Energy Storage—a Cheaper, Faster, & Cleaner Alternative to Conventional Frequency Regulation

Introduction

Energy storage systems store energy for use at a later time—for as little as several seconds to many hours—when electric power is most needed and most valuable. There are a number of available or emerging technologies, from mechanical storage (e.g., flywheels), to chemical storage (e.g., batteries), to thermal storage (e.g., ice).[1] By ensuring availability during periods of high demand, enhancing grid reliability, and smoothing fluctuations in supply and demand, energy storage technologies play a critical role in an efficiently functioning grid. Recently, energy storage has gained attention as a fundamental component in addressing climate change given their ability to displace fossil-fueled peaking power plants and enable integration of renewables into the grid. Due to the "fast response" nature of some energy storage technologies, they are ideally suited to meet grid stability and reliability challenges as providers of grid support, or "ancillary" services.

Key points of this white paper include the fact that greater use of energy storage can lower overall system and ratepayer costs while reducing unwanted emissions of CO2 and other greenhouse gases. Further, in order to foster the wider use of energy storage we must rethink how energy storage is compensated and reflect the superior performance of storage for selected applications. Finally, energy storage assets must have a reasonable certainty of being paid for 10-years or more in order to encourage access to project-based debt on reasonable market terms.

To illustrate the value of energy storage in the ancillary services frequency regulation market, the California Energy Storage Alliance (CESA) selected a specific ancillary service – frequency regulation – and compared the performance of a flywheel kinetic energy storage device with a conventional baseload combined cycle combustion turbine (CCGT). We use flywheels as our comparison technology due to commercial availability and access to data from an existing facility. However, a number of other energy storage technologies can provide frequency regulation, and examples of existing and developing projects are also described below.

Ancillary Services

One of the key challenges in grid management is maintaining reliability. As demand and supply vary throughout the day, the entity responsible for coordinating, controlling, and monitoring the electric power system – typically an Independent System Operator (ISO) – is tasked with maintaining the real time balance between generation and usage of electricity, or load. In addition, the ISO must adjust generation to manage appropriate power flows based on transmission constraints and control voltages, and restart the system in the event of a collapse.[2] These objectives are achieved through various forms of ancillary services. According to the California Independent System Operator (CAISO), ancillary services support the transmission of energy from generation to load by ensuring system reliability, and include the following: regulation up, regulation down, spinning reserve, non-spinning reserve, voltage support, and black start.[3,4]

1 Other examples of energy storage technologies include ultracapacitors, pumped hydro, and compressed air energy storage.
2 Kirby, B. (2007). *Ancillary Services: Technical and Commercial Insights.* Prepared for Wartsila.
3 CAISO (2010) *Business Practice Manual for Definitions & Acronyms*.
4 Definitions of each ancillary service are provided in the glossary.

Why Ancillary Services Are Important

As states implement increasingly aggressive renewable portfolio standards (RPS), increasing the share of intermittent resources like solar and wind, one challenge will be maintaining grid reliability. In 2010, the California Energy Commission (CEC) modeled the variability and system performance related to 20% and 33% renewable energy penetration. Results indicate that system performance degrades "significantly" in the 20% renewables scenario, and becomes "extreme" in the 33% scenario.[56] This increase in variability will in turn require a substantial increase in ancillary services, in particular frequency regulation. Frequency regulation includes both "regulation up" and "regulation down," and is defined below:

- Regulation Up: An increase in electricity output in response to direct digital control (Automatic Generation Control, or AGC) signals in order to maintain the target system frequency. In other words, an online resource that can respond rapidly to fluctuations in the system load.[7] AGC is used to maintain the Area Control Error (ACE), which is the deviation from the ideal frequency and output. Associated reliability standards are defined by the Western Electricity Coordinating Council (WECC) and the North American Electric Reliability Corporation (NERC).[8]
- Regulation Down: A decrease in energy output in response to ACG signals in order to maintain system frequency. Regulation Up and Regulation Down fulfill similar objectives, but are considered separate services, each with its own reliability criteria.[9]

Without taking energy storage into account, the amount of regulation necessary for conventional generating resources to maintain system performance at an acceptable level during morning and evening "ramp" hours for the 33% scenario in 2020 is 3,000-5,000 megawatts (MW). In comparison, in 2008 the CAISO required approximately 390 MW of regulation up capability, and 360 MW in regulation down capability.

Additional analyses suggest similar outcomes. In a study focused on wind generation capacity, the New York ISO (NYISO) concluded that for every 1,000 MW increase in installed wind generation (between the 4,250 MW and 8,000 MW penetration level), the regulation requirement will increase by 9%, necessitating additional capacity.[10] Traditionally, ancillary services are provided by conventional thermal power plants, pumped hydro, or other generating resources. In California, the 2009 regulation requirement was 419 MW[11] and the CAISO predicts that to meet the 33% RPS by 2020, it will require 1,114 MW[12] of regulation. In other words, in order to ensure grid reliability, we will either need to build additional conventional generating units such as fossil-fuel emitting combustion turbines, or integrate non-generation resources such as energy storage into existing grid infrastructure. Energy storage is a more effective way of meeting the increasing demand for ancillary services at a lower cost—in both economic and environmental terms—than these traditional resources.

5 Based on ACE excursions and NERC control performance standards. CEC 2010

6 KEMA (2010). *Research Evaluation of Wind Generation, Solar Generation, and Storage Impact on the California Grid.* Prepared for the California Energy Commission, Public Interest Energy Research Program.

7 Kirby 2007

8 CAISO 2010

9 CAISO 2010

10 NYISO (2010). *NYISO Wind Generation Study.*

11 PG&E (2010, August 24). *Pacific Gas and Electric Company, Long Term Procurement Plan Proceeding: Renewable Integration Model Results and Model Demonstration.* Slides presented at the CPUC Renewable Integration Workshop.

12 CAISO (2010, October 22). *ISO Study of Operational Requirements and Market Impacts at 33% RPS, Continued Discussion and Refinement of Step 1 and Step 2 Simulation Methodology.* Slides presented at the CPUC Renewable Integration Workshop #2.

Energy Storage is More Effective than a Combustion Turbine

Of the ancillary services listed above, energy storage is particularly suited to performing frequency regulation. First, many energy storage technologies, such as flywheels or batteries, have extremely fast response rates. Maintaining grid stability and reliability requires balancing the output of generating units with demand. Frequency regulation maintains this balance through a rapid increase or decrease in output, matching generating power to load.[13] It naturally follows that a faster response would enable more accurate and effective regulation. Figure 1 below compares the ability of a flywheel and a conventional generator to perform frequency regulation. While the flywheel has the ability to "chase the ACE" almost instantaneously, the generator responds more slowly, often working against the ACE.[14]

There are two reasons why encouraging fast response resources to provide regulation can result in fewer total MW capacity of regulation that needs to be procured. First, resources that are more flexible and can ramp more quickly will reach their dispatch target faster and can then be re-dispatched more often. Thus, fast regulation resources provide much greater ACE correction than more ramp-limited resources. Second, because slower-ramping resources cannot switch directions quickly, they sometimes provide regulation in a counterproductive direction and, as a result, actually add to the ACE, requiring dispatch of other resources to counteract it.

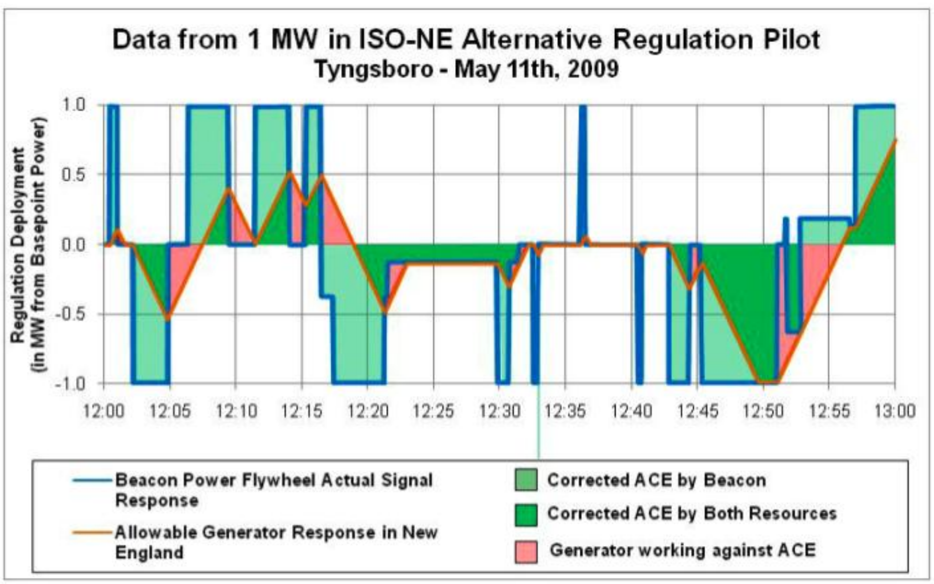


Figure 1: Regulation Performance of a Flywheel vs. Conventional Generation
Source: Beacon Power Corporation.

These fast response rates also lead to higher efficiency, meaning that a MW of energy storage is not equivalent to a MW of conventional generation. The Pacific Northwest National Laboratory (PNNL) defines an "ideal" fast

13 Most system frequencies around the world are set to 50 or 60 Hz. Source: Lazarewicz, M. and Ryan, R. (2010). *Grid-Scale Frequency Regulation Using Flywheels.* Beacon Power Corporation.

14 KEMA 2010

responding resource as one with "instantaneous response and unlimited energy."[15] For example, according to These fast response rates also lead to higher efficiency, meaning that a MW of energy storage is not equivalent to a MW of conventional generation. The Pacific Northwest National Laboratory (PNNL) defines an "ideal" fast responding resource as one with "instantaneous response and unlimited energy."[16] For example, according to PNNL, an ideal resource is 2.7 times more efficient than a combustion turbine. Although some energy storage technologies, such as flywheels, have energy limitations, they experience a very high relative efficiency when compared with combustion turbines, steam turbines, or combined-cycle turbines.[17] PNNL concluded that with faster Regulation resources on the grid the CAISO could reduce procurement of regulation by as much as 40%. A recent CEC study supports these claims, concluding that "on an incremental basis, storage can be up to two to three times as effective as adding a combustion turbine to the system for regulation purposes."[18] This means that a 100 MW storage unit can be as effective as a comparable 200-300 MW combustion turbine. Figure 2 demonstrates the effectiveness of different resources in performing frequency regulation.

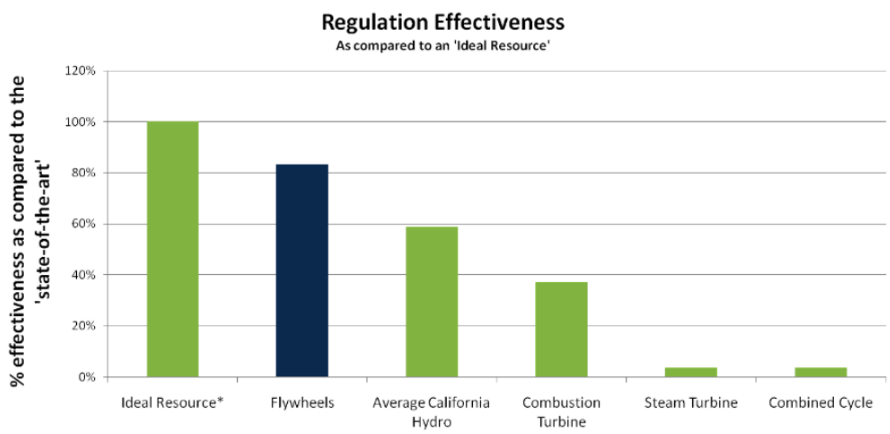


Figure 2: Regulation Effectiveness of an "Ideal Resource"
Source: Beacon Power Corporation

Use of conventional resources not only requires more MWs to provide the same service, but can also lead to additional indirect costs that are often not taken into account when comparing systems. For example, the increased need for ancillary services will put stress on existing equipment, leading to additional maintenance costs and potentially reducing generator life. This increased use will also lead to more greenhouse gas emissions, as generation resources are forced to remain on-line to meet regulation requirements, and will be "ramping up," which is less efficient than standard generation.[19] As we add renewables to the grid to increase our use of clean energy, energy storage can maximize the value of those resources without compromising emissions reduction goals. Figure 3 represents potential emissions savings from the use of energy storage.

15 Makarov, Y., Ma, J., Lu, S., and Nguyen, T. *Assessing the Value of Regulation Resources Based on Their Time Response Characteristics.* Prepared by Pacific Northwest National Laboratory for the California Energy Commission.

16 Makarov, Y., Ma, J., Lu, S., and Nguyen, T. *Assessing the Value of Regulation Resources Based on Their Time Response Characteristics.* Prepared by Pacific Northwest National Laboratory for the California Energy Commission.

17 Makarov et al 2008

18 KEMA 2010

19 KEMA 2010

Flywheel Emission Savings Over 20-year Life: CA-ISO					
	Coal		Natural Gas		Pumped Hydro
	Baseload	Peaker	Baseload	Peaker	
CO2					
Flywheel	91,079	91,079	91,079	91,079	91,079
Alternate Gen.	322,009	608,354	194,534	223,997	123,577
Savings (Flywheel)	230,930	517,274	103,455	132,917	32,498
Percent Savings	72%	85%	53%	59%	26%
SO2					
Flywheel	63	63	63	63	63
Alternate Gen.	1,103	2,803	0	0	85
Savings (Flywheel)	1,041	2,741	-63	-63	23
Percent Savings	94%	98%	n/a	n/a	27%
NOx					
Flywheel	64	64	64	64	64
Alternate Gen.	499	1,269	80	118	87
Savings (Flywheel)	435	1,205	16	54	23
Percent Savings	87%	95%	20%	46%	26%

Figure 3: Emissions Savings from the Use of Energy Storage
Source: Beacon Power Corporation

How Energy Storage is 2.5X More Effective than Generation

The following provides a simplified example of how energy storage can be two to three times more effective than a combustion turbine.

Assume regulation is only procured from a gas turbine with a 5.1% per minute ramp rate, allowing the turbine to move from zero output to full output in about 20 minutes.[20] Imagine that a system operator experiences a sudden generation loss. To meet NERC requirements, the operator must bring on 25 MW in additional generation within the next ten minutes.[21] In other words, over the next ten minutes, the system operator needs a 2.5 MW per minute ramp rate total from all generators providing regulation. If the only regulation generators are gas turbines with a 5.1% ramp rate, there needs to be 49.1 MW of these gas turbines online to meet the operator's ramp requirement. In contrast, 25 MW of energy storage could provide the full 25 MW of additional power within 20 milliseconds.

The essentially immediate availability of energy storage allows system operators to maintain ACE while providing enough time to call up traditional generators (on spinning or non-spinning reserve) in an orderly manner. In the scenario above, 25 MW of energy storage provided the performance equivalent of 49.1 MW of natural gas turbines, or 1.9 times the amount of generation. The multiplier could be higher (for example, if the system operator didn't find out about the problem until a few minutes later) or lower (for example, if there are faster generators online). Over a wide variety of scenarios and a wide variety of turbine models, studies have found that, on average, energy storage provides 2.5x the performance of a combustion turbine.[22]

20 Represents an unscientific midpoint from GE's brochures. Not GE's fastest unit, but there are also many old turbines in CAISO that would bring down the average.
21 NERC CPS2 requirements
22 Makarov et al 2008

Energy Storage is Here Today

Despite misconceptions that energy storage is only a technology of the future, numerous successful energy storage projects are operating today. Below is a sample list of ten projects including A123, Altairnano, Beacon Power, and Xtreme Power systems that provide energy storage frequency regulation project examples currently underway.

A123

Los Andes Energy Storage

Project Details	
Technology:	Lithium Nanophosphate
Plant Size:	4MWh (12MW)
ISO:	Chile
ISO Market Share:	N/A
Operational Date:	2009

Johnson City[23]

Project Details	
Technology:	Lithium Nanophosphate
Plant Size:	20 MW, 8 MW (in operation now)
ISO:	NYISO
ISO Market Share:	N/A
Operational Date:	December 2010

AltairNano

AltairNano PJM Project

Project Details	
Technology:	Lithium Titanate
Plant Size:	250MWh (1MW)
ISO:	PJM
ISO Market Share:	0.1% of Regulation Market
Operational Date:	2008

23 Unofficial project name at this time

Beacon Power

3 MW, Tyngsboro, MA

Project Details	
Technology:	Flywheels / Beacon Power
Plant Size:	750 kWh, 3 MW
ISO:	New England ISO
ISO Market Share:	2% Regulation Market
Operational Date:	November 2008

20 MW, Stephentown, MA

Project Details	
Technology:	Flywheels / Beacon Power
Plant Size:	5 MWh, 20 MW
ISO:	New York ISO
ISO Market Share:	10% of Regulation Market
Operational Date:	December 2010

20 MW, Hazle Township, PA

Project Details	
Technology:	Flywheels / Beacon Power
Plant Size:	5 MWh, 20 MW
ISO:	PJM Interconnection
ISO Market Share:	2% of Regulation Market
Operational Date:	2011/12

20 MW, Chicago Heights, IL

Project Details	
Technology:	Flywheels / Beacon Power
Plant Size:	5 MWh, 20 MW
ISO:	PJM Interconnection
ISO Market Share:	2% of Regulation Market
Operational Date:	2012

Xtreme Power

Xtreme Power KWP 1

Project Details	
Technology:	Solid state dry cell
Plant Size:	1 MWh (1.5 MW)
ISO:	MECO
ISO Market Share:	15% of MECO Regulation Market
Operational Date:	2010

Xtreme Power Kahuku

Project Details	
Technology:	Solid state dry cell
Plant Size:	10 MWh (15 MW)
ISO:	HECO
ISO Market Share:	10% of HECO Regulation Market
Operational Date:	2011

Xtreme Power La Ola

Project Details	
Technology:	Solid state dry cell
Plant Size:	0.5 MWh (1.1 MW)
ISO:	MECO
ISO Market Share:	50% of Regulation Requirement
Operational Date:	2011

Case Study: Modeling CCGT vs. Flywheel for Frequency Regulation

The following case study models a conventional baseload CCGT plant participating in the CAISO frequency regulation market and compares it side-by-side with a flywheel system also participating in the CAISO frequency regulation market. The ultimate goal of this modeling simulation is to compare the merchant-owned financial returns and greenhouse gas (GHG) impacts of the CCGT and flywheel projects.

The base case modeling results indicate that the flywheel achieves significantly higher financial returns and

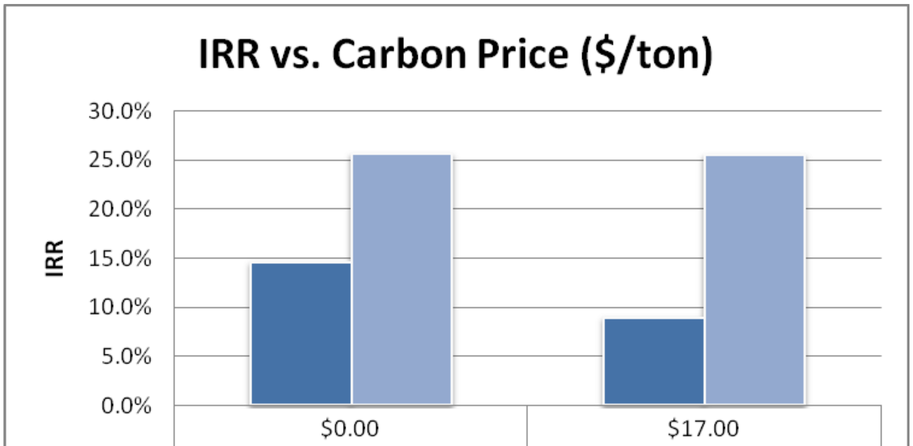
GHG savings. The flywheel has a 26% internal rate of return (IRR) and a lifetime carbon emissions of 69,975 tons whereas the CCGT has a 15% IRR and a lifetime carbon emissions of 986,595 tons. An overview of the assumptions and results are listed in Table 1 below:

Table 1: Case Study Assumptions and Results

Project Specifications	***Flywheel***	***CCGT Baseload***
Plant Ownership Model	Merchant	Merchant
Project Tenor (yr)	20	20
System Capacity Dedicated to Regulation (MW)	20	20
Plant Heat Rate (Btu/kWh)	N/A	7,050.0
Heat Rate Degradation	N/A	0.0
Capacity Degradation	0.00%	0.24%
Plant Parasitic Losses	2.00%	2.90%
Efficiency	87.00%	N/A
Efficiency Degradation	0.00%	N/A
CAPEX ($/MW)	1,900,000	600,000
OPEX		
Fuel Cost - Conventional ($/MMBtu)	N/A	4.31
Fuel Cost - Storage ($/MWh)	50.00	N/A
Fuel Cost Escalation Rate	1.53%	1.53%
Carbon Price ($/ton)	0.00	0.00
Carbon Price Escalation Rate	0.00%	0.00%
Revenue Assumptions	***Flywheel***	***CCGT Baseload***
Average Regulation Clearing Price ($/MW/h)	33.41	33.41
Regulation Clearing Price Escalation Rate	3.5%	3.5%
Comparative Performance Factor	2.5	1.0
Base Case Results	***Flywheel***	***CCGT Baseload***
IRR	25.7%	14.6%
Payback Period (yr)	3.9	8.1
Lifetime Carbon Emissions (tons)	69,975	986,595

The base case does not include a carbon price. One can reasonably assume that some form of a carbon pricing regime will be imposed upon the CAISO and other markets within the next few years. Given that the flywheel produces approximately 14x less carbon emissions than the CCGT and assuming a carbon price of $17/ton[24] (0% p.a. escalation rate), the financial results are substantial to the CCGT, whereas on the flywheel, the carbon price should have little effect as seen in Figure 4 below:

24 Based on EU ETS future price data



	$0.00	$17.00
CCGT	14.6%	9.0%
Flywheel	25.7%	25.6%

Figure 4: IRR and Carbon Price Comparison

Performance is a fundamental driver of the modeling results. Assuming 2.5x performance for the flywheel is critical, as explained above in the "How Energy Storage is 2.5X More Effective" section. Below in Figure 5 depicts the sensitivity to the performance factor assumption:

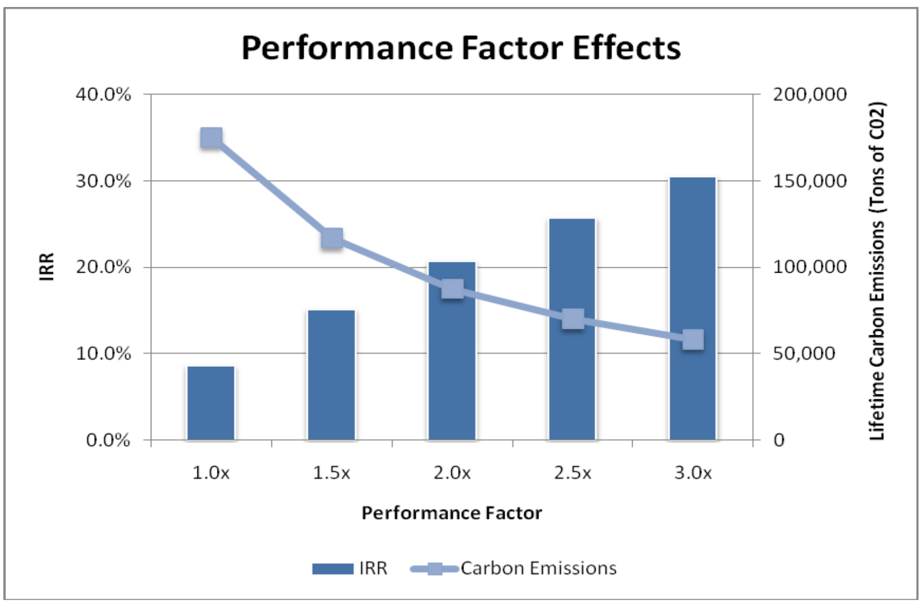


Figure 5: Performance Factor Effects on IRR and Emissions

Assumptions for the CCGT plant come from the CEC's Levelized Cost of Generation (LCOG) Model[25] as well as KEMA's report: *Cost Comparison for a 20 MW Flywheel-based Frequency Regulation Power Plant.*[26,27] Assumptions for the flywheel system were also taken from the previously cited KEMA report, as well as operating data from Beacon Power, the owner-operator of the system.

The assumptions listed above are utilized to generate the financial and GHG results using StrateGen's comparative financial model. StrateGen's model, including detailed assumptions for the CCGT plant and flywheel system, is available on CESA's website:

http://www.storagealliance.org/work-whitepapers.html

California Barriers

Recent CAISO tariff changes have improved wholesale market access for energy storage. For example, July 2010 amendments reduced the minimum ancillary resource capacity from 1MW to 500 KW; reduced the continuous energy requirement from 2 hours to 30 minutes for spinning and non-spinning reserves and regulation up and down in real time (60 minutes day-ahead); and converted to measurement of continuous energy from the time a resources reaches its award capacity instead of the end of a 10 minute ramp requirement.[28] Further refinements in this direction would reduce or eliminate barriers to storage while simultaneously providing additional savings to California ratepayers. Additional barrier lowering measures have been identified, including dispatch-based compensation, a long-term capacity mechanism, a further reduction in the continuous energy requirement, and adjustments to the dispatch algorithm.

Prices paid for fast response regulation do not yet sufficiently reflect the quality of the service provided, despite the fact that energy storage-based resources follow ACG signals more accurately and can reduce the overall need for, and cost of, regulation services.[29] To attract investment in fast response storage technologies, the market must pay the true monetary value of the speed and accuracy that energy storage resources provide to the grid. For equivalent MW capacities, a faster, more accurate system will deliver greater grid reliability benefits than a slower, less responsive system Therefore, the compensation given to faster systems should reflect this additional value.

While recent tariff amendments have removed many legacy market assumptions, some rules still reflect the limitations of traditional generation. The current continuous energy requirement of 30 real time and 60 minutes day ahead remains greater than necessary for providing highly effective frequency regulation. More generally, the procedures, business practices and manuals of the CAISO do not fully accommodate energy storage as a valuable asset class. For example, the CAISO's Energy Management System (EMS) presently cannot

25 CEC (2009). Comparative Cost of California Central Station Electricity Generation Technologies. (CEC_COG_Model_Version_2.02-4-5-10)

26 KEMA (2007). Cost Comparison for a 20 MW Flywheel-based Frequency Regulation Power Plant. Prepared by KEMA Inc. for Beacon Power Corporation.

27 According to the CEC, levelized cost of generation of a resource represents a constant cost per unit of generation computed to compare one unit's generation costs with other resources over similar periods. This is necessary because both the costs and generation capabilities differ dramatically from year to year between generation technologies, making spot comparisons using any year problematic.

28 132 FERC ¶ 61,211 (2010)

29 Kirby, 2007

accommodate a negative power dispatch, a capability that will be needed to integrate energy storage.[30] Rules and systems that recognize the unique strengths of both new energy-neutral systems and traditional energy generation resources will be able to fully utilize both in the most economical manner.

The current market structure treats regulation services like a spot market, i.e., there are no long-term purchase agreements for regulation services. Consequently, it is impossible to obtain project financing for energy storage regulation assets because the capital markets will not provide debt financing without some level of revenue certainty. In contrast, traditional generators are financed on the basis of long-term power purchase agreements (PPAs). With PPA-backed financing in place based on its primary wholesale energy function, a generator has the option to provide part of its operating range in the form of regulation services (a secondary function). A long-term resource adequacy-type payment for regulation-only energy storage systems would help overcome the project financing barrier similar to conventional generators.

Suggested California Policy Changes

To achieve greater deployment of energy storage for regulation and reduce costs to ratepayers, the CAISO should:

- Structure payments for ancillary services that reflect the actual regulation impact on the grid versus nameplate power rating of the resource. Appropriate price signals must be built into the Regulation markets using "pay-for-performance" compensation that values the speed and accuracy with which a resource responds to a regulation control signal. The ISO-NE currently does this by incorporating a regulation performance factor in its payments to regulation resources called "mileage," which quantifies the amount and speed of energy transferred between the resource and the grid. The more energy transferred, the more useful regulation work is performed, and the higher the payment should be to the resource. Thus, we recommend the CAISO adopt a Regulation compensation mechanism that has two components: (1) a performance payment ("mileage") based on the speed and amount of energy transferred by the resource in response to a control signal, and ultimately the actual regulation value to the grid compared to conventional resources, and (2) a capacity (or reserve) payment based on the amount of MW that a resource makes available to provide regulation.
- Implement Regulation Energy Management (REM), as described in the CAISO's *Regulation Energy Management Draft Final Proposal* dated January 13, 2011, which removes the barriers to storage providing regulation by using the 5-minute real-time energy market to manage the state of charge of resource. REM will enable resources with 15-minute storage capability to continuously provide Regulation service for a full hour – and for hours in succession, almost without limit.
- The CAISO should work with the CPUC to ensure that those needs are reflected in Load-Serving Entity (LSE) RA obligations. This is necessary for two reasons. First, like capacity and energy to meet current resource adequacy requirements, the ability of new technologies or existing technologies/facilities to provide the additional needed services will be greatly enhanced by (and may require) revenue certainty from long-term contracts. Second, , it makes sense to plan in advance for expected Regulation needs through reflection of those new needs in resource adequacy requirements.
- Employ a regulation dispatch algorithm that selects fast resources before slow resources in order to minimize the total amount of regulation capacity required in the balancing area. This in turn will reduce the cost of regulation to ratepayers. The NYISO's regulation tariff selects "fast first" and this feature

30 Negative power dispatch provides both injection and withdrawal of energy.

should be adopted as best practice for energy storage-enabling tariffs.

- Adopt conforming changes to tariffs and business practice manuals to modify language that may preclude non-generation resources from providing regulation.

At the same time, the California Public Utilities Commission (CPUC) should:

- Continue collaboration with CAISO stakeholder processes, and closely interrelated CPUC retail rulemaking proceedings, including demand response, long-term procurement and resource adequacy.
- Include interaction between wholesale and retail aspects of ancillary services and adoption of enabling rules and policies as part of the scope of the CPUC's recently opened Energy Storage Rulemaking.

Glossary

Unless otherwise noted, the following definitions are taken from the CAISO *Business Practice Manual for Definitions and Acronyms.*

Ancillary Services: Regulation, Spinning Reserve, Non-Spinning Reserve, Voltage Support and Black Start together with such other interconnected operation services as the CAISO may develop in cooperation with market participants to support the transmission of energy from generation resources to loads while maintaining reliable operation of the CAISO controlled grid in accordance with WECC standards and good utility practice.

Area Control Error (ACE): The sum of the instantaneous difference between the actual net interchange and the scheduled net interchange between the CAISO balancing authority area and all interconnected balancing authority areas, taking into account the effects of the CAISO balancing authority area's frequency bias, correction of meter error, and time error correction obligations.

Automatic Generation Control (AGC): Generation equipment that automatically responds to signals from the ISO's EMS control in real time to control the power output of electric generators within a prescribed area in response to a change in system frequency, tie-line loading, or the relation of these to each other, so as to maintain the target system frequency and/or the established interchange with other areas within the predetermined limits.

Black Start: The procedure by which a generating unit self-starts without an external source of electricity thereby restoring a source of power to the CAISO balancing authority area following system or local area blackouts.

California Independent System Operator (CAISO): See "Independent System Operator."

Combined Cycle Combustion Turbine (CCGT)[31]: An electric generating technology in which electricity is produced from otherwise lost waste heat exiting from one or more gas (combustion) turbines. The exiting heat is routed to a conventional boiler or to a heat recovery steam generator for utilization by a steam turbine in the production of electricity. This process increases the efficiency of the electric generating unit.

Federal Energy Regulatory Commission (FERC)[32]: The Federal agency with jurisdiction over interstate electricity sales, wholesale electric rates, hydroelectric licensing, natural gas pricing, oil pipeline rates, and gas pipeline certification. FERC is an independent regulatory agency within the Department of Energy and is the successor to the Federal Power Commission.

Independent System Operator (ISO)[33]: An independent, federally regulated entity established to coordinate regional transmission in a non-discriminatory manner and ensure the safety and reliability of the electric system.

31 U.S. Energy Information Administration Energy (EIA) Glossary. Available online at http://www.eia.gov/glossary/index.cfm

32 EIA Glossary

33 EIA Glossary

New England Independent System Operator (ISO-NE): See "Independent System Operator."

New York Independent System Operator (NYISO): See "Independent System Operator."

Non-Spinning Reserve: The portion of generating capacity that is capable of being synchronized and ramping to a specified load in ten minutes (or load that is capable of being interrupted in ten minutes) and that is capable of running (or being interrupted).

North American Electric Reliability Corporation (NERC)[34]: A nonprofit corporation formed in 2006 as the successor to the North American Electric Reliability Council established to develop and maintain mandatory reliability standards for the bulk electric system, with the fundamental goal of maintaining and improving the reliability of that system. NERC consists of regional reliability entities covering the interconnected power regions of the contiguous United States, Canada, and Mexico.

Regulation Down: Regulation reserve provided by a resource that can decrease its actual operating level in response to a direct electronic (AGC) signal from the CAISO to maintain standard frequency in accordance with established reliability criteria.

Regulation Up: Regulation provided by a resource that can increase its actual operating level in response to a direct electronic (AGC) signal from the CAISO to maintain standard frequency in accordance with established reliability criteria.

Spinning Reserve: The portion of unloaded synchronized generating capacity that is immediately responsive to system frequency and that is capable of being loaded in ten minutes, and that is capable of running for at least two hours.

Voltage Support: Services provided by generating units or other equipment such as shunt capacitors, static VAR compensators, or synchronous condensers that are required to maintain established grid voltage criteria. This service is required under normal or system emergency conditions.

Western Electricity Coordinating Council (WECC)[35]: The WECC is responsible for coordinating and promoting bulk electric system reliability in the Western Interconnection, including the provinces of Alberta and British Columbia, the northern portion of Baja California, Mexico, and all or portions of the 14 Western states between.

34 EIA Glossary
35 Western Electricity Coordinating Council Website. "About Us." Available online at http://www.wecc.biz