology and Lifetime

Created "Primary Solar Hybrid Dataset" by filtering ERCOT January 2024 GIS Report and confidential duration data provided by ERCOT staff (70 plants and 20 GW of capacity), considering plants:

- with a COD between 2021-2026
- excluded those without storage
- separated those with and without a signed Interconnection Agreement

Solar hybrid and standalone storage are both prevalent

**Solar hybrid** was selected because it is dispatchable and produces primary energy Comparison of Existing or Planned Storage and Generator Capacities for Hybrid and Standalone Storage Plants in ERCOT (COD 2021 – 2026)

		Exi	sting	Planneo	d with IA	Planned without IA			
Technology	Notes	Storage Capacity (MW)	Generator Capacity (MW)	Storage Capacity (MW)	Generator Capacity (MW)	Storage Capacity (MW)	Generator Capacity (MW)		
Solar Hybrid	[1]	1,264	4,214	8,881	15,928	16,736	25,332		
Wind Hybrid	[2]	224	698	195	582	100	435		
Thermal Hybrid	[3]	263	358	0	0	0	0		
Standalone Storage	[4]	2,468	0	13,495	0	64,422	0		

Notes and Sources: IA = Interconnection Agreement.

[1] to [4]:

Confidential data provided by ERCOT staff;

ERCOT, January 2024 Generator Interconnection Status (GIS) Report, February 12, 2024.

### ALTERNATIVE REFERENCE TECHNOLOGY

## **PV** Capacity

Filtered the Primary Solar Hybrid Dataset for only planned plants with a signed Interconnection Agreement (IA) which resulted in 55 plants total (16 GW)

The histogram on the right displays the number of plants (teal, right axis) and solar generation portion of capacity (blue, left axis) for the planned solar hybrid plants and shows grouping around 200 MW, the median generator size is 204 MW

Based on the distribution of solar generator sizes, we selected **200 MW** to be the representative solar capacity

### Planned ERCOT Solar Generation Capacity and Solar Hybrid Plants Size Distribution (COD 2023-2026)

![](_page_36_Figure_6.jpeg)

Confidential data provided by ERCOT staff; ERCOT, January 2024 GIS Report, February 12, 2024.

# PV Module Technology and Tracking System

Cross referenced the Primary Solar Hybrid Dataset (70 plants) with confidential solar project data prepared by UL Solutions for ERCOT, which resulted in 29 solar hybrid plants (7.8 GW of capacity) that overlapped between the two datasets

Based on these 29 solar hybrid plants, 58% of solar hybrid capacity has monocrystalline solar panels, 54% has bifacial solar panels, and 74% has a single-axis tracking system

Additionally, Sargent & Lundy reviewed their extensive project database and public sources (Form EIA-860) for ERCOT solar hybrid projects which confirmed our analysis, so we selected a PV system with **monocrystalline and bifacial solar panels with a single-axis tracking system** 

### PV Technology Characteristics of Existing or Planned Solar Hybrid Plants (COD 2021-2026)

PV Module Technology	Notes	Plants	Total Capacity (MW)	Share of Capacity (%)
Monocrystalline	[1]	17	4,534	58%
Polycrystalline	[2]	1	601	8%
Thin Film	[3]	3	698	9%
Unknown	[4]	8	1,936	25%
Sum	[5] = SUM([1]:[4])	29	7,769	100%
Solar Panel Type	Notes	Plants	Total Capacity (MW)	Share of Capacity (%)
Bifacial	[1]	14	4,174	54%
Not Bifacial	[2]	7	1,659	21%
Unknown	[3]	8	1,936	25%
Sum	[4] = SUM([1]:[3])	29	7,769	100%
Tracking System	Notes	Plants	Total Capacity (MW)	Share of Capacity (%)
Single	[1]	21	5,769	74%
Dual	[2]	1	210	3%
Unknown	[3]	7	1,791	23%
Sum	[4] = SUM([1]:[3])	29	7,769	100%

Notes and Sources: Confidential data provided by ERCOT brattle.com | 13 staff; ERCOT, January 2024 GIS Report, February 12, 2024.

## Storage Technology, Storage Capacity, and Duration

From our Primary Solar Hybrid Dataset (70 plants total), all storage systems were lithium-ion and the median duration and median storage-to-solar capacity ratio were 2-hours and 50%, therefore we selected a lithium-ion battery system with a 2-hour duration and 50% storage-to-solar capacity ratio

Based on the 200 MW PV generator size and the 50% storage-to-solar capacity ratio, we selected a **100 MW storage capacity** 

Storage Durations for Existing or Planned Solar Hybrid Plants vs. Standalone Storage in ERCOT (COD 2021 – 2026)

	Exi	sting	Planned with IA					
Technology	Median Storage Duration (Hrs)	Median Storage / Solar Capacity Ratio (%)	Median Storage Duration (Hrs)	Median Storage / Solar Capacity Ratio (%)				
Solar Hybrid Standalone Storage	1.5 1.0	34%	2.0 1.1	50%				

Notes and Sources: IA = Interconnection Agreement. Confidential data provided by ERCOT staff;

ERCOT, January 2024 GIS Report, February 12, 2024.

### ALTERNATIVE REFERENCE TECHNOLOGY

### Location

Filtered the Primary Solar Hybrid Dataset for only planned plants which resulted in 55 plants total (16 GW)

37% (5.8 GW) of solar generator capacity is in the top 5 counties (see the highlighted counties in the map) and Brazoria County (in green) is the county with the most capacity and contains 12% (1.9 GW) of the total, so we selected **Brazoria County as the reference location** 

### Locations of Planned Solar Hybrid Plants in ERCOT (COD 2023 – 2026)

![](_page_39_Figure_5.jpeg)

Sources: Confidential data provided by ERCOT staff; ERCOT, January 2024 GIS Report, February 12, 2024.

# Storage Augmentation (1/2)

Problem of battery degradation: Li-ion battery systems degrade due to time, usage, and environmental factors. This degradation impacts the capacity, duration, and efficiency of the storage system, so to maintain capabilities as sized for the interconnection and hybrid system (as well as contract and warranty terms) mitigation techniques are needed.

Storage augmentation: is a common practice for Li-ion storage systems which entails over-building a fixed percentage of design capacity and over-designing some system components (such as battery module rack space) to later enable battery modules to be added (augmented) during the project lifetime to offset degradation during normal system operations.

### Illustrative Example of BESS Overbuild and Augmentation Approach

![](_page_40_Figure_5.jpeg)

# Storage Augmentation (2/2)

**How augmentation frequency is determined**: if the project's financial plan includes augmentation, the frequency may depend on several factors including the project use case, battery degradation profile, capacity requirements of project agreements, site space availability constraints, and anticipated costs for batteries at the anticipated dates of augmentation.

**How we selected the augmentation approach**: the battery cycling and augmentation frequency we selected is based on a review of financial models from several similar PV+BESS installations and the median augmentation period. In ERCOT, solar hybrid plants are intended primarily for energy shifting. Based on our review, for this service we assumed on average one cycle per day for the battery storage component and predict annual degradation based on battery manufacturer warranty curves for the anticipated time and energy throughput. We selected an augmentation frequency of every 5 years with an initial overbuild to ensure the energy capacity exceeds the minimum required system output.

**How this is included in CONE calculation**: this is included as separate line items to i) fixed O&M cost based on an annualized cost of storage augmentation over the project lifetime and ii) CAPEX based on the additional balance of plant equipment (e.g., reserved rack space and conductors) included in the initial construction to accommodate future augmentation.

# **Timeline and Next Steps**

![](_page_42_Picture_1.jpeg)

# **Project Timeline**

![](_page_43_Figure_1.jpeg)

### Next Steps

Develop Cost Estimates for Reference and Alternative Technologies

Determine Financial and Cost Escalation Parameters