ELECTRICITY STORAGE WHITE PAPER

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This white paper is written to raise the issues of integrating energy storage devices into the ERCOT grid.

I. SUMMARY OF EMERGING ELECTRIC STORAGE TECHNOLOGIES

There is a wide variety of storage technologies, with differing technology and market characteristics. The technical characteristics and economics of these technologies directly impact the regulatory and legal aspects of storage commercialization and integration in the Texas electric grid.

There are four key characteristics of energy storage devices:

- Energy Density: The amount of energy that can be supplied from a storage technology per unit weight (measured in Watt-hours per kg, Wh/kg).
- Energy Rating: (expressed in kWh or MWh) is how much total energy storage can be provided by a storage device.
- Power Capability: (expressed in kW or MW) determines how much energy can be released over a defined time period. Some technologies can reach full capacity almost instantaneously, other technologies may require a ramp up period of a few minutes to reach full capacity. A 100 kWh device rated at 20 kW can supply 20 kW of output for 5 hours (20x5 = 100 kWh).
- Discharge Time: The period of time over which an energy storage technology releases its stored energy.

These characteristics are interrelated, as Energy Density determines the “footprint” or physical size of the device required to reach a given Energy Rating. The Energy Rating constrains the Power Capability and Discharge Time. A device that has a high Power Capability will exhaust stored energy at a faster rate and thus have a shorter Discharge Time. A higher Energy Rating allows either an increase in Power Capability, Discharge Time or some combination of these two factors.

Costs of energy storage devices are usually quoted in terms of cost/kWh or cost/kW. Costs are usually related to the application the device was designed to satisfy. Some devices will have a high cost per kWh but relatively lower cost/kW while others will be the reverse. The economics of a storage technology will depend both upon cost and its operating capabilities, and thus the eligible markets in which it could expect to participate. The economics of a storage device will also depend upon the customer and purpose (for example, market arbitrage for a power marketer, ancillary services for an independent generator, or transmission/distribution investment deferral for a transmission and distribution service utility).

Storage technologies can be grouped into sets of technologies with similar characteristics.

- Batteries, Capacitors and Flywheels

There are a wide range of battery technologies, some which have been employed for almost a century, such as lead-acid batteries, and some of which are still in develop and have yet to be commercialized.

- *Lithium Ion (Li) Batteries* - offer high-power densities and generally acceptable cycle life. Charge/discharge efficiencies around 90% (i.e. round trip efficiency from initial charge to complete discharge) have been reported for Lithium batteries. The main hurdle associated with mass energy storage systems using Li batteries is the high cost (above $600/kWh) due to special packaging and internal overcharge protection circuits.

- *Sodium Sulfur (NaS) Batt*eries - NaS batteries have a relatively high energy density, although less than Li batteries. NaS batteries are designed for long discharge cycles (8 hours), but have the capacity to discharge very rapidly and at multiples of rated power. These batteries have an estimated lifetime of 15 years and approximately 2500 cycles (charge/discharge/recharge) and charge/discharge efficiencies up to 90%.

- *Flow Cell Batteries* - Electrochemical flow cell systems, also known as redox flow cells, convert electrical energy into chemical potential energy by means of a reversible electrochemical reaction between two liquid electrolyte solutions. Installations to date have principally used the vanadium redox batteries (VRB) and zinc bromine batteries (ZBB). Several dozen are in place, mainly in Japan and North America. A major advantage of the technology is the ability of the technology to perform discharge cycles indefinitely. These systems have relatively low efficiencies varying from 70% to 85% (VRB). The VRB can be fully discharged without reducing life expectancy, as one system has undergone around 14,000 discharge cycles.

- *Lead-Acid Batteries* - Lead-Acid batteries are electrochemical cells, based upon chemical reactions involving lead and sulfuric acid. Lead-Acid is one of the oldest and most developed battery technologies, used in electrical power systems for more than a century. Lead acid batteries are low cost but have limited cycle life, low-energy density and a large footprint. Charge/discharge efficiencies for lead-acid batteries are 60 – 95% with self-discharge rates of 2 to 5% per month. The chemical reaction favors several hours of low-rate discharge. Battery life ranges from 3 years to as long as 9 years at > 80% capacity.

- *Nickel Batteries* - There are a number of Nickel-based batteries currently under development, though Nickel-Cadmium (NiCd) and Nickel-Metal Hydride (Ni-MH) are the most developed. The NiCd and NiMH batteries can reach up to around 1500 deep cycles. Despite being used widely in electric vehicles, there are few examples of their application to electricity markets. Golden Valley Electric Association (GVEA) in Fairbanks, Alaska has installed a 27 MW NiCd battery system. The NiCd batteries are expected to provide 100 complete and 500 partial discharges in the system's 20 year design life.[1] Concerns about cadmium toxicity and associated recycling issues are a barrier to gaining consent for large-scale storage systems based upon NiCd technology.

- *Flywheels* - A flywheel acts as a mechanical battery, storing kinetic energy. A flywheel storage device comprises a shaft-mounted mass rotating in (or carrying) a motor-generator winding – converting electrical energy into kinetic energy as it accelerates (charges when speeding up) and reserving the process when it discharges energy. In general, flywheels can be classified as low speed or high speed. Increasing rpm significantly increases the energy density of a flywheel, but a higher mass flywheel can store more energy per rpm. Flywheel energy storage systems are generally more reliable than batteries, so applicability is mostly an issue of cost-effectiveness. Flywheels are more attractive in operating environments that are detrimental to battery life, such as frequent cycling.

- *UltraCapacitors* - To build standard capacitors that can hold a significant amount of energy requires a very large dielectric. Ultracapacitors (also known as supercapacitors) solve this problem through the use of a high surface area material such as activated carbon. Ultracapacitors are capable of charging substantially faster than conventional batteries, staying recharged almost indefinitely and can operate down to temperatures of -25°C. Ultracapacitors have been marketed since the 1980s, with the first application in military projects.[2] However, cost and small energy storage capacity has limited Ultracapacitors to niche applications.

- Compressed Air Energy Storage (CAES)

The first commercial scale CAES plant in the world was the 290 MW plant in Huntorf, Germany, operated by Nordwest Deutsche Kraftwerke (NDK) since 1978. The Alabama Electric Co-operative in McIntosh, Alabama, built the second commercial scale CAES plant, with a capacity of about 110 MW. There have been a number of proposed CAES plants, but none have yet to go past the planning stage.

First generation CAES used a simple design with the compressor and generator on the same shaft. New CAES designs eliminate operation switchover time by decoupling the compression and turbo-expander trains, permitting direct switching between compression and expansion operation. This change means compressor size can be optimized independently of the turbo-expander design and permits standard production compressors to be used in the system configuration. It also means that a CAES would be an ideal ancillary service machine, since it

[1] Steven Eckroad, EPRI, *Golden Valley Cooperative Project in Alaska - 40 MW Nickel-Cadmium Battery*, California Energy Commission Staff Workshop, February 24, 2005. 27 MW is for 15 minutes, the system has supplied 46 MW for five minutes. In 2006 the system responded to 82 events

[2] Chris Naish, Ian McCubbin, Oliver Edberg and Michael Harfoot, *Outlook of Energy Storage Technologies*, for European Parliament's committee on Industry, Research and Energy (ITRE), February 2008, p. 11.

would provide a controllable load in compression mode, and a fast start generator, both able to operate independently.[3] The ramp rates for a CAES system are better than for an equivalent gas turbine plant. The McIntosh plant can ramp at approximately 18 MW per minute, which is about 60% greater than for typical gas turbines. Proposed plants have been designed to reach full power in 14 minutes (or 7 minutes for an emergency start)—which translates to 10 to 19 MW per minute per 135 MW module.[4]

CAES storage is dependent on the availability of suitable salt dome formations or rock caverns. Above ground air storage vessels or air storage pipeline systems can also be used to store compressed air. Such systems are attractive because they allow CAES plants to be sited almost anywhere, since no underground geologic formation is needed. However, a mini-CAES facility has only a few hours of energy storage. Such systems are estimated to be more expensive than underground salt-based air storage caverns.[5]

- Thermal Energy Storage

Thermal storage technologies are primarily a demand-side load shift/load management application, and should have limited impact on reliability or ancillary services. Systems based on the sensible heat capacity of materials include hot and cold water tanks, underground thermal energy storage (UTES) or specific materials and structures. The storage of either hot or chilled water is a well-established technique and is practiced over a full spectrum of capacities. Systems based on the latent heat capacity of materials include ice storage and the use of various phase change materials. Lower cost night time electricity is used to generate ice or cool water, which in turn provides cooling capacity during the day.

Technologies such as Li batteries and Flywheels, which have high costs per kWh of energy storage, but also the ability to respond quickly, tend to be more suited to the supply of ancillary services, especially regulation (frequency control). In the past, utilities and industries have accepted mediocre voltage quality as the norm, due to the limitations of the generation units that supply voltage support to rapidly respond to voltage fluctuations. Generator units can take up to five minutes to ramp to their regulation target capacity, whereas Li batteries and Flywheels can respond in seconds.

Flow batteries are more suited to transmission reliability and energy arbitrage, where they can balance larger energy storage capacity with reduced charge/discharge efficiencies and slower response to dispatch commands. CAES combines both operational flexibility and the ability to participate in almost all ERCOT markets, but a CAES facility is a large scale solution with high operating costs (due to co-firing of natural gas with compressed air), large initial capital costs

[3] Electric Power Research Institute, *Compressed Air Energy Storage Scoping Study for California*, for the California Energy Commission, PIER Final Report, November 2008, p. 5.

[4] Samir Succar and Robert H. Williams, *Compressed Air Energy Storage: Theory, Resources and Applications For Wind Power*, Princeton Environmental Institute, April 8, 2008, p. 23.

[5] NYSERDA, Mini-Compressed Air Energy Storage for Transmission Congestion Relief and Wind Shaping Applications, July 2008.

and constraints on location.

The economics of storage in Texas will depend on the eligibility of these technologies to participate in ERCOT markets and to provide value at the distribution level.

II. OWNERSHIP AND CONTROL IN ERCOT

A. Background: PURA and PUCT Rules

A key issue in the ERCOT market is related to ownership and control of storage devices, due to prohibitions on the provision of energy and ancillary services by Transmission and Distribution Service Providers (TDSPs). Under the Public Utilities Regulatory Act (PURA), transmission services in ERCOT excludes control area services, scheduling resources, regulation services, provision of operating reserves, and reactive power support, voltage control, and other services provided by generation resources.[6] At the retail level, PURA is a bit less restrictive, holding only that regulated utilities shall not provide customer energy services business activities that are widely available in the competitive market.[7]

The Commission definition of transmission service includes construction or enlargement of facilities, transmission over distribution facilities, and any other associated electrical service the Commission determines appropriate.[8] At the distribution level, the Commission includes storage as a demand-side energy efficiency resource.[9] Distribution relates to system and discretionary services associated with facilities below 60 kV. There is an exception to the Competitive Energy Services restriction that includes equipment on the customers' side of the point of deliver that is necessary to support utility facilities, which specifically includes batteries.[10]

At the transmission level, if a battery is permitted to be owned by a TDSP, there will be a question of whether it is eligible for Transmission Cost of Service (TCOS) recovery, and whether a Certificate of Convenience and Necessity (CNN) is required. Transmission costs are socialized within ERCOT, so inclusion of storage in transmission has been a contentious issue, as transmission customers prefer to include storage facilities in distribution costs. Facilities that do not require a CNN include high voltage switching stations, or substations and distribution facilities within the electric utility's service area.[11]

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[6] PURA § 31.002(20).

[7] PURA § 39.051a.

[8] PUCT Substantive Rule § 25.5(141).

[9] Sub. R. § 25.5(32).

[10] §25.343(f)(3).

[11] §25.101(c).

Some of these issues were addressed in the only case before the Commission that has dealt with a battery or other storage device. Unfortunately, the Commission restricted its ruling to the specific case in question, and has not built upon that case to initiate a rulemaking that would clarify some of these issues for a potential investor in storage technologies.

B. The ETT Presidio Battery Case

These storage ownership and control issues were brought to light by the application of Electric Transmission Texas, LLC (ETT) for approval of the installation of a battery at Presidio, Texas, filed in August of 2008. ETT proposed to install a 4.8 MW NaS (sodium sulfur) battery in Presidio as part of an ERCOT-approved transmission reliability solution. Due to the first-of-its-kind nature, ETT filed an application requesting Commission confirmation that the battery complied with Texas law and would be a transmission asset eligible for inclusion in the Company's transmission cost of service.[12] ETT contended that the battery qualified as a transmission asset under § 25.192(c)(1)(D), since it would be located in a distribution substation with a power factor in excess of 0.95 and would be controlled by an operator or automatically switched in response to transmission voltage.[13] ETT also requested a finding that the useful life of the NaS battery for depreciation purposes was fifteen years. Absent this finding, there would be no applicable depreciation rate for the battery other than the 62-year useful life applied to station assets.[14]

The battery would be cycled on a routine basis (daily to weekly) in order to maintain its operational readiness and sustain its temperature. Such cycling would be on the order of 10-20% of its energy capacity. The battery would automatically discharge to supply power to the available load for the outage of the line to Marfa. Typically, 24 MWh (4 MW for 6 hours) of energy can be discharged from the battery before being recharged. The battery was expected to be connected to the distribution bus of the load-serving substation to avoid the cost of a dedicated transformer, and prevent a line outage from interrupting the connection between the battery and the Presidio load. Power discharged from the battery would be absorbed by the local load and, if treated as unaccounted for energy (UFE), would not enter the wholesale or retail market. Charging would follow when the line is placed back in service. If the battery was not metered and not included in the settlement process, energy discharged from the battery would cause a maximum 0.0001 Hz deviation in system frequency. ERCOT frequency deviates in excess of 0.001 Hz continuously without impacting market prices. Any peak-shaving from cycling the battery would be inconsequential to the market but would reduce overall losses on the system during such cycling. As a transmission provider, ETT stated that it could not provide ancillary services from the battery.[15]

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[12] Application of Electric Transmission Texas, LLC for Regulatory Approvals Related to Installation of a Sodium Sulfur Battery at Presidio Texas, Project 35994_18, August 12, 2008.

[13] *Id*., pp. 4-5.

[14] *Id*., p. 6.

[15] Application of Electric Transmission Texas, LLC for Regulatory Approvals Related to Installation of a Sodium Sulfur Battery at Presidio Texas, Project 35994_25, Electric Transmission Texas' Response to Staff and intervenors First Request for Information, Response No. 1-11, 1-12, 1-17, 1-19.

The Power Converter System (PCS) component of the battery installation included DC-to-AC inverters, which create an output voltage wave that is controlled in magnitude and phase angle to produce either leading or lagging reactive current. Functionally, both the real and reactive capacity of the installation was needed to relieve anticipated transmission planning criteria violations. The reactive compensation capacity of the device provides local voltage support and the real power capacity of the device relieves the overload of the transmission line.

The Commission accepted the Texas Industrial Energy Consumers' (TIEC) contention that ETT's request for a determination of the useful life of the battery for depreciation purposes was a request for piecemeal ratemaking. Establishing a depreciation rate in isolation contravenes the Commission's responsibility to ensure that ETT's rates as a whole, including the proposed depreciation rate, will be just and reasonable.[16]

The Commission rejected TIEC's contention that a battery is a generation facility. TIEC claimed that § 25.192(c)(1) delineates the facilities that the Commission has deemed transmission facilities, and this list does not include batteries. ETT contended that the battery is a reactive power device, and that it qualifies as a transmission facility under § 25.192(c)(l)(D). TIEC claimed that because a battery stores and produces electricity, it is a generation asset as defined in § 25.5(54).[17]

The Commission ruled that the battery was a transmission asset:

> The Commission finds that the battery does not generate electric power by converting another source of energy into electricity; therefore, it cannot be a generation asset, which would preclude it from constituting a transmission asset. Even though the battery does produce real power when it is discharged, without power from the grid, the battery does not remain charged. Therefore, the manner in which ETT proposes to operate the battery provides reliability service rather than power for commercial sales, the hallmark of a generation asset.
>
> The Commission finds that ETT's proposed use of the NaS battery is appropriate for a transmission utility because the battery system provides benefits associated with transmission service operations, including voltage control, reactive power, and enhanced reliability. The Commission rejects the proposition that the back-up function of the battery is a service of the type governed by a tariff for wholesale transmission at distribution voltage. Therefore, the Commission concludes that ETT's proposed NaS battery installation complies with Texas law

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[16] Application of Electric Transmission Texas, LLC for Regulatory Approvals Related to Installation of a Sodium Sulfur Battery at Presidio Texas, Project 35994_25, Texas Industrial Energy Consumers' Reply to Commission's Staff's Response to TIEC's Motion to Dismiss, November 12, 2008, p. 4.

[17] Application of Electric Transmission Texas, LLC for Regulatory Approvals Related to Installation of a Sodium Sulfur Battery at Presidio Texas, Project 35994_25, Texas Industrial Energy Consumers' Statement of Position, November 18, 2008, p. 3.

> and is eligible for inclusion in TCOS.[18]

However the Commission was careful to limit the ruling to this particular asset, responding to requests to limit the scope of the proceeding:[19]

> The Commission's decision to classify ETT's proposed NaS battery as a transmission asset is based upon electric reliability facts that are unique to Presidio, Texas, as set forth in the findings of fact in this Order. The Commission's regulatory analysis in another application or location for the same or similar battery device may not necessarily result in a regulatory classification as a transmission asset.[20]
>
> This case is not precedential with respect to any subsequent application, proceeding, or process for determining whether a similar battery or other energy storage facility is a transmission asset eligible for inclusion in TCOS. [21]

For purposes of congestion management and reliability, certainty about the conditions governing the status of a battery as an asset would simplify regulatory proceedings and allow investments in storage by TDSPs with a greater degree of certainty.

C. Ownership and Control Issues in ERCOT

Ownership and control is especially complex with storage devices, because there are so many permutations of technology and characteristics. Storage could be applied at a generation site(s), in a transmission function, for distribution reliability, or even at the customer or local transformer level. Services can include arbitrage and hedging, load management, transmission and distribution reliability and ancillary services. We present a number of permutations of ownership and control of storage devices, and the potential regulatory issues raised by each arrangement.

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[18] Application of Electric Transmission Texas, LLC, For Regulatory Approvals Related To Installation Of a Sodium Sulfur Battery at Presidio, Texas, Final Order, April 6, 2009, pp. 3-4.

[19] Application of Electric Transmission Texas, LLC for Regulatory Approvals Related to Installation of a Sodium Sulfur Battery at Presidio Texas, Project 35994_83, Concerned ERCOT Market Participants' Initial Brief, January 27, 2009, p. 3. Concerned ERCOT Market Participants (International Power America, NRG Texas LLC, Exelon Generation and PSEG Texas) agreed with ETT that future proposed energy storage installations by transmission service providers would best be addressed in a rulemaking proceeding. Staff contended that as a fully litigated, contested case before the Commission, a final order in this proceeding should be considered precedential for future proceedings relating to the installation of NaS batteries. Application of Electric Transmission Texas, LLC for Regulatory Approvals Related to Installation of a Sodium Sulfur Battery at Presidio Texas, Project 35994_84, Commission Staff's Initial Brief, January 27, 2009, pp. 13-14.

[20] Final Order at p. 5.

[21] *Id*. at p. 12.

1. *Generator Ownership and Siting*

This is the simplest configuration. Legally, there would be no issues, since generators (or other third parties) can own storage and use a storage resource to arbitrage, hedge and sell ancillary services. In this case, the only issues will be interaction with ERCOT, which will be discussed in the next section. The generator provides these services to itself, the market or third parties. By siting the facility independently, or in conjunction with a renewable energy facility, the storage device may provide local reliability benefits but limited system benefits.

2. *Generator Ownership and Transmission Siting*

In some instances a generator will want to locate a battery on or adjacent to a TDSP's transmission facilities to provide reliability services to the TDSP. Many of the storage devices are mobile, such as batteries built on truck trailers, and thus can provide a feasible method of short-run transmission investment deferral. This solution will raise no legal issue concerning the ownership of the facility or the sale of services, but there may be a question about whether the storage resources' contribution to transmission reliability would be properly valued and compensated.

There are often situations where new transmission investment will be required, but substantial savings can be achieved from temporary deferral of the investment if a bridge solution such as a battery can be deployed. Upgrading a transmission line is a good example, since transmission tends to be built in discrete "blocks" of capacity, there is often a period of time during which an existing line is inadequate but an upgrade would be inefficiently utilized. If a generator owns a battery or other storage device, and with the cooperation of the TDSP and confirmation of value through the ERCOT planning process, sites and operates the storage device to achieve the same result as if a TDSP owned the storage device, it should be eligible for compensation up to the deferred transmission investment costs. A TDSP might prefer to lease the reliability service from a third party and then receive compensation for lease costs by including them in TCOS as a reasonable expense. In many instances, a TDSP will want to purchase storage reliability services to defer investment for a limited time period, and facilitating this arrangement would maximize social benefits relative to accelerated investment in new transmission facilities.

This is an example where a PUCT rulemaking is probably required to clarify the circumstances under which a lease agreement and/or service purchase contract would be valid and eligible for inclusion into TCOS. One question which would need to be addressed would be the limits on operation of the storage device to ensure that the value of reliability services was not impaired if used for other purposes. For example, if the storage device is needed only to prevent overloading during a few peak hours, then the owner could sell ancillary services the rest of the year. On the other hand, if like the Presido battery, the device provides insurance against line outages, then it might be necessary to require that the storage device remained fully charged at all times. This determination should be a fact based issue, balancing reliability considerations with the potential to share the additional value from the sale of ancillary and energy services between the storage device owner and transmission service ratepayers.

3. *Transmission Ownership and Transmission Siting*

This is the Presido case. While the Commission refrained from setting a precedent, there is no reason to expect a different ruling under similar circumstances. A TDSP could use a mobile storage device for both transmission and distribution investment deferral projects. If the TDSP added storage to defer transmission investment, it could potentially receive approval for that investment up to the present value of deferred costs, since this would maintain reliability at minimum cost. The investment would be eligible for inclusion in TCOS. However, ownership by the TDSP precludes obtaining any value for the storage device other than deferred investment savings from alternative solutions.

4. *Distribution*

The three examples above could be repeated with distribution storage, though the issues shift slightly. Instead of the question of eligibility for inclusion in TCOS, the question becomes eligibility for recovery in the TDSP's ratebase or as an expense. Instead of restricting the TDSP from the sale of services to ERCOT or wholesale market participants, the TDSP is restricted from the sale of competitive retail services. One complex situation may occur when the TDSP owns or operates a battery on a commercial customer's site, and the customer wants to battery to be used to reduce their energy and/or ancillary costs as well as provide reliability services to the utility. The question becomes whether this is a private contractual matter or if the contract should be subject to PUCT approval.

III. ERCOT OPERATIONS AND MARKET ISSUES

In this section, we examine potential problems presented by the fact that storage devices were not planned for, nor incorporated into the nodal protocols and rules. Since it is unlikely that few storage devices will be operational before the Nodal market is implemented, we will ignore the current zonal protocols. The following review of the nodal protocols is meant to be illustrative, and not necessarily comprehensive, and requires industry input. The wide range of storage technologies and applications almost ensures that unexpected "glitches" in the protocols will surface as ERCOT and the stakeholders attempt to incorporate a new technology that was not envisioned years ago when the design of the new market was initiated.

A. ERCOT Nodal Protocols Section 2: Definitions and Acronyms

Dynamic Rating - The current-carrying capability of a Transmission Element adjusted to take into account the effect of ambient weather conditions.
Transmission Element - A physical Transmission Facility that is either an Electrical Bus, line, transformer, generator, Load, breaker, switch, capacitor, reactor, phase shifter, or other similar device that is part of the ERCOT Transmission Grid and defined in the ERCOT Network Operations Model.

Q: Will storage be considered to be a Transmission Element when it is used for transmission reliability? Will a Dynamic Rating need to be determined for such a storage device?

Electrical Bus - (1) A physical transmission element defined in the Network Operations Model that connects, using breakers and switches, one or more

(a) Loads;
(b) Lines;
(c) Transformers;
(d) Generators;
(e) Capacitors;
(f) Reactors;
(g) Phase shifters; or
(h) Other reactive control devices to the ERCOT Transmission Grid where there is negligible impedance between the connected Transmission Elements.

> *Q: Should storage devices be added to the list of devices connected to Electric busses?*

Emergency Base Point (High Emergency Limit) - The target MW output level for a Resource that is selected by ERCOT during an Emergency Condition.

> *Q: Will storage devices have emergency base points? How will this be determined? For example, a flywheel or Li battery used for regulation would not be able to provide emergency power, but a flow battery would have a range of outputs, depending on the desired duration of discharge from the battery. A CAES facility would be modeled like a combustion turbine.*

Generation Entity - The owner of an All-Inclusive Generation Resource.

> *Q: If a storage device is owned by a "storage entity," does such an entity need to be defined? Is a battery from the perspective of ERCOT modeling and operations considered a generator, a controllable load or both?*

High Sustained Limit (HSL)

High Ancillary Service Limit (HASL)
High Sustained Limit (HSL) for a Generation Resource
High Sustained Limit (HSL) for a Load Resource

Low Sustained Limit (LSL)

Low Ancillary Service Limit (LASL)
Low Sustained Limit (LSL) for a Generation Resource
Low Sustained Limit (LSL) for a Load Resource

> *Q: How will the above terms apply to storage devices?*

Maximum Power Consumption (MPC)

> *Q: How does this apply to storage devices, if at all?*

Net Dependable Capability - The maximum sustained capability of a Resource as demonstrated by performance testing.

> *Q: How does this apply to storage devices, if at all? With many storage devices, this is dependent on the time period over which it is measured. Should this vary by market or by technology?*

Rating
Emergency Rating - Two-hour MVA rating of a Transmission Element.
15-Minute Rating - The 15-Minute MVA rating of a Transmission Element.
Normal Rating - The rating at which a Transmission Element can operate without reducing its normal life expectancy.

> *Q: If a storage device is being used for transmission purposes, should it be rated as a Transmission Element? How?*

Resource - The term is used to refer to both a Generation Resource and a Load Resource. The term "Resource" used by itself in these Protocols does not include a Non-Modeled Generator.
All-Inclusive Generation Resource - A term used to refer to both a Generation Resource and a Non-Modeled Generator.
All-Inclusive Resource - A term used to refer to a Generation Resource, Load Resource and a Non-Modeled Generator.

> *Q: Do we need a class of "storage resources" with the various options specified?*

Resource ID (RID) - A unique identifier assigned to each Resource used in the registration and Settlements systems managed by ERCOT.

> *Q: Does a storage device require two RIDs? One for charging (load) and one for discharging (generator)?*

Section 3.6: Except for voluntary load response, loads participating in any ERCOT market must be individually registered as a Load Resource by ESID and are subject to qualification testing administered by ERCOT. All ERCOT settlements resulting from Load Resource participation are made only with the QSE representing the Load Resource.

Section 3.7.1.1 Generation Resource Parameters –

> *Q: Which parameters does a storage resource need to file when it operates in discharge mode?*

Section 3.7.1.2 Load Resource Parameters –

> *Q: Which parameters does a storage resource need to file when it operates in*

discharge mode? Does it have to be selling load resource services to be considered a load resource?

Resource Node **-** Either a logical construct that creates a virtual pricing point required to model a Combined-Cycle Configuration or an Electrical Bus defined in the Network Operations Model, at which a Generation Resource's Settlement Point Price is calculated and used in Settlement.

Q: Do we need a similar logical construct for a storage resource?

Settlement Point - A Resource Node, Load Zone, or Hub.

Q: What is the settlement point for a storage resource? Can it be at both a Node and Zone? Node when it discharges and Zone when it charges? Does that create the potential for gaming?

Startup Cost - All costs incurred by a Generation Resource in starting up and reaching LSL, minus the average energy produced during the time period between breaker close and LSL multiplied by a heat rate proxy "H" multiplied by the appropriate FIP, FOP, or $1.50 per MMBtu, as applicable and as described in the Verifiable Cost Manual. The Startup Cost is in dollars per start.

Q: Are discharge/recharge losses startup costs? UFE? Or do we treat purchases and sales separately and there are no losses?

B. Other Nodal Protocols

3.10.7.1 Modeling of Transmission Elements and Parameters

(2) Each Transmission Element must have a unique identifier using a consistent naming convention used between ERCOT and TSPs.

Q. Is storage used for transmission reliability a "Transmission Element."

3.10.6 Resource Entity Responsibilities

(1) QSEs and Resource Entities shall provide ERCOT and TSPs with information describing each Generation Resource and Load Resource that it represents under Section 3.10.7.2, Modeling of Resources and Transmission Loads.

Q: What information needs to be provided for storage resources and in what form?

3.10.7 ERCOT System Modeling Requirements

3.10.7.1.5 Reactors, Capacitors, and other Reactive Controlled Sources

(1) ERCOT shall model all controlled reactive devices. Each Market Participant shall provide ERCOT with complete information on each device's capabilities and normal

switching schema.

3.10.7.2 Modeling of Resources and Transmission Loads

(1) Each Resource Entity shall provide ERCOT and TSPs with information describing each of its Generation Resources and Load Resources connected to the transmission system. All Resources greater than ten MW, Generation Resources less than ten MW but providing Ancillary Service, . . ., must be modeled to provide equivalent generation injections to the ERCOT Transmission Grid. ERCOT shall coordinate the modeling of Generation Resources, Private Use Networks, DC Tie Resources and Load Resources with their owners to ensure consistency between TSP models and ERCOT models.

Q: How does ERCOT plan to model storage facilities?

4.6.2.3.1 Day-Ahead Make-Whole Payment

(2) Any Ancillary Service Offer cleared for the same Operating Hour, QSE, and Generation Resource as a Three-Part Supply Offer cleared in the DAM shall be included in the calculation of the Day-Ahead Make-Whole Payment.

Q: Does this apply to storage in discharge mode? Does it apply to net energy losses. The Startup Offer component represents all costs incurred by a Generation Resource in starting up and reaching its LSL.

4.4.7.2.1 Ancillary Service Offer Criteria

(1) Each Ancillary Service Offer must be submitted by a QSE and must include the following information:

(d) An Ancillary Service Offer linked to a Three-Part Supply Offer from a Resource designated to be Off-Line for the offer period in its COP may only be struck if the Three-Part Supply Offer is struck. The total capacity struck must be within limits as defined in item (4)(c)(iii) of Section 4.5.1, DAM Clearing Process;

(e) An Ancillary Service Offer linked to other Ancillary Service Offers or an Energy Offer Curve from a Resource designated to be On-Line for the offer period in its COP may only be struck if the total capacity struck is within limits as defined in item (4)(c)(iii) of Section 4.5.1;

(f) The first and last hour of the offer;

Q: "High quality regulation" devices (Li batteries and Flywheels) will not be able to submit economic energy offers. Will they be permitted to submit energy offers that reflect their opportunity costs? That is, to produce energy for an hour would derate these devices to make them prohibitively expensive, but if their energy offer reflected that cost, their energy bids could be set high enough that they'd never be asked to produce energy. Even in emergency situations, an operator might prefer to maintain the ability of these resources to provide regulation rather than exhaust their capacity to obtain a limited amount of energy (permitting other regulation resources to run at full power).

6.5.7.1.12 Resource Limits

6.5.7.6.1 LFC Process Description

(2) . . . ERCOT shall develop a methodology, subject to Technical Advisory Committee (TAC) approval, to determine the optimal frequency bias for given system conditions.

(4) Based on the ACE MW correction, the LFC issues a set of control signals every four seconds to each QSE providing Regulation and, if required, each QSE providing RRS. . . .

(6) If all Reg-Up capacity has been deployed, ERCOT shall use the LFC system to deploy Responsive Reserve on Generation Resources and Controllable Load Resources.

(7) ERCOT shall settle energy that results from LFC deployment at the Settlement Point Price for the point of injection.

> Q: *There is no response rate specified. A generator that takes far longer to respond than a "High quality regulation" device would be valued equally.*

B. <u>Operating Considerations of Specific Technologies/Configurations</u>

1. Short Duration Resources

Flywheels and Li batteries provide much faster and fine tuned response for regulation services than generators are capable of achieving. The planned co-optimization of ancillary services and energy implicitly assumes that reserves have value only with respect to providing energy. Response rate and accuracy of response are not explicitly valued, and their contribution to power quality is ignored. For regulation resources, once the minimum level of performance is met (under the Nodal protocols, these resources must reach their bid capacity within five minutes, instead of ten minutes under the Zonal protocols), based on the limitations of steam generator to respond to dispatch signals, the only value is the quantity of energy supplied.

An alternative would be to create a category of "high quality regulation" resources that would be called more often than generator regulation, and used to provide more rapid and accurate frequency control to maintain power quality. Generator regulation would be called after a set proportion of this resource is exhausted (reg up or down, once the capacity to continue supplying that service is diminished past a threshold value), and the high quality regulation capacity would then be restored to its base point by charging or discharging.

These high quality regulation resources would not be co-optimized with the energy market, rather, they would be treated as a control resource (i.e., the ability to smooth frequency variations) rather than an energy resource. They would not have to meet the hourly requirement, but would have to be able to respond at a faster rate than conventional regulation resources.

2. *Flow Batteries and Long Duration Resources*

Flow batteries are ill-suited to being cycled numerous times, and are more cost effective if used for purposes such as responsive reserves and energy arbitrage. Since they can easily meet the hourly energy flow requirement, they can be integrated into the AS-Energy market co-optimization paradigm. However, there is still the question of how they should be modeled and dispatched. If they are loads and generators, they would purchase energy when charging and sell it when discharging. Would one be at Zonal prices and the other at Nodal prices? Can they sell RRS as a controllable load when charging? Are net losses (between charging and discharging cycles) costs that they can request to be treated as no-load or startup, or as UFE?

3. *CAES*

Combined-cycle Resources have to file information for various operating configurations. Can a similar process be created for CAES facilities, which can operate in charge, discharge, and CT/discharge mode? The compressor could qualify as a controllable load under current protocols, and the generator is similar to a combustion turbine with a very low heat rate. If the compressor doesn't qualify as a controllable load, it should qualify as a LaaR if a UFR was applied to just the compressor. However, when modeling the generator, should the opportunity cost of energy losses due to utilizing compressed air be included in costs? Can the unit be simultaneously modeled as a load and generator, and as a combination of both?

4. *TSDP Transmission Reliability Storage*

This configuration provides the least problems from an ERCOT perspective, in that the storage unit is used only to respond to outages or overloads on a transmission line or substation, and the TDSP is prohibited from participating in ERCOT markets. There is still the question of how the storage device will be modeled in the ERCOT transmission model. Is it a transmission element? Does it have a separate bus? Should net energy losses be treated as UFE, as suggested by ETT in their filing?

5. *TSDP Distribution Reliability Storage*

This should not require any interaction with ERCOT other than ERCOT planning, which will need to be notified of the implementation of storage devices and the expected pattern of operation to ensure accurate forecasting of loads.

6. *Retail Storage (Behind the Meter)*

The problem presented by widespread application of storage at the retail level is similar to the one presented by distributed renewable generation. ERCOT is required to make load predictions, but those predictions depend on economic relationships between weather, price and electricity demand. Market penetration by new technologies that allow load shifting or arbitrage can change those relationships without the explicit knowledge of ERCOT staff, resulting in inaccurate predictions that could be correlated with price. Therefore, it may be necessary for ERCOT to be able to monitor storage and other activities at the retail level at least to the extent necessary to incorporate the impact of these technologies on load forecasts.