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Electricity Storage: Technologies and Regulation

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Acknowledgements

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Executive Summary

This paper aims to empower state regulators and legislators to take actions that enable the benefits of well-directed investments in storage to be realized and flowed through to consumers. To that end, it begins with a primer on storage technologies. It defines storage, explains what it can do and why it has value, provides quantitative estimates of the value of its functions, and reviews past and emerging storage technologies. Following this primer, the paper explores regulatory issues that have emerged and are likely to emerge as new storage technologies become more widely deployed, focusing on these threshold questions:

- Who might sell what services to whom, under what competitive conditions?
- Is society best served if those services are provided by traditional (incumbent) utilities, or by independent suppliers?
- Should society rely on competitive markets to determine prices for these services, or set them through cost-of-service regulation?
- On what legal bases do federal and state regulators have jurisdiction to supervise the pricing and other aspects of storage service?

The paper concludes by identifying issues for further research and questions that a pro-active commission might wish to pose through an investigatory proceeding.

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I. Introduction and Overview

Electricity is dynamism's currency: the fungible and pervasive medium of exchange that, within broad limits, enables any modern energy source to power any modern application. Electricity's versatility freed factories from stream valleys and is now freeing automobiles from gas pumps. But one main limit has persisted: Because storing electricity has been too costly, each moment's usage has had to be supplied almost entirely from sources available and deliverable to load at that instant. Modernity's currency could not be banked. Even as high-voltage transmission fundamentally altered industry economics by enabling one area's generators to serve another area's load, creating a "multi-sided market platform,"[1] each moment's generators and loads remained islanded in time. Now, technologies that can overcome that limitation and add another dimension to that market platform are emerging.

Because electricity storage can exponentially advance electricity's core function of connecting diverse energy sources to diverse energy uses, its potential to improve industry economics is radical. If inexpensive storage had always been available, it would have enabled the entire generation fleet to consist of base-load generators, *i.e.*, generators optimized for efficient conversion of fuel to kWh. Instead, because peak loads must be served from peak capacity, the industry has needed large numbers of less efficient but lower-capacity-cost peaking units. Similarly, if distributed electricity storage were inexpensive, stored electricity would be available at load centers regardless of equipment outages upstream of the distributed storage facilities. The industry therefore could have invested far less in generation, transmission, and distribution system reliability. In short, the lack of inexpensive electricity storage has necessitated very costly alternatives: a generation fleet designed and operated such that production occurs simultaneously with consumption, and transmission and distribution systems designed to maintain at all times an uninterrupted connection from turbine to toaster.

For regulators, the fact that electricity storage can address such fundamental industry issues is a blessing that is not unmixed. Title XIII of the Energy Independence and Security Act of 2007 declared that "It is the policy of the United States to . . . achieve . . . [d]eployment and integration of advanced electricity storage and peak-shaving technologies, including plug-in electric and hybrid electric vehicles, and thermal-storage air conditioning." 42 U.S.C. § 17381. But if that policy is realized on a large scale, it will result in a "disruptive innovation"[2] that will cut across existing regulatory and industry categories and thereby raise difficult and important regulatory issues. Regulators are beginning to grapple with those issues.

This paper aims to empower state regulators and legislators to take actions that enable the benefits of well-directed investments in storage to be realized and flowed through to consumers.

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[1] *See, e.g.*, David S. Evans, *The Antitrust Economics of Multi-Sided Platform Markets*, 20 Yale J. on Reg. 325, 332 n.17 (2003); Wells M. Engledow, *Handicapping the Corporate Law Race*, 28 Iowa Corp. L. 143, 165-66 (2003); Kent Walker, *The Costs of Privacy*, 25 Harv. J. L. & Pub. Pol'y 87, 93-94 (2001); Mark A. Lemley & David McGowan, *Legal Implications of Network Economic Effects*, 86 Calif. L. Rev. 479 (1998).

[2] *See* Clayton M. Christenson and Michael E. Raynor, *The Innovator's Solution: Creating and Sustaining Successful Growth* (2003).

To that end, it begins with a primer on storage technologies. **Part II** defines storage and distinguishes it from other means of addressing electricity timing issues. **Part III** explains why storing electricity reduces electric system costs, identifies various functions that storage can serve, and provides quantitative estimates of the value of each of the identified functions. **Part IV** reviews past and emerging storage technologies. It includes a table that identifies the key functional characteristics of each of the emerging technologies, thereby indicating which of the technologies presently appears well-suited for which of the identified functions. Following this primer, **Part V** explores regulatory issues that have emerged and are likely to emerge as new storage technologies become more widely deployed, focusing on these threshold questions:

> Who might sell what services to whom, under what competitive conditions?
>
> Is society best served if these services are provided by traditional (incumbent) utilities, or by independent suppliers?
>
> Should society rely on competitive markets to determine prices for these services, or set them through cost-of-service regulation?
>
> On what legal bases do federal and state regulators have jurisdiction to supervise the pricing and other aspects of storage service?

To set the stage for this discussion, **Part V.A** surveys the range of existing providers of storage services. **Part V.B** then considers what regulatory mode (such as supervised market-based competition or cost-of-service regulation of licensed monopolies) should apply to the various identifiable storage services. **Part V.C** identifies key questions that arise if storage is rate-regulated, including questions of accounting, prudence, and time of recovery. **Part V.D** addresses jurisdiction: the legal bases under which federal and state regulators have jurisdiction to supervise the pricing and other aspects of storage service. **Part V.E** then identifies miscellaneous other regulatory issues. Finally, **Part VI** identifies potential next steps: issues for further research and questions that a proactive commission might wish to pose through an investigatory proceeding.

II. What Is Storage?

This part provides a working definition of "storage," distinguishes storage from other means to affect the timing of electricity production and electricity consumption, and defines other useful terms. In this paper, "storage" means a series of acts: converting grid-interconnected electricity to another form of energy, holding that other form of energy for future use, and then converting it back to grid-interconnected electricity at a different time. The individual acts that comprise this series may be referenced as, respectively, "charging," "holding," and "discharging." The facilities that perform those acts will be referred to as "storage facilities," and the service(s) of performing them will be referred to as "storage services."[3] "Grid-interconnected" as used in this definition is intended to encompass all situations in which the energy, upon conversion back into electricity, enters circuits that are electrically interconnected to the transmission grid. This interconnection can be either direct or through other conductors; thus, it includes situations where the connection to the high-voltage transmission grid is made through lower-voltage distribution facilities and the conversion occurs at end-use locations.[4]

This definition intentionally excludes several related concepts in order to focus the discussion. First, it excludes the storage of electricity for later use without conversion back to grid-interconnected electricity. For example, it generally excludes storage in the battery of a plug-in hybrid automobile.[5] Second, it excludes other means to time-shift electricity demand (*e.g.*, by increasing industrial load when other loads are low and vice versa, or by performing heating or cooling outside of peak periods and storing the resulting temperature differential in thermal mass).[6] Third, it excludes means to time-shift the initial (or "primary") generation of

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[3] Where the context makes clear which sense is intended, the single word "storage" may be used to reference not only this series of three acts, but also the facilities used to perform them or the transactions through which the service of performing them is sold. In formal contexts such as the drafting of legislation or rules, however, definitional clarity may be more important.

[4] Under this definition, for example, retail customers who install "uninterrupted power supply" batteries to firm up and condition the quality of the electricity they receive from their grid-interconnected distribution utility are providing a storage service to themselves.

[5] Storage as used herein does, however, encompass situations where the stored energy is fed back onto the electric system rather than being used to propel the receiving automobile. It also encompasses the redeployment of former automotive batteries, after their useful vehicular life, as part of a grid storage system. The U.S. Department of Energy's ("DoE") research program contemplates such redeployment. U.S. DoE, Office of Electricity Delivery & Energy Reliability, Energy Storage Program Planning Document at 9 (2011), *available at* http://www.oe.energy.gov/DocumentsandMedia/OE_Energy_Storage_Program_Plan_Feburary_2011v3.pdf ("DoE 2011").

[6] Such time-shifting is becoming more economic and more common, with advances in thermal storage and as communication and metering advances, such as "smart meter" systems,

electricity, *e.g.*, by managing conventional hydroelectric resources so that their gravitational potential is not converted to electricity until the most useful times. Such time-shifting of demand or generation is an alternative to storage, not a form of storage, because it does not involve converting electricity to a different energy form and back. Although storage and the foregoing alternatives to storage may in some circumstances be economically substitutable, the technologies and institutions associated with actual round-trip conversions are sufficiently distinct (and complex) that they warrant special treatment.

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enable electricity-consuming appliances, HVAC systems, and other end uses to respond to bulk electric system prices and conditions.

III. Why Store Electricity?

A. Storing electricity smoothes and flattens the load curve

At the most general level, all electricity storage accomplishes the same thing: It enables some portion of one time's consumptive load to be met from another time's primary generation. Its effect on system planning and costs is therefore equivalent to that of moving load from relatively high points to relatively low points on a load curve,[7] thereby smoothing or leveling the curve.

Storage's potential to straighten the load curve and its value in doing so are not limited to lowering monthly or annual system peaks and filling in the corresponding valleys. Storage can be performed at a wide range of time scales and quantities, and different storage technologies have different costs and operating characteristics. Consequently, different storage technologies are practical in different ways.

For example, if one zooms in to examine load's minute-to-minute variations, the load curve at that time scale is jagged and chaotic. Storage facilities that operate very responsively, vacillating between charging mode and discharging mode on a scale of minutes or less, have the effect of smoothing out that fine-scale jaggedness. Such smoothing has value, because each jag must be met somehow lest the system frequency deviate from the desired 60 Hz, and a smoother load curve results in smaller frequency regulation costs.[8] Indeed, in an ongoing rulemaking, the Federal Energy Regulatory Commission ("FERC") is proposing that payments to "frequency response" service providers be modified to look to a finer time scale in order to better recognize the fine-scale smoothing provided by certain types of storage facilities.[9] But the storage

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[7] A "load curve" is a graph that plots load (the y axis) over time (the x axis). The time scale can be any duration of interest. Load curves commonly show how loads vary over the course of an hour, a day, a week, or a year.

[8] A transportation analogy may help to provide an intuitive feel for this technical point. Hiking a rocky trail is laborious, because the rough surface necessitates taking each step differently. The smoother the path, the less effort is required; and if the path is truly smooth, it can be travelled very efficiently on a bicycle.

[9] *See* Frequency Regulation Compensation in the Organized Wholesale Power Markets, 76 Fed. Reg. 11,177, 11,178 (proposed Mar. 1, 2011), FERC Stats. & Regs. ¶ 32,672, P 1 (proposed 2011). Frequency regulation involves minute-to-minute changes in the output of dispatch-controlled resources in order to keep output closely matched to load and thereby keep the electric system frequency acceptably close to the target frequency of 60 Hz. The proposed rule would modify the performance determinants for compensation paid to frequency regulation service providers by paying them for changes made from one minute to the next, rather than for the net change made over a longer "dispatch interval" period of five to ten minutes. The purpose of the proposed change is to be more favorable to resources that have the fast responsiveness characteristic of certain storage technologies. FERC's Notice of Proposed Rulemaking ("NOPR") relies heavily on a technical presentation made by the flywheel storage firm Beacon

technologies that provide such immediate responsiveness cannot economically store large quantities or hold them for long periods. Toward the other end of the time scale, if one zooms out to view how load varies on any given system over the course of a year, a somewhat predictable seasonal periodicity emerges, in which daily average loads during the lowest-load months are typically something like three quarters of the system average and daily average loads during the highest-load months are typically something like five quarters of the system average.[10] Smoothing out (*i.e.*, flattening) that periodicity does not require responsiveness on a second-to-second time scale, but it does require storage of large quantities held for long periods. Part III.B below delineates various storage functions, based on time scale, quantity, and other functional variations.

While it is important to recognize the different time scales on which storage operates and distinguish accordingly among the different functions that storage can serve, it is also important to remember that that these distinctions are matters of degree on a continuum, not differences in kind. A storage facility that is optimal for functions involving any given time scale will have some value for functions involving somewhat longer or shorter time scales. Indeed, a 2010 paper by the Electric Power Research Institute ("EPRI") indicates that such multi-functionality will be the norm, not the exception. It states that "due to the current high installed capital costs of most energy storage systems, applications (for either utilities or end users) must be able to realize multiple operational uses across different parts of the energy value chain, an aggregation of complementary benefits known as 'stacking.'"[11] For the same reasons, a facility originally planned to serve predominantly one identified function might later be used to serve a different mix of identified functions.

Power. The proposed rule would apply to the centralized energy markets operated by the Regional Transmission Organizations ("RTOs") that operate in the Northeast, Midwest, and California. The Southwest Power Pool (which operates in the south-central U.S.) may be covered by the rule indirectly, and other regions may be influenced as well.

[10] According to U.S. Energy Information Administration ("EIA") data for the U.S. as a whole in 2010, the electricity generated during the lowest-load month (April) was 84 percent of the annual average monthly quantity, and the electricity generated during the highest-load month (July) was 119 percent of the annual average monthly quantity. *See* U.S. EIA, Monthly Energy Review May 2011, Table 7.2a (2011), *available at* http://www.eia.gov/totalenergy/data/monthly/pdf/sec7_5.pdf. The month-to-month variations on individual systems are larger; diversity across systems results in smaller variations when the data is aggregated at EIA's national level.

[11] EPRI, Report No. 1020676, *Electricity Energy Storage Technology Options at ER-6* (2010), *available at* http://www.electricitystorage.org/images/uploads/docs/EPRI_StorageReport_5_11.pdf ("EPRI 2010").

B. Storage services' estimated values

Electricity storage has enormous long-run potential economic significance. The upper bound of this potential is suggested by the industry's generation capacity factor (that is, generators' total actual output divided by the output they would produce if they ran at full capacity for all 8,760 hours of the year). According to EIA data, the generation capacity factor for all electric energy sources averages less than 50 percent.[12] If electricity storage cost nothing to install and operate, a capacity factor approaching 100 percent would be achievable. Fewer generators would be needed, and those generators that were built would run at their full output level, constrained only by the availability of their energy input and by forced and maintenance outages. With storage, although output summed over a long period would still have to meet loads summed over a long period, it would no longer be necessary to meet each moment's loads from resources on line at that moment. With the moment-to-moment constraint gone, there would be no need for intermediate or peaking plants that take up capital, produce nothing for most hours of the year, and (because they are designed to optimize the capacity provided per dollar invested, not to convert fuel to electricity efficiently) operate with suboptimal efficiency when they do run. Instead, all generation would be either efficient base-load generation or generation powered by unpriced energy inputs such as hydro, wind, and solar power. Similar savings are theoretically available in transmission and distribution system development as well. For example, transmission and distribution are generally more reliable if configured in "loops" such that each load location is served by more than one feeder, so that even if one line fails the load remains continuously connected. But reliable storage located at the end of a radial transmission or distribution line would provide as much or more reliability than a looped configuration, because even if the single line failed, electricity deliverable to load would remain continuously available. Such distributed storage would also reduce peak loadings on that radial to the average, thereby enabling reduced voltages and lowering costs.[13] Consequently, even at present levels of electricity use, the gross savings theoretically available from electricity storage are on the order of half the electric system's gross receipts, or more—that is, $176 billion or more per year.[14]

Estimating the value of "perfect" storage in this way is a useful exercise. It suggests the share of system costs that storage may obviate in the long run, as the technology matures, its

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[12] U.S. EIA, Electric Power Annual 2009, Table 5.2 (2011), *available at* http://www.eia.gov/cneaf/electricity/epa/epa_sum.html ("Electric Power Annual 2009") (averaging EIA's annual data over the ten most recent reporting years, 2000-2009, capacity factors of all electric energy sources averages 48.86 percent).

[13] The instantaneous transfer capacity of a transmission line is a function of its voltage squared. Transmission facilities generally must be designed to meet the peak loading expected to occur on that facility (with a margin to cover system contingencies). Accordingly, spreading transmission loads out over time reduces the required facility voltage. Higher-voltage lines require more expensive components, wider rights of way, and taller structures, raising their costs.

[14] This $176 billion figure represents half of the industry's $353 billion in 2009 retail sales. *See* Electric Power Annual 2009, Table 7.3.

costs drop, and system planning takes storage into account. However, such estimates overstate storage's near-term value. Actual storage has costs and does not function perfectly. Moreover, the sunk costs of the existing electric system, even if they might have been avoided had storage been deployable as an alternative, are by definition no longer avoidable. In a going-forward cost comparison between meeting peak load through a prospective storage investment and doing so from an existing natural-gas-fired peaking generator, the generator's costs will be relatively small, consisting mainly of fuel and incremental operation and maintenance ("O&M").

Taking the legacy electric system into account, Sandia National Laboratories ("Sandia") and EPRI have developed more modest—but still impressive—projections of storage's potential value. Sandia monetized its estimates and presented them as the net present value, over the first decade after deployment, if the existing economic potential for storage were fully exploited at the start of the first year.[15] On that basis, Sandia developed approximately[16] the following estimates (see next page).

[15] Jim Eyer and Garth Corey, Sandia Nat'l Labs., SAND 2010-0815, *Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide* (Feb. 2010) ("Sandia 2010").

[16] Sandia's estimates were carried to more places than those presented above. In order to emphasize the big picture, Sandia's estimates have been rounded and presented as billions of dollars.

Benefit Type	**10-Year U.S. Value ($ Billion)**
Electric Energy Time-Shift	10.1
Electric Supply Capacity	9.8
Load Following	29.5
Area Regulation	1.4
Electric Supply Reserve Capacity	0.8
Voltage Support	5.5
Transmission Support	2.7
Transmission Congestion Relief	3.2
T&D Upgrade Deferral[17]	2.9
Substation On-Site Power	0.6
Time-of-Use Energy Cost Management	78.8
Demand Charge Management	18.7
Electric Service Reliability	6.2
Electric Service Power Quality	6.2
Renewables Energy Time-Shift	11.5
Renewables Capacity Firming	29.9
Wind Generation Grid Integration (short-duration discharges)	1.7
Wind Generation Grid Integration (long-duration discharges)	8.1
Nominal[18] Ten-Year Total	**227.6**

[17] Sandia presents both a "50th percentile" value, representing the value if the most expensive half of the upgrades otherwise needed in a given year were deferred, and a "90th percentile" value, representing the value if only the most expensive 10 percent of the otherwise needed upgrades were deferred. *See id.* at 85-86. For simplicity, the table above presents only the first of these values.

Along generally similar lines, EPRI has presented low ("high-value market"), medium ("feasible market"), and high ("technical market potential") estimates for the MW quantity of various specific storage applications that would be economically feasible based on current market conditions.[19] Although EPRI does not directly monetize them, it does provide a comparison table showing how its estimated present valuations per kWh stored and per kW compare to those developed by Sandia.[20] In general, EPRI's projected per-unit benefits are larger than Sandia's. The table below presents data derived from the MW-per-application quantities projected by EPRI. For simplicity, the table focuses on the middle ("feasible market") value. It aggregates and reorganizes EPRI's benefit categories in order to present the benefits associated with storage functioning as, respectively, (1) a substitute for injections of electricity onto the grid from on-line generation (*i.e.*, what EPRI calls "system integration"), (2) a basis to defer transmission or distribution upgrades, (3) utility-owned distributed (*i.e.*, in-load-center) storage, (4) commercial or industrial customer-owned distributed storage, and (5) residential customer-owned distributed storage. In order to enable a rough comparison to the monetized Sandia figures presented above, the table below adds a second column. This second column represents the MW quantity repeated over ten years, multiplied by a national average all-in energy price at retail of $385,488 per year per MW of installed capacity[21] and discounted to present value using Sandia's 10 percent discount rate.

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[18] It is not clear from Sandia's methodology whether these amounts can be considered additive. For example, the projected savings from retail customers' time-of-use energy cost management may be based on an *ex ante* time-of-use differential that would shrink if utilities contemporaneously achieved the savings projected from electric energy time shifting and electric supply capacity reductions.

[19] *See* EPRI 2010 at 3-1, 3-16 to 3-17.

[20] EPRI 2010, Table 2-5 at 2-15.

[21] *See* Electric Power Annual 2009, Table ES-1 (showing $353.28 billion of sales to ultimate consumers and 916,449 MW of summer capacity resources; the ratio of these two quantities is $385,488/MW-year).

Benefits Category	**MW**	**$ Billion**
System Integration	26,750	$63.4
T&D (wires) deferral	5,600	$13.3
Utility-owned distributed storage	31,800	$75.3
Commercial/Industrial distributed storage	18,010	$42.7
Residential distributed storage	35,720	$84.6
Total[22]	**117,880**	**$279.2**

The data above is for U.S. markets. However, when considering the potential of storage technologies to achieve scale economies and widespread commercial use, it is important to remember that the market for electricity storage equipment will likely be global. The timing differences that give storage value (*e.g.*, between efficient base-load generation and renewable intermittent generation on the one hand and load curves on the other) are prevalent worldwide, not just in the U.S. Of course, the specific opportunities for storage to be economically deployed will vary with nations' institutional structures, market rules, and industry characteristics. For example, the complex, bid-based markets for "ancillary services"[23] into which U.S. storage vendors plan to sell regulation service are not prevalent worldwide, and China's relatively heavy reliance on hydroelectric power may reduce the near-term usefulness of certain storage technologies in that large market.[24] On the other hand, in economies lacking well-interconnected electric grids, storage technologies may substitute for transmission, much as nations that lacked well-developed wires-based telephony leapfrogged to cellular. Germany, which in the wake of

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[22] The caveat regarding summing identified at note 18 applies here as well.

[23] "Ancillary services" is used here in the same sense that the EIA recites as FERC's definition: "Necessary services that must be provided in the generation and delivery of electricity . . . [such as] coordination and scheduling services (load following, energy imbalance service, control of transmission congestion); automatic generation control (load frequency control and the economic dispatch of plants); contractual agreements (loss compensation service); and support of system integrity and security (reactive power, or spinning and operating reserves)." *Electricity Terms and Definitions*, U.S. EIA, http://www.eia.gov/cneaf/electricity/page/glossary.html (last visited June 8, 2011).

[24] The EIA reports that "China was the world's largest producer of hydroelectric power in 2009, generating 549 Bkwh of electricity from hydroelectric sources. This represented 16 percent of its total generation." *Countries: China*, U.S. EIA, http://www.eia.gov/countries/cab.cfm?fips=CH (last visited June 8, 2011). The U.S. share of electricity generated from hydropower that year was only seven percent. *See* note 28 infra.

the Fukushima nuclear events has recently announced a national plan to phase out nuclear power and rely heavily on renewable energy, may become a leading market for storage facilities. Surveying these variations is beyond the scope of this paper, and in any event the value of storage to foreign markets may not be of direct concern to U.S. federal and state regulators. However, it is worth bearing in mind that domestic uses are not the only ones that can provide early economic niches for new storage technologies and thereby enable start-up costs to be spread over multiple installations.

IV. How Can Electricity Be Stored?

Electricity storage is not new. What are new are technologies that are increasing its economic viability and an industry context that increases its value.

A. Storage past: pumped-hydroelectric

Pumped-hydroelectric storage has been used in Europe for over a century[25] and in the U.S. for almost as long.[26] In a pumped-hydroelectric storage facility, electricity is used to pump water to a higher elevation—typically, a reservoir atop a plateau or river bluff—thereby converting the electric energy to gravitational potential energy, which is subsequently converted back to electricity by running the water back down through a turbine. With each conversion, some of the energy being converted is lost.[27] A pumped-hydroelectric storage facility therefore resembles a conventional dam, except that instead of impounding water that has been elevated through the natural cycle of sun-powered evaporation and precipitation, the water is raised to the reservoir level by expending electricity, and the energy expended in pumping exceeds that retrieved from the facility's turbines when the stored water is allowed to fall.

The extent to which a technology is deployed depends on both its costs and its value, *i.e.*, on the cost of alternatives. In economic terms, a pumped storage plant is essentially a hydroelectric facility that, as compared to a conventional dam-with-impoundment at a favorable site, has comparable capacity value, a higher capacity cost (due to the added capacity cost of the pumping facilities necessary to elevate the water), and negative rather than positive net energy value. The last point has been pivotal: Because pumped storage, in the long run, consumes more energy than it provides, it cannot compete with conventional impoundment hydroelectric power so long as appropriate sites for new impoundments remain available. For many decades, when hydroelectric power represented a larger share of U.S. generating capacity than it does now and pumped hydroelectric was the only technologically mature form of bulk electricity storage, finding a niche in which such storage had economic value was an uphill proposition.

Despite its costs, pumped-hydroelectric storage received increased attention and investment in the 1960s and 1970s because the value of such storage increased. By then, favorable impoundment sites had been fully exploited, and coal and nuclear power were

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[25] The world's first pumped-hydroelectric storage plant was built near Schaffhausen, Switzerland, in 1909. It had a capacity of 1.5 MW. *Encyclopedia Britannica*, "Turbine - History of Water Turbine Technology."

[26] The first US. pumped-hydroelectric storage plant was built on Connecticut's Rocky River in 1929.

[27] Physically, energy is converted, not lost. However, due to the laws of thermodynamics, each time energy is converted from one form to another, some of it is converted to and dissipated as waste heat, thereby losing its capacity to perform work. References to energy "losses" are shorthand for this dissipation.

representing increasing shares of the U.S. electric power supply.[28] The steady, round-the-clock output to which coal and nuclear base-load power plants are suited is ill-matched in time to electricity demands, which vary widely over time—both across seasonal, weekly, and daily cycles and in less predictable ways. The costs of pumped storage were viewed as worth incurring in order to bridge the differences between base-load plants' flat power production curves and electricity consumers' up-and-down load curves.[29]

After the 1970s, however, nuclear plant cancellations coupled with the emergence of relatively inexpensive and efficient natural gas peaking generators changed the economic context for pumped storage. This change slowed both deployment and technological development of bulk electricity storage. Consequently, storage capacity relative to U.S. generating capacity actually *decreased* between 1989 and 2009.[30] For example, a developer planning to turn the cavern left by a former limestone mine in Norton, Ohio into a Compressed Air Energy Storage facility with an up to 2,700 MW capacity received a FERC declaratory order going to jurisdiction in 2001[31] but never proceeded with development. Today, U.S. electrical output capacity exceeds 1000 GW, but of that only about 22 GW—barely 2 percent—is storage

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[28] Hydroelectricity's energy share of total U.S. electric utility generation fell from 35.5 percent in 1925 (U.S. Dep't of Commerce, Bureau of the Census, Statistical Abstract of the United States 471, Table No. 558 (1950), *available at* http://www2.census.gov/prod2/statcomp/documents/1950-06.pdf) to 29.2 percent in 1948 (*id*.) to 7 percent today (Electric Power Annual 2009, Table 2.1) (of 3,950,331 GWh generated, conventional hydroelectric supplied 273,445 GWh).

[29] Consider Michigan's 1,872 MW Ludington pumped-storage plant, which when completed in 1973 was the world's largest. It was planned and built contemporaneously with a nuclear power program that, in Michigan, began producing substantial energy in 1975. (*See State Nuclear Profiles: Michigan*, U.S. EIA, http://www.eia.doe.gov/cneaf/nuclear/state_profiles/michigan/mi.html (last visited June 8, 2011).) Despite the energy losses and other costs of its operation, it has stayed in service for almost four decades, and is approaching a refurbishment and expansion project slated to cost more than twice as much as the original investment. Press Release, DTE Energy, Consumers Energy and Detroit Edison Announce Major Maintenance and Upgrade Project at Ludington Pumped Storage Plant (Feb. 7, 2011), *available at* http://dteenergy.mediaroom.com/index.php?s=43&item=587.

[30] *See* U.S. EIA, Report No. DOE/EIA-0384 (2009), Annual Energy Review 2009, Table 8.11 *available at* http:wwww.eia.gov/emeu/aer/elect.html ("Annual Energy Review 2009")(pumped hydroelectric storage as a share of net U.S. summer generating capacity fell from 18.1 GW of 721.8 GW, *i.e.*, 2.5 percent (in 1989), to 21.9 GW of 1027.6 GW, *i.e.*, 2.1 percent (in 2009). Although these figures are for pumped hydroelectric storage only, that form was the only one with sufficiently large installed capacity to be listed in the referenced years.

[31] *Norton Energy Storage, L.L.C.*, 95 FERC ¶ 61,476 (2001).

capacity rather than generating capacity.[32] That small percentage contrasts markedly with natural gas, for which existing geologic storage facilities alone can hold almost 40 percent of annual consumption.[33] Unlike the gas industry, the electric industry has operated with the ultimate just-in-time inventory.

B. Storage future

In recent years, the expanding power supply role of intermittent, renewable generation (particularly wind[34]), and related increased research funding and technological advancements, has led to a resurgence of policy and industry interest in large-scale electricity storage. For example, FirstEnergy Corp. ("FirstEnergy") recently purchased the rights to develop the Norton, Ohio Compressed Air Energy Storage project discussed above; its press release focused on the potential of such a project to store wind energy.[35] Contemporaneously, the U.S. has grown increasingly dependent on computers and other electrically powered devices that rely on uninterrupted and high-quality power, leading to renewed interest in storing electricity within the distribution system or at end-use locations. A wide array of new electricity storage technologies is therefore entering or approaching commercial deployment, as discussed below.

The historically prevalent pumped-hydroelectric form of electricity storage emphasized large-volume storage on a long time scale. It was designed mainly to meet demands in peak seasons and on peak days with off-peak generation. While that storage role remains important, its importance has diminished with the spread of natural-gas-fired generation and the rapid recent increase in proven natural gas reserves due to the ongoing development of shale gas and other sources. Because natural gas can be stored before it is converted to electricity and natural gas generators can be built relatively inexpensively, natural-gas-fired generation can sometimes be economically substitutable for large-volume, long-time-scale storage. What has come to the fore

[32] Annual Energy Review, Table 8.11a (2009 U.S. Net Summer Capacity was 1027.6 MW, of which 21.9 MW was pumped-hydroelectric storage; no other storage technology had sufficient capacity to be listed).

[33] The EIA reports that as of 2009, underground natural gas storage capacity (which does not include storage in above-ground tanks or as line pack) totaled 8,655,740 Mcf, compared to 22,839,158 Mcf of consumption. *Underground Natural Gas Storage Capacity*, U.S. EIA, http://www.eia.doe.gov/dnav/ng/ng_stor_cap_dcu_nus_a.htm (last visited June 8, 2011); *Natural Gas Consumption by End Use*, U.S. EIA, http://www.eia.doe.gov/dnav/ng/ng_cons_sum_dcu_nus_a.htm (last visited June 8, 2011).

[34] U.S. wind generation grew from 3.0 GWh in 1998 to 94.6 GWh in 2010, and now accounts for 2.3 percent of the national total. *See* U.S. EIA, Monthly Energy Review May 2011, Table 7.2a (2011).

[35] *See* Press Release, FirstEnergy Corp., "FirstEnergy acquires rights to Norton Energy Storage Project" (Nov. 23, 2009), http://www.firstenergycorp.com/content/dam/newsroom/files/news-releases/2009-11-23%20Norton%20Project.pdf.

are technologies for meeting operating contingencies (such as forced outages of generation plants or transmission facilities) and smoothing shorter-term fluctuations in the load curve.

Two recent studies are particularly helpful in surveying the numerous technologies that are (or are expected soon to be) commercially available and provide electricity storage as defined above. In February 2010, Sandia, building on a 2004 study, published *Energy Storage for the Electric Grid: Benefits and Market Potential Assessment Guide* (Sandia Report No. SAND2010-0815). In December 2010, EPRI published *Electricity Energy Storage Technology Options* (EPRI Report No. 1020676).[36] Synthesizing those reports and turning to other sources to fill in certain gaps in their coverage yields the table that appears below.[37]

The table's rows classify electricity storage technologies by the form in which they hold energy before reconverting it to electricity, much as generators can be classified by their fuel sources. The table's columns provide information on the function(s) that each technology are most suited to serve, expressed either in terms of the existing non-storage facilities for which they can substitute or by selected performance parameters such as kW of capacity, kWh of energy, "ramp" speed with which their stored energy can be converted to electricity, and efficiency in converting electricity to another form and back.

[36] Sandia's report includes basic information on numerous storage technologies but is written mainly from the perspective of identifying and distinguishing the functions that electricity storage may serve. Because this perspective starts with system needs and then seeks to identify storage technologies that can fill them, it can be called a "top-down" approach. EPRI's report supplements Sandia's top-down discussion of energy storage applications, but is especially valuable for its "bottom-up" review of various technologies' costs and performance characteristics.

[37] The varied studies synthesized in the table use varying assumptions. To facilitate comparisons, rule-of-thumb conversion factors have been applied and details in the varying assumptions have not been rigorously brought to a common basis. Moreover, projected costs and performance characteristics of new technologies change rapidly. Accordingly, comparisons across technologies should not rely on the table without further research.

Overview of Storage Technologies[38]

Type of Storage		**Analog**[39]	**Cycle Characteristics**		**Discharge Characteristics**					
Stored Energy Form	**Technology Group**		**Net Energy Yield**[40]	**Cycling Issues**	**Ramping**	**Energy/ Capacity**[41]	**Capacity (MW)**	**$/kW**	**Energy (MWh)**	**$/kWh**
Gravitational Potential	Pumped Storage	Dam	75%-82%[42]	No[43]	Slow (up to 10 minutes)[44]	6-10	280-1400	1500-4300	1680-14,000	250-430
Chemical	Electrochemical cell battery (Pb-acid, NiCad, Li-ion, Na/S, Zn/Br, Ni-MH, *etc.*)	Small gas peaker with emissions limitations	60%-75% (conventional) 75%-90% (advanced)[45]	Yes, for some systems[46]	Rapid (able to provide frequency regulation)[47]	4-5[48]	20-100	varied	80-500	100-200[49]

[38] Unless otherwise noted, source is EPRI 2010, mainly the table at 4-22.

[39] This column is especially in need of a caveat. The intent here is to identify a conventional rough analogue—a single existing technology, known to most readers, that most resembles the subject storage technology. The correspondence will necessarily be inexact, and subjective: Whether the "right" comparison has been drawn between existing and new technologies necessarily depends on which features are considered to be the most significant.

[40] Net of conversions losses.

[41] Unless otherwise noted, the Energy/Capacity ratio is expressed as hours of discharge if discharged at the full capacity rate (regardless of whether the technology is capable of maintaining that discharge rate throughout its discharge cycle).

[42] Sandia 2010 at 14 states 75-78 percent (citing Mears & Gotschall, EPRI-DOE Handbook of Energy Storage for Transmission and Distribution Applications, Electric Power Research Institute Report No. 1001834 (Dec. 2003)), whereas EPRI 2010 at 4-22 states 80-82 percent. The range stated in the table spans both ranges.

[43] "No" indicates that if issues exist, they are not material.

[44] Sandia 2010 at 17; DoE 2011 at 21.

[45] Sandia 2010 at 14; EPRI 2010 at 4-22.

[46] Li-Ion batteries and advanced lead-acid batteries that are optimized for cycling can maintain their energy efficiency over many more cycles. *See* EPRI 2010 at 4-24.

[47] *See* J. Himelic, F. Novachek, Xcel Energy, *Sodium Sulfur Battery Energy Storage and its Potential to Enable Further Integration of Wind* at 44 (July 7, 2010), *available at* http://www.electricitystorage.org/images/uploads/docs/W2BMilestone5Report_Public.pdf.

[48] EPRI 2010 at 4-22 (or up to 6 hours for Na-S).

[49] Gene Berry, Lawrence Livermore National Laboratory, *Present and Future Electricity Storage for Intermittent Renewables* at 2, *available at* http://www.pewclimate.org/docUploads/10-50_Berry.pdf.

Type of Storage: Stored Energy Form	Type of Storage: Technology Group	Analog[39]	Cycle Characteristics: Net Energy Yield[40]	Cycle Characteristics: Cycling Issues	Discharge Characteristics: Ramping	Energy/ Capacity[41]	Capacity (MW)	$/kW	Energy (MWh)	$/kWh
	Electrochemical "flow" battery (Zn/Br, V-redox, *etc.*)	Larger gas peaker	Same as above	Electrolytes replaceable	Same as above	5	50	1440-3700	250	290-740
	Hydrogen Electrolysis	High-heat-rate peaker	20%-36%[50]	Yes[51]	Via gas turbine or fuel cell	6[52]	<50[53]	1575-3675[54]	Varied	High due to energy loss
	Asymmetric lead-carbon capacitors for storage[55]	Customer-owned backup generation	75-85%[56]	No	Swift	3-8	1-8	200-1000, per year[57]	3-64	675-1125
Kinetic	Flywheel	Automatic Generation Control	80%-90%[58]	No	20 MW/4 seconds[59]	0.25	20	1950-2200	5	7800-8800

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50 Sérgio Faias, Patrícia Santos, Jorge Sousa, & Rui Castro, Technical University of Lisbon, *An Overview on Short and Long-Term Response Energy Storage Devices for Power Systems Applications* at 5 ("Response Overview"), *available at* http://www.icrepq.com/icrepq-08/327-faias.pdf

51 *Id.*

52 Darlene M. Steward, National Renewable Energy Laboratory, *Scenario Development and Analysis of Hydrogen as a Large-Scale Energy Storage Medium* at 6-12 (June 10, 2009) ("Hydrogen Scenario"), *available at* http://gisceu.net/PDF/U807.pdf.

53 *Response Overview* at 5.

54 *Hydrogen Scenario* at 11.

55 Susan M. Shoenung & William Hassenzahl, Sandia Nat'l Labs., SAND2007-4253, *Long vs. Short-Term Energy Storage: A Sensitivity Analysis* (2007), *available at* http://prod.sandia.gov/techlib/access-control.cgi/2007/074253.pdf.

56 *Id.*

57 *Id.* at 23.

58 Sandia 2010 at 14.

59 Comments of Beacon Power Corp. at 5 n.6, *Frequency Regulation Compensation in Organized Wholesale Power Markets*, FERC Docket No. AD10-11 (June 17, 2010), eLibrary No. 20100617-5027.

Type of Storage		Analog[39]	Cycle Characteristics		Discharge Characteristics					
Stored Energy Form	**Technology Group**		**Net Energy Yield[40]**	**Cycling Issues**	**Ramping**	**Energy/ Capacity[41]**	**Capacity (MW)**	**$/kW**	**Energy (MWh)**	**$/kWh**
Pressure Differen-tial	Compressed Air (underground)	Natural Gas geologic storage	73%-80%[60]	Cavern geology (salts, porosity) may matter[61]	18-19 MW/Min[62]	8-20	180	960-1150	1440-3600	60-120
	Compressed Air (above-ground)	Natural Gas LDCs' propane and LNG peak-storage	79-81%	No	Similar to underground	5	50	1950-2150	250	390-430
Field	Superconducting Magnetic Energy Storage ("SMES") for power quality	Batteries built into laptops and like devices	95%[63]	No	milliseconds[64]	1 sec.[65]	1-10[66]	200-250[67]	<1	650,000 - 860,000[68]

[60] *Id.*

[61] Samir Succar & Robert H. Williams, Princeton Environmental Institute, *Compressed Air Energy Storage* at 29-30 (2008), *available at* http://www.princeton.edu/~ssuccar/caesReport.html ("Succar") (noting also that emergency ramp rate for one plant is twice as fast).

[62] *Id.* at 29 (noting also that emergency ramp rate for one plant is twice as fast).

[63] Sandia 2010 at 14.

[64] Hasan Ali, Bin Wu, & Roger A. Dougal, *An Overview of SMES Applications in Power and Energy Systems* at 3, IEEE Transactions On Sustainable Energy (Apr. 2010), *available at* http://vtb.engr.sc.edu/vtbwebsite/downloads/publications/IEEE%20Sustainable%20energy-published%20paper.pdf ("SMES Overview"); *see also* Paul Breeze, *Power Generation Technologies* 135 (2005) ("Breeze").

[65] Robert B. Schainker, *EPRI RD&D Focus: CAES, Scoping Workshop on CAES Research, Development and Deployment* (Oct. 21-22, 2008), *available at* http://www.clca.columbia.edu/papers/CAES_WorkshopReport_web.pdf ("CAES")

[66] National Renewable Energy Laboratory, *Power Technologies Energy Data Book* at 87 (3d ed. 2005), *available at* http://www.nrel.gov/analysis/power_databook_3ed/docs/pdf/db_chapter02_adv_storage.pdf.

[67] CAES.

[68] *Id.*

Type of Storage		Analog[39]	Cycle Characteristics		Discharge Characteristics					
Stored Energy Form	Technology Group		Net Energy Yield[40]	Cycling Issues	Ramping	Energy/ Capacity[41]	Capacity (MW)	$/kW	Energy (MWh)	$/kWh
	SMES for energy storage	Customer-owned backup generation	85%[69]-95%[70]	No	Same as above	hours	1[71]	>3000[72]	5000[73]	Emerging technology; TBD
	Supercapacitor for power quality	Batteries built into laptops and like devices	95%[74]	No	Virtually instantaneously[75]	10 sec.[76]	1[77]	250-350[78]	0.003	20,000-30,000[79]

[69] *See ABB Inc.: Superconducting Magnet Energy Storage System with Direct Power Electronics Interface*, ARPA-E, http://arpa-e.energy.gov/ProgramsProjects/GRIDS/SuperconductingMagnetEnergyStorageSystemwith.aspx (last visited June 9, 2011).

[70] SMES Overview at 3.

[71] CAES.

[72] Breeze at 147.

[73] SMES Overview.

[74] Sandia 2010 at 14.

[75] Breeze at 135.

[76] CAES.

[77] European Commission, *Electricity Storage in the Power Sector* at 3 (available at http://setis.ec.europa.eu/newsroom-items-folder/electricity-storage-in-the-power-sector-technology-information-sheet/at_download/Document).

[78] CAES.

[79] *Id.*

Substantial research and demonstration projects are ongoing across and beyond the wide range of storage technologies identified above. The U.S. Department of Energy is a principal source of research funds. The scale of its funding is an indicator that storage technology is for real, and the breakdown of that funding across the various storage technologies provides an indication of which ones the DoE views as holding the most immediate promise. The DoE's recent program summary[80] identifies $771 million[81] in ongoing demonstration projects for which some funding comes from the DoE. They consist of

- Bulk-scale battery storage projects funded at $155 million;[82]
- Distributed battery storage projects funded at $503 million;[83]
- Flywheel storage projects funded at $58 million;[84] and
- Compressed air storage projects funded at $65 million.[85]

In addition to these pilot demonstration projects, the DoE's Advanced Research Projects Agency ("ARPA-E") focuses on "high-risk, high-payoff concepts" by funding technology prototypes and proof-of-concept research-and-development projects.[86] ARPA-E is funding projects related to superconducting magnetic energy storage, flywheel storage, compressed air, electrolysis, and a wide range of battery technologies.

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[80] DoE 2011.

[81] All research funding amounts cited in this discussion are rounded and represent the total project funding including non-DoE sources.

[82] *Id*. at 24, 26.

[83] *Id*. at 25-27.

[84] *Id*. at 25-26.

[85] *Id*. at 26-27.

[86] *See* Mission, ARPA-E, http://arpa-e.energy.gov/About/Mission.aspx (last visited June 8, 2011), *and Grid-Scale Rampable Intermittent Dispatchable Storage (GRIDS)*, ARPA-E, http://arpa-e.energy.gov/ProgramsProjects/GRIDS.aspx (last visited June 8, 2011).

V. Who Might, and Who Should, Provide What Storage Services to Whom, and Under What Regulatory Supervision?

The primary policy question that regulators must answer as various types of storage facilities enter widespread use concerns market structure, *i.e.*, "who" (entities[87] with what regulatory status) should be allowed, encouraged, or required to provide storage services. Should they be provided by regulated, vertically integrated utilities under cost-based regulation, by grid operators that do not participate in markets, by "merchant" entities selling storage services at unregulated prices, by end-use customers providing storage services to themselves, or by other types of service providers? The solutions will likely vary depending on the type of storage service. After a brief review (in Part V.A below) of who is now providing storage services, that policy question is examined in Part V.B. Next, Part V.C identifies the principal rate-related issues that arise where storage service is provided by regulated entities at cost-of-service prices. Part V.D then examines the legal bases under which regulators have jurisdiction to supervise the pricing and other aspects of storage service. Finally, Part V.E identifies miscellaneous additional storage-related regulatory issues.

A. Existing providers of storage services

At present, the following are among the types and leading names of entities that own existing U.S. storage facilities and use them to provide storage services to themselves or others.[88]

- ***Traditional vertically integrated utilities (or their generating affiliates) that continue to own pumped-hydroelectric facilities.*** Owners of facilities larger than 1 GW include both investor-owned and government-owned entities, such as Allegheny Power and Dominion (Bath County, jointly), Consumers Energy and Detroit Edison (Ludington, jointly), Duke Energy (Bad Creek), Exelon (Muddy Run), Los Angeles Department of Water & Power (Pyramid/Castaic), New York Power Authority (Blenheim-Gilboa), Oglethorpe Cooperative and Southern Companies (Rocky Mountain, jointly), Pacific Gas & Electric (Helms), Tennessee Valley Authority (Racoon Mountain), and Western Area Power Administration (Mount Elbert). In addition, one such project formerly owned by Northeast Utilities, namely Northfield Mountain, has been sold to a subsidiary of GDF Suez.

- ***Transmission owners that have built storage facilities in connection with transmission lines in order to increase the effective capacity of those lines.*** For

[87] "Entity" is used herein as a general term for corporation, cooperative, or other form of business firm; government body participating in the electric industry; or natural person.

[88] *See generally Pumped-Storage Plants in the USA*, Power Plants Around the World, http://www.industcards.com/ps-usa.htm (last visited June 8, 2011). As new storage technologies move from the laboratory to commercial use, the list of leading industry players will likely change rapidly. The list provided here focuses on entities that own operating storage facilities, rather than vendors who manufacture storage systems and sell them to storage operators, because the former are more relevant to regulatory concerns.

example, since 1981, a "Superconducting Magnetic Energy Storage System" has been in commercial operation on the 500 kV Pacific Intertie, where it has raised a stability limit on transmission capacity by some 400 MW.[89] EPRI anticipates a substantial likely market for storage facilities deployed to allow transmission investments to be deferred, totaling about 6 GW in the "target" scenario that EPRI considers most likely.[90]

- ***Utilities that own distribution systems might build storage facilities in load centers in order to address bulk electric system or distribution system reliability issues.*** For example, American Electric Power, with partial funding from the DoE/Sandia, has built three 2 MW battery stations as demonstration projects that provide community-scale backup power.[91] EPRI anticipates a substantial likely market for utility-owned distributed storage: rounded, 6 GW of commercial/industrial distributed power backup, and 14 GW of facilities deployed in order to allow distribution upgrades to be deferred.[92]

- ***Entities that install storage facilities with the intent of bidding their output into "ancillary service" markets (i.e., "merchant" entities).*** For example, Beacon Power Corp., a flywheel storage firm, summarizes its market strategy as follows: "Our initial market entry is in North America, where the total regulation[[93]] market is divided into the 'open-bid' and 'vertical market' segments. As a merchant provider of frequency regulation, the open-bid segment is more accessible to new technologies, so our market strategy is to enter the open-bid

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[89] *See* Los Alamos National Laboratory, Progress Report No. LA-9208, *Superconducting Magnetic Energy Storage (SMES) Program* at 3 (1982), *available at* http://www.osti.gov/bridge/servlets/purl/5370179-c1IIhs/5370179.pdf. This system stores energy in the form of a magnetic field that is propagated by direct electrical current circulating through a superconducting loop.

[90] EPRI 2010 at 3-11 to 3-12. These estimates sum those that EPRI has developed for both "stationary" and "mobile" storage facilities, *i.e.*, facilities that are installed permanently at a single location, and facilities that are deployed in any given location for a relatively short period as a stopgap pending other construction, and designed to be relocated from time to time. The distinction is analogous to the difference between fixed and portable generators.

[91] Emeka Okafor, *Dynamic Islanding: Improving Electric Service Reliability with Energy Storage* 2 (presentation) (Nov. 2, 2010), *available at* http://www.sandia.gov/ess/docs/pr_conferences/2010/okafor_aep.pdf.

[92] EPRI 2010 at 3-12. As with the estimates cited in note 90 above, these estimates sum those that EPRI has developed for both "stationary" and "mobile" storage facilities.

[93] "Regulation" as used in this quotation refers to keeping electrical system frequency acceptably close to 60 Hz, *i.e.*, the service that is captured in FERC's *pro forma* open access transmission service as the Schedule 3 ancillary service.

market [*i.e.*, centralized ISO ancillary services market] segment first, followed by the vertical market segment."[94] AES is another such "merchant" entity; it is completing a 20 MW lithium-ion battery facility that sells regulation service to the New York ISO, and another 32 MW storage facility that will sell regulation service to PJM.

- ***Industrial, commercial, or residential retail customers who install storage facilities at their end-use locations to ensure that their electric-powered uses can continue to run notwithstanding disturbances or outages in the upstream bulk electric system or distribution system.*** EPRI sees very large likely markets for such customer-owned storage: 18 GW of commercial/industrial applications and 47 GW of residential applications.[95] This market is important not only in its own right, but also because the early adoption of storage technologies by end users who value it most highly can give storage technology vendors a starting point, from which they can scale up their offerings and achieve lower costs per stored MW or MWh. For example, the flywheel systems that Beacon Power is now deploying as part of the bulk electric system at utility scale evolved from systems that telecommunications providers used to provide backup power for their electricity end-uses.[96]

B. What regulatory modes and market structures fit what storage services?

1. Potential owners and providers

As the range of existing storage providers reviewed above illustrates, storage services could be provided by a wide range of entities, under a wide range of regulatory modes. Without being exhaustive, the potential types of storage facility owners and storage service providers include:

- *Entities that lack both obligations to serve and captive customers, and sell their storage services at market-based prices (i.e., "merchant" providers)*. Such merchants might also own conventional (non-storage) generating resources, or could be special-purpose, storage-only entities not affiliated with existing market participants.

- *Entities that own transmission facilities and provide transmission service (either directly or through a regional entity) at cost-based rates*. Such entities might or might not own conventional generating resources. They might provide storage

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[94] *Investors' Frequently Asked Questions: In Which Markets is Beacon Looking to Sell Its Regulation Services?*, Beacon Power Corp., http://www.beaconpower.com/faq.asp (last visited June 8, 2011).

[95] EPRI 2010 at 3-12.

[96] *Company Overview*, Beacon Power Corp., http://www.beaconpower.com/company/index.asp (last visited June 8, 2011).

service as an adjunct to their transmission service, and recover its costs too under cost-based rates. Alternatively, they might provide storage service in the market-based fashion described above.

- *Transmission-only, market-operating regional entities such as RTOs*. Although in theory the market-based mode of selling services could extend to such entities, all of the existing regional entities are not-for-profit and thinly capitalized. Accordingly, it would be more plausible for such entities to provide storage service as an adjunct to their transmission and market operations services and recover its costs under cost-based rates.

- *Special-purpose, storage-only entities* that do not make decisions about when to charge or discharge, but rather operate at the direction of transmission owners or operators of generators or of load—much as natural gas pipelines that own storage facilities store and release gas at shippers' direction, and as some natural-gas-fired generators operate under "tolling"[97] arrangements.

- *Distribution-system, retail-level utilities*.

- *Individual consumers* or groups of consumers aggregated by a non-franchised retail electricity vendor or storage service provider.

For most of these business modes, at least two variants are possible: The owner of the storage facility can either take title to the stored energy or store energy legally owned by others. The latter role is analogous to that played by the granary in one of the foundational cases of U.S. public utility law—*Munn v. Illinois*, 94 U. S. 113 (1876).

To date, little explicit attention has been paid to the question of what regulatory mode for the various identifiable storage services would best serve the public interest. Moreover, the cases that have arisen have tended to be decided based on formalistic analysis of whether the storage facility at issue should be viewed as "generation" or as "transmission." They may have reached sound results, but their reasoning has been dubious. This part will review and critique two recent orders in which FERC has applied a formalistic analysis, identify more substantive approaches to these issues, and very tentatively suggest, for each of the types of storage services identified in Part IV.B above, a regulatory mode that might be appropriate.

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[97] A "tolling" arrangement typically involves two parties: a power marketer and the owner of a gas-fired electricity generation plant. The plant owner agrees to convert to electricity the natural gas that the power marketer arranges to have delivered to the plant. Title to the natural gas and electricity is held only by the power marketer; the plant owner performs the service of converting the power marketer's energy from one form to another, rather than selling energy.

2. FERC's formalistic analysis

In *Nevada Hydro Co.*, 122 FERC ¶ 61,272 (2008), FERC addressed a proposed 500 MW, $1.1 billion pumped-hydroelectric storage project planned in conjunction with a 500 kV transmission line in southern California.[98] The storage project developer wanted its project to be deemed a transmission facility so that it would receive assured cost recovery through the California ISO ("CAISO") non-bypassable transmission access charge ("TAC"). It also sought the same incentive-heightened rate of return that FERC granted for the developer's associated transmission line.[99] Accordingly, it filed under Federal Power Act ("FPA") Section 205 for such rate-related approvals. In angling for these rate treatments, Nevada Hydro offered to place the storage facility under some form of CASIO control, by giving the ISO operational control while creating some kind of information firewall, or periodically auctioning to market participants the right to operate the facility, or contracting with a market participant to operate it.[100]

FERC rejected the proposal to roll the storage facility's costs into the CAISO's non-bypassable transmission access charge.[101] FERC based this holding mainly on a finding that "the purpose of the TAC is to recover the costs of transmission facilities under the control of the CAISO; the purpose is not to recover bundled services."[102] Relatedly, FERC found that none of Nevada Hydro's several proposals for placing the facility under ISO auspices was workable, because all of them would have inappropriately placed the independent grid operator in the position of profiting from time differences in electricity prices.[103] FERC also pointed out that it would be unduly discriminatory to roll the costs of Nevada Hydro's pumped-hydroelectric

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[98] *See* Dariush Shirmohammadi & Sam Van Vactor, *A Preliminary Economic Assessment and Strategic Review of the LEAPS Project* (2007), *available at* http://www.evmwd.com/civica/filebank/blobdload.asp?BlobID=4372. The project has not been built, and is on the verge of being cancelled. Michael J. Williams, "Lake Elsinore: Federal Agency Ready to Drop Hydroelectric Project," *The Californian*, May 7, 2011, http://www.nctimes.com/news/local/lake-elsinore/article_f9467e4c-4f9e-5e3e-b951-c2474a6ce4de.html.

[99] For detailed discussions of FERC's treatment of transmission "incentives," *see* Transmission Access Policy Study Group, *Effective Solutions for Getting Needed Transmission Built at Reasonable Cost*, *available at* http://www.tapsgroup.org/sitebuildercontent/sitebuilderfiles/effectivesolutions.pdf, *and* Adam Pollock, NRRI No. 09-12, *How Can FERC Improve the Transmission Incentive Policy? Ways to Improve Clarity, Transparency, and Performance* (2009), *available at* http://www.nrri.org/pubs/electricity/NRRI_FERC_trans_incentives_aug09-12.pdf.

[100] *Nev. Hydro Co.*, 117 FERC ¶ 61,204, P 29 (2006).

[101] *Nev. Hydro Co.*, 122 FERC ¶ 61,272, P 83 (2008).

[102] *Id.*

[103] *Id.*

facility into transmission rates when other pumped-hydroelectric storage owners collected their revenues only by succeeding in wholesale power markets.[104] Given the rejection of transmission rate treatment, the request for a heightened rate of return was moot, but in any event FERC denied it.[105]

While these outcomes were defensible, FERC's reasoning was dubious. Non-bypassable transmission rates do commonly recover the costs of certain "bundled" services, such as the "ancillary" services that are recovered under Schedules 1-6 of FERC's *pro forma* Open Access Transmission Tariff ("OATT"), generation redispatch costs, and reliability must-run generation. Placing a "bundled" label on the services at issue in *Nevada Hydro* is another way of restating the conclusion that they should be viewed as generation services and thereby made ineligible for cost recovery through transmission rates, but such labeling is not a basis for reaching that conclusion. FERC's concerns about CAISO being placed in the position of participating in markets were more substantive, but surely ways could have been found to ensure that CAISO had no stake in any market outcome, *e.g.*, by returning directly to transmission customers any revenues CAISO derived from operating the storage facility or from auctioning the rights to do so. Moreover, the concern about transmission operator market independence arises only in the context of a regional RTO or ISO. If a comparable facility were built in, say, Nevada, where the grid is operated by vertically integrated market participants, this basis for FERC's rejection would be unavailable. In that case, would it be appropriate to roll the facility's costs into transmission or ancillary service rates, and if not, why not?

In *Western Grid Development, LLC*, 130 FERC ¶ 61,056, *reh'g denied*, 133 FERC ¶ 61,029 (2010), FERC again followed a label-based approach to determining what regulatory rubric should apply to a storage facility. That case involved several sodium sulfur battery storage projects, owned by Western Grid and located in the CAISO area, at various locations selected for transmission constraint relief. As in *Nevada Hydro*, the storage facility owner filed under FPA Section 205, seeking authorization to include the costs of its facilities in non-bypassable transmission rates and to include in those rates an incentive-heightened return on equity. The batteries' operating arrangements (as described in FERC's order) provided that CAISO would decide when to discharge them, whereas the batteries' owner was to decide at what other times to charge them. The batteries' output would not be bid into CAISO power markets, and any revenues that resulted from differences in the prices of charging energy and discharged energy were to be credited to transmission ratepayers.[106] FERC found these arrangements sufficient to distinguish *Nevada Hydro*. It proceeded to find that because CAISO would decide when to discharge the batteries, they should be classified as wholesale transmission facilities and as such deserved to be rolled into CAISO's rates and to receive transmission rate incentives, including a heightened return on equity.[107]

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[104] *Id*.

[105] *Id*. PP 84-85.

[106] *Id*. PP 45-46.

[107] *Id*. PP 43-56.

Taken together, the explanations stated in these two cases imply a poor decisional rule. FERC seems to hold that if a storage facility is operated by a transmission operator (or more particularly, if decisions to discharge the facility are made by a transmission operator), then it will be classified as transmission, whereas if the same storage facility, providing the same service, is operated by a generation seller, then it will be classified as generation. This reasoning is circular and of no real help in resolving how to treat a situation where a new, project-specific entity seeks one treatment or the other. It also runs counter to the logic of the FPA's jurisdictional provision, § 201(b)(1).[108]

A better basis for decision—and what FERC may in fact have been thinking, even though it did not really explain itself this way—can be found in the different planning origins and technical characteristics of the storage facilities at issue in these two cases. The *Nevada Hydro* pumped storage facility was large (500 MW), and its siting was determined by the location of water supply and elevation differences. On these bases, its predominant function appears to have been to meet peak loads with off-peak generation. As such, rolling its costs into transmission rates would have been equivalent to classifying a generator as a must-run reliability resource whose costs are covered by a non-bypassable charge to ratepayers instead of through market outcomes. Nevada Hydro did not justify such treatment. In contrast, Western Grid's facilities were designed to store and discharge smaller quantities of power, were dispersed among multiple locations selected based on transmission system needs, and were oriented more toward providing ancillary services than time-shifting demand. Thus, Western Grid's facilities were not simply a substitute for peaking generation. By themselves, those distinguishing facts remain insufficient to justify rolling Western Grid's costs into non-bypassable transmission charges rather than including them in ancillary service charges. However, they do present a closer case.

FERC appears to recognize that its approach to regulating storage requires rethinking. In a currently open docket, FERC has sought comments on storage rates, accounting, and financial reporting.[109] In addition, FERC Chairman Jon Wellinghoff has stated that FERC will soon begin

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[108] The Act proceeds from what facilities do to how their owners are classified, not the other way around. That is, the Act defines as "public utilities" those entities that own or operate facilities that do certain things (namely, facilities for interstate commerce transmissions or wholesales); it does not define as FERC-jurisdictional those facilities that are owned by jurisdictional entities. Jurisdictional issues are addressed in Part V.D infra.

[109] FERC Office of Energy Policy & Innovation, *Request for Comments Regarding Rates, Accounting, and Financial Reporting for New Electric Storage Technologies*, Docket No. AD10-13, 75 Fed. Reg. 36,381 (June 25, 2010).

a rulemaking on electricity storage,[110] and an item on FERC's public agenda for its June 16, 2011 public meeting appears to constitute that rulemaking.[111]

3. Some functional ways to make decisions about regulating storage

A functional, rather than formalistic, approach to deciding whether and how to regulate storage facilities and services would involve asking questions like the following.

Can competition among providers of a given type of storage and between such storage and its alternatives be relied upon to keep storage prices in line with cost, or is rate regulation necessary as a substitute for competition? Consider a storage facility that is built to enable peak-period loads to be met from off-peak generation, and suppose that purpose can be met by selling the facility's output into wholesale electric markets that are competitive. In that case, consumers will typically be best served by requiring the facility owner to find willing buyers through those markets and by leaving to those markets the pricing of the facility's output.[112] As a contrary example, free-market competition might not yield competitive prices if the economically viable storage technology is a site-dependent one like pumped-hydroelectric or compressed air storage, a single firm controls the available sites, and prospective customers lack substitutes. On the other hand, if a non-storage technology is a sufficiently close substitute to a storage technology, then in some circumstances competition between the two could be relied upon to keep storage service prices in line with cost. From an antitrust perspective, it is considered pro-competitive, and therefore economically efficient, to disperse ownership absent an economic efficiency advantage to integration. If so, then rate-regulated transmission and distribution utilities should own storage facilities only where scope economies make such ownership a sensible extension of their existing natural monopolies.

Do the potential providers of a storage service have conflicting business interests that would distort their storage-related decisions? Absent regulatory restrictions, unregulated storage providers may also operate (or be affiliated with entities that operate) non-storage electricity generators. Such multi-resource owners can be expected to utilize and bid their storage facilities in ways that are suboptimal for society as a whole. This suboptimal market conduct would occur because they would seek to protect the value of their other resources.[113]

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[110] *US FERC May Propose Rulemakings on Storage, DC Power Lines.* Wellinghoff, Platts, Mar 23, 2010, http://www.platts.com/RSSFeedDetailedNews/RSSFeed/ElectricPower/8698576.

[111] The agenda item in new Docket No. RM11-24 is titled "Third-Party Provision of Ancillary Services: Accounting and Financial Reporting for New Electric Storage Technologies."

[112] *See* Laurence D. Kirsch, *Compensating Electrical Storage Resources*, 24 Electricity J. 72, 73 (2011).

[113] *See* Ramteen Sioshansi, "Welfare Impacts of Electricity Storage and the Implication of Ownership Structure" (2009), *available at* http://ise.osu.edu/isefaculty/sioshansi/papers/storage_ownership.pdf.

Consider a merchant firm that owns both a storage facility and a peaking generator whose profitability depends on wholesale market prices rising during load peaks. Such a firm will have reason to bid its storage resource's output at an inefficiently high price during load peaks, in order to avoid undercutting the profitability of its peaking generator.[114] This consideration suggests that merchant storage owners should be kept independent from non-storage electricity generators. On the other hand, where storage is being used to firm intermittent generation sources such as wind, there may be countervailing economies of scope in placing under common control decisions that affect the usefulness of both resources. For example, if a generator and a storage facility are planned together so that the latter may bank energy from the former, then it may be advisable to allow common ownership so that decisions regarding the installation and operation of both resources are kept coordinated. Alternatively, it may be possible to realize the benefits of both coordination and competition through contractual terms.

Would provision of storage service create a conflict of interest that would distort the provider's decisions related to its non-storage services? An entity that is responsible for supplying energy to a storage facility and that owns the facility's energy output will be a market participant, with a direct stake in market outcomes such as the spread between different periods' electricity prices. That raises conflict-of-interest issues for storage provided by a transmission provider and/or market operator, particularly as to Independent System Operators established in order to provide market neutrality. The incentives for such market-neutral entities should point toward treating all market participants non-discriminatorily while facilitating transactions by others that meet consumer needs at low cost. A contrary incentive would arise if, for example, the entity profits when peak prices make stored electricity more valuable.

Among the potential types of service providers, which is best positioned to make efficient decisions regarding the location and quantity of storage resources and to efficiently operate such resources? Which will have perverse incentives that might lead to wasteful investment and operation? Consider storage facilities designed to perform what Sandia calls "Electric Energy Time-shift," *i.e.*, to obtain "inexpensive electric energy, available during periods when price is low, to charge the storage plant so that the stored energy can be used or sold at a later time when the price is high."[115] If the costs of such facilities are funded by ratepayers while the profits they create go to shareholders, then shareholders will have a misdirected incentive to overbuild. This consideration points toward a "merchant generator" model of regulation for such facilities, under which the entity that builds the facility bears both the risk of loss and the upside potential for profits.

Are the storage technology's economics sufficiently robust (i.e., reasonably profitable over a wide range of foreseeable conditions, or at least extremely profitable over a narrow range of potential conditions) that a merchant storage builder can get financing? For example, consider storage facilities designed to perform what Sandia calls "Voltage Support," *i.e.* to "offset the need to use large/central generation to provide reactive power to the grid when

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[114] *See id*.

[115] Sandia 2010 at 25.

region-wide voltage emergencies occur."[116] Sandia envisions such facilities preventing one outage lasting one to two hours over the course of their 10-year service life.[117] A facility expected to be used so rarely may be worth building, but likely will not be built if funding depends on an emergency actually arising. Accordingly, such facilities are not good candidates for the application of a merchant model; if they are to be built, ratepayer funding (presumably through cost-of-service rates) would appear to be necessary.

Are there economies of scale such that multiple storage resources in a given geographic area or market segment are best owned by the same entity? For example, consider storage facilities designed as what EPRI calls "Distributed Energy Storage Systems," *i.e.*, as storage located in load centers, sized to serve "four to eight residences, a business park, a campus, or multi-family units."[118] If each such storage unit operated independently, one can envision the connected end users owning them (*e.g.*, ownership by the landlord of a multi-family unit, or by several home-owning neighbors through a homeowners' association or the like). However, if there were substantial economies of scale in maintaining or operating adjacent units together, then it might be more efficient for the operational control, and perhaps the ownership as well, to be unified through an aggregating entity. In particular, the EPRI report envisions that many such units would have their operation controlled together through SCADA systems to "provide large-scale grid support management."[119] The utility providing distribution service to the load center could be one such aggregator. Other possibilities include an independent entity under contract to that utility or a retail-choice alternative supplier that signs up slates of loads connected to one or more proximate distributed storage facilities.

Given economies of scale, should certain storage facilities be treated as "essential facilities" to which all competitors should be given open access? Consider the situation that remains common in retail-choice states: Although retail customers have the option to obtain their generation supply from an alternative retail supplier, the incumbent utility continues to provide bundled retail service to most retail loads in its traditional service territory, under "standard offer" service or the like. Suppose that either the incumbent utility's bundled loads or the total distribution system loads (comprising both those bundled retail loads and the loads of alternative retail suppliers) could support a storage facility of economically large size. But suppose further that alternative retail suppliers' loads (cumulatively, or cumulatively within the area that can be served by distributed storage) are too small to support a storage facility of economically large size. If the incumbent utility is allowed to build a storage facility and keep its output for use on behalf of its bundled retail customers, it will be advantaged in competition with alternative retail suppliers. In this situation, the storage facility might appropriately be considered a natural monopoly, to which all distribution system loads would be granted open access.

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[116] *Id.* at 81.

[117] *See id*.

[118] EPRI 2010 at 3-10.

[119] *Id*. at 3-11.

Is the storage facility's usefulness specifically tied to a non-storage facility in ways that argue for placing the two facilities under common ownership or control? For example, consider storage facilities designed to perform what Sandia calls "Renewables Integration," including a facility through which "low-value electric energy from wind generation is stored at night and during early mornings," then "discharged when it is most valuable—during weekday afternoons when demand for electricity is highest."[120] If an interdependent wind farm and storage facility are owned in common, then decisions regarding project size, completion or abandonment, maintenance, retirement, and so forth are more likely to be kept complementary. This consideration is reinforced if the generating and storage facilities are located on the same site, but may be compelling even if they are remote from each other. On the other hand, suppose that a storage facility's funding depends on out-competing an incumbent provider (*e.g.*, by providing frequency regulation service more nimbly, as discussed in FERC's frequency response NOPR[121]). In that case, price-reducing competition, and thus the public interest, may be best served by separating ownership of the competing resources.

Is the storage facility being relied upon by transmission (or distribution) system planners to meet location-specific needs, with integrated planning consequences such that decisions regarding the installation of the storage facility are best left in the hands of the same entity that will be making decisions regarding the related transmission (or distribution) facility? For example, consider storage facilities designed to perform what Sandia calls "Transmission and Distribution Upgrade Deferral."[122] Sandia provides an example in which a 375 kW storage facility could defer a "lumpy" investment to upgrade a substation by 5 MVA.[123] In such a situation, where the storage facility is being relied upon as a location-specific element of a dynamic regional or area transmission or distribution plan, common ownership of the storage facility and the transmission or distribution system with which it is being planned may be appropriate.

Will the storage facility serve an individual retail customer, and if so can that customer efficiently own, maintain, and operate it? For example, consider the storage function for which EPRI projects the largest feasible market potential of all, namely "Home Back-Up," *i.e.*, "home and home office reliability and back-up power."[124] Decisions about the sizing and operation of such facilities may best be left with the same individual consumers who will be making related decisions about home energy usage, home wiring, and purchases of electricity-consuming equipment (such as HVAC equipment plug-in electric vehicles).

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[120] Sandia 2010 at 44.

[121] Frequency Regulation Compensation in the Organized Wholesale Power Markets, 76 Fed. Reg. 11,177, 11,178 (proposed Mar. 1, 2011), FERC Stats. & Regs. ¶ 32,672, P 1 (proposed 2011).

[122] Sandia 2010 at 36.

[123] *See id*.

[124] EPRI 201 at 3-13. EPRI projects a target (feasible) market for such storage of 27,560 MW. *See id*.

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The practical way to answer the above-listed questions is to ask what economic consequences would result, and what regulatory treatments would be necessary, if the storage facility were owned by a given sector, and whether those outcomes are likely to yield end results that are in the public interest. In turn, that perspective indicates that different types of storage facilities are likely to warrant different regulatory classifications and treatments. As Part IV.B above makes clear, facilities that provide storage will come with a range of performance characteristics. It should not simply be assumed that the same mode of regulation will be well-suited to all of them. To the contrary, there is a going-in reason to expect that a range of regulatory modes should be employed. The storage benefit categories identified in Part III above identify a wide range of functions, now served variously by existing generation, transmission, and distribution facilities, that storage can be tailored to provide. Existing regulatory approaches vary across the range of existing industry sectors, and it is a reasonable starting assumption that practical regulatory approaches to the various comparable functions served by storage will similarly vary.

4. Some tentative regulatory approaches based on the above functional perspective

Based on current storage technology expectations, and looking to the storage benefit types identified by Sandia and reviewed in Part III.B above, the functional perspectives recommended above might suggest the following market structure. The tentativeness of these suggestions must be emphasized, given the many important factors that remain unknown as to storage facility costs, institutional arrangements, *etc*. To help address those unknowns, Part V below identifies some areas for further research and provides a template for a formal investigation.

Benefit Type	**Service Provider**	**Buyer (if applicable)**
Electric Energy Time-Shift	Wholesale market merchant	Load-serving entity (distribution utility, aggregator, or wholesale-level market participant serving them)
Electric Supply Capacity	”	”
Load Following	Load-serving entity	Self
Area Regulation	Control area operator	Ancillary service customers (*i.e.*, transmission customers, including transmission owners serving their own load)
Electric Supply Reserve Capacity	Wholesale market merchant	Load-serving entity

Benefit Type	**Service Provider**	**Buyer (if applicable)**
Voltage Support	Control area operator	Ancillary service customers (*i.e.*, transmission customers)
Transmission Support	Transmission provider	Transmission customers
Transmission Congestion Relief	Wholesale market merchant (in organized markets)	Transmission customers
T&D Upgrade Deferral	Transmission or distribution utility	Transmission or distribution customer
Substation On-Site Power	Substation owner (transmission or distribution utility)	Self
Time-of-Use Energy Cost Management	End-use consumer(s) or aggregators thereof	End-use consumer(s)
Demand Charge Management	End-use consumer(s) or aggregators thereof	End-use consumer(s)
Electric Service Reliability	End-use consumer(s) or Distribution utility	End-use consumer(s)
Electric Service Power Quality	End-use consumer(s) or Distribution utility	End-use consumer(s)
Renewables Energy Time-Shift	Wholesale market merchant or renewable energy generator	Renewable energy customer
Renewables Capacity Firming	Wholesale market merchant or renewable energy generator	Renewable energy customer
Wind Generation Grid Integration (short-duration discharges)	Wholesale market merchant or wind generation owner	Wind energy customer
Wind Generation Grid Integration (long-duration discharges)	Wholesale market merchant or wind generation owner	Wind energy customer

C. Cost-based rate regulation of storage services

As discussed above, the appropriate, public-interest-oriented market structure and regulatory mode will vary across storage services. Some cases will call for a merchant model, in which storage providers bear the risk of funding their investments and operations out of sales of ancillary services, energy price arbitraging, or the like. Others will call for a cost-of-service, regulated-rates approach. In the latter case, the familiar (and familiarly debated) principles of cost-based rate regulation will apply, but their novel application to new electricity storage technologies will raise new issues.

Grossly simplifying in order to define terms, cost-of-service regulation proceeds roughly as follows. First, utility plant is "functionalized," *i.e.*, sorted into functional categories (traditionally, generation, transmission, distribution, and common). Then the annual fixed cost associated with each dollar invested in the functional categories is determined by applying a cost of capital to the invested funds. Depreciation expense is determined through studies of service lives. Other recoverable fixed costs and expenses are likewise identified and apportioned to functional categories. The costs of each function are then allocated to responsible customers or classifications, usually based on cost causation. The resulting revenue requirement for each classification is then recovered through rates. Most commonly, rates are designed as a one-part rate per kWh (in which case the revenue requirement is divided by a kWh measure of paying load to yield the billable rate per kWh), or as a two-part rate (in which the main rate is like a one-part-rate per kWh, while a "customer charge" collects costs that vary mainly with the number of customers). In some cases (typically, for larger customers with more sophisticated meters), more complex multi-part rates[125] are developed, and may be refined into distinct on-peak and off-peak rates, other forms of time-sensitive pricing, and the like.[126]

Each of these ratemaking steps will raise new issues when applied to electricity storage. The likely thorniest one is functionalization, *i.e.*, whether storage should be functionally categorized as "generation," transmission," or "distribution." Under generally applicable ratemaking principles, the customer classes that cause or benefit from a given facility should bear its costs. But with storage, it will often be difficult to ascertain which of these functional categories is predominant, and therefore difficult to determine which customer classes cause or benefit from a storage facility's costs. The complexities that are arising in functionalizing "smart

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[125] The classic formulation at retail is a demand charge for recovering costs driven mainly by peak demand, an energy charge for recovering costs driven mainly by the total energy taken over time, and a customer charge for recovering costs driven mainly by the number of customers.

[126] For a useful summary of rate designs, with a focus on energy efficiency, *see* Adam Pollock, *Rate Designs to Promote Energy Efficiency* (2010), *available at* http://www.nrri.org/pubs/electricity/NRRI_rate_designs_energy_efficiency_jun_10.pdf.

grid" technologies[127] therefore apply to storage as well. Consider the following pair of examples.

1. *Storage inside transmission constraint: Generation vs. Transmission.* Suppose a storage facility is located inside a transmission constraint and thereby enables the deferral of transmission investment—investment that normally would be paid for by customers of transmission service. A storage facility that is sited and operated so as to enable electricity deliveries to bypass binding transmission constraints by being made off-peak might substitute for transmission expansion. But because it enables peak loads to be met from off-peak generation, it also reduces fuel costs and generation investment costs, thereby reducing costs normally borne by customers of bundled or unbundled generation services. Under cost-based ratemaking, transmission-only customers should not be allocated the same share of the storage facility's costs as customers who take bundled service, unless they receive the same share of its benefits.

2. *Storage inside distribution system: Distribution vs. Transmission vs. Generation.* Suppose that in the above example, the storage facility is located on the load side of both a transmission constraint and a distribution system constraint and enables the deferral of both transmission and distribution investments. In that case, the same questions would arise as in the first example, along with additional questions as to the share of costs properly allocable to the distribution function.

In addition to the above questions regarding the allocation of costs among functions, similar allocation issues will also arise as among generation customers (both retail and wholesale) who pay cost-based rates. Are the costs of a facility that both reduces fixed costs by avoiding investment and reduces losses and fuel costs by reducing peak loadings predominantly demand-related or energy-related? The answer may differ among storage technologies and depend on the specific characteristics of the storage facility at issue. Where the facility is designed for a long discharge, *i.e.*, stores many kWh of energy for each kW of discharge capacity, it is more likely to be appropriately classified as energy-related. As discussed above, storage technologies vary widely in this regard.

Parallel allocation issues will arise as among transmission customers. On an interconnected transmission network, a storage facility may increase the firm transfer capacity of transmission lines, and thus may have "public good" attributes of the kind that are commonly associated with transmission. These benefits, and the reasons for planning a storage facility installation, will not necessarily be confined to only one transmission owner's system.

In addition to inter-functional and intra-functional cost allocation issues, the generic costing issues that apply to any utility investment apply to storage as well. For example, if the rate is designed to provide a return on investment, then the storage provider's cost of capital must be determined—which may be problematic if the facility is built by a new entrant.[128] What

[127] *See* Tom Stanton, *Smart Grid Strategy: How Can State Commission Procedures Produce the Necessary Utility Performance?* (2011), *available at* http://www.nrri.org/pubs/electricity/NRRI_smart_grid_strategy_feb11-05.pdf.

[128] *See, e.g., Western Grid Development*, *supra*.

service life should be assumed in determining storage facilities' depreciation expense? As with any new technology, it will be difficult to project storage facilities' useful life. Assessing the physical durability of a new technology is largely a matter of guesswork. Moreover, the economically useful life of storage facilities does not depend solely on physical durability. It also is affected by energy and capacity price differences as between the times of charging and the times of discharging. Projecting the durability of such price differences is inherently somewhat speculative. Regulatory answers to the useful-life question will affect financing availability and cost.

The ratemaking issues raised by electricity storage also extend beyond the question of quantifying and providing for the recovery of costs associated with storage facilities. Widespread storage deployment would change ratios that existing regulatory treatments assumes are constant. Such changes would need to be taken into account in ratemaking for non-storage services. For example, suppose that in the interval between a ratemaking test period and the period when the associated rate applies, storage located on customers' sides of retail meters increases the system load factor. Further suppose that the increased load factor enables deferral of an investment in generation capacity notwithstanding continued growth in system kWh usage, and thereby reduces system capacity costs per kWh. In that case, a one-part kWh-only rate based on unadjusted test period data would over-recover, because it would assume a stable ratio of capacity costs to units of energy sold, when in fact that ratio would be declining. The same would be true of a multi-part rate in which the kWh rate was designed to include some test-period capacity costs.

D. Jurisdictional issues

The policy questions discussed above (concerning the extent to which the various types of storage services should be regulated) intertwine with the jurisdictional questions of whether any given storage service will be, or should be, subject to regulation by FERC, by state commissions (or other political subdivisions of the states), or not at all.

1. FERC jurisdiction

One aspect of FERC jurisdiction over storage facilities and the transactions they enable is straightforward. When the electric output of a storage facility is sold in interstate commerce for resale, then that sale is a FERC-jurisdictional "sale of electric energy at wholesale."[129] In contrast, where the storage facility's output is owned by or sold to a single end user, the wholesale sales basis for federal jurisdiction would not apply.

The more problematic issue in distinguishing federal from state storage-related jurisdiction concerns jurisdiction over sales of electricity used to charge storage facilities. The leading case addressing this aspect of FERC jurisdiction related to electricity storage is *Norton Energy Storage, L.L.C.*, 95 FERC ¶ 61,476 (2001) ("*Norton*"). In *Norton*, FERC declared that

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[129] Federal Power Act § 201(b)(1), 16 U.S.C. § 824(b)(1). Such jurisdiction does not apply if the owner is exempt from public utility status as a government instrumentality, including a government-financed cooperative.

transactions in which energy is sold to a storage provider for charging the storage facility constitute FERC-jurisdictional wholesale transactions, not state-jurisdictional retail transactions. FERC held that "a pumped storage project is *not a source of new energy*. . . . The Commission views the pumping energy not as being consumed, but rather as being converted and stored."[130]

Norton's jurisdictional rationale is not convincing.[131] The fact that FERC views the pumping energy as being stored rather than consumed does not explain why FERC should hold that view. Moreover, while it is true that in a physical sense the energy that enters and leaves a storage facility is transformed rather than created or consumed, so what? That is equally true of the energy that enters and leaves a conventional generator, and equally true of the energy that enters and leaves a toaster. Physically, the only "source of new energy" is a sub-atomic reaction (celestial, solar, or terrestrial) in which mass is converted to energy. The fact that the "same" energy enters and leaves a storage facility does not distinguish it from any other non-nuclear facility on the path from turbine to toaster.

Norton's jurisdictional rationale is also problematic when applied to a different way to structure the storage arrangements. A storage facility's business can be structured such that a second entity, distinct from the storage facility owner, both provides the charging energy and sells the discharged energy. That is, transactions can be structured such that title to the energy value of stored electricity does not pass to the owner of the storage facility. That is the standard, indeed generally obligatory, transaction structure for natural gas storage: Natural gas stored in depleted reservoirs and the like generally must be and is owned by the shipper.[132]

Although *Norton*'s rationale is both difficult to defend and problematic when extended to other situations, its case-specific result is justifiable and can be squared with the FPA on grounds other than those relied upon in *Norton*. Exclusive FERC jurisdiction over sales of charging energy to storage facilities whose output is sold at wholesale is necessary to effective federal regulation of the subsequent wholesale of discharged energy.[133] State-level economic regulation of such charging energy sales could conflict with federal regulation of the wholesales for which charging energy is a principal input. If state-jurisdictional rates for the charging energy were set inconsistently with and higher than FERC-jurisdictional rates for sales of discharged energy, the storage facility would be forced to buy high and sell low and might be unable to stay in business,

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[130] *Norton* at 62,702 (emphasis in original).

[131] In that respect, it resembles the rate-related rulings in the *Western Grid* and *Nevada Hydro* cases discussed in Part V.B.2 above.

[132] *See, e.g., In re Entergy New Orleans, Inc.*, 122 FERC ¶ 61,219, P5 (2008). ("A central element of the Commission's capacity release program is that all shippers must have title to the gas at the time the gas is tendered to the pipeline or storage facility and while it is being transported or held in storage.")

[133] For simplicity, it is assumed throughout this Part V.D.1 that none of the entities being discussed are exempt from FERC jurisdiction as municipal, federally financed, or other governmental utilities.

even if it were providing real economic value. Conversely, if state-jurisdictional rates for the charging energy were set inconsistent with and lower than FERC-jurisdictional rates for sales of discharged energy, the storage facility could profit by arbitraging that difference, even if it provided no real economic value.

There are two better ways to square *Norton*'s result with the FPA's jurisdictional language.

First, where the storage facility's output is sold at wholesale, the entire storage sequence (charging, holding, and discharging) can reasonably be considered a form of transmission, for jurisdictional purposes. That is the approach followed under the Natural Gas Act as to gas storage.[134] As to electricity, the Commission has long held that "Transmission . . . extends from the generator, where generation is complete, to the point where the function of conveyance in bulk over a distance (the essential characteristic of 'transmission') is completed and the process of subdividing the energy to serve ultimate consumers (the characteristic of 'local distribution') is begun."[135] Thus, in the Commission's longstanding jurisdictional analysis, the "category of transmission facilities" includes "devices used for metering and controlling the flow of bulk energy" and "devices which are necessary to keep the parts of the interconnected system or systems 'in tune.'"[136]

Storage facilities can fit under this rubric. They control the flow of bulk energy and keep generation and distribution "in tune," *i.e.*, in temporal alignment. Where a storage facility sells its output at wholesale, the storage does not begin the process of subdividing energy to serve ultimate consumers; rather, they fall within FERC's view that "any facilities of a public utility used to deliver electric energy in interstate commerce to a wholesale purchaser . . . are subject to the Commission's jurisdiction under sections 205 and 206."[137] Moreover, the charging energy

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[134] *See, e.g., Marathon Oil Co.*, Opinion No. 735, 53 F.P.C. 2164, 2173 (1975) (facility for liquefying Alaskan natural gas to prepare it for shipment by boat to Oregon was "an integral part of the interstate flow of this gas," like "a jurisdictional compressor station").

[135] *Conn. Light & Power Co.,* 3 F.P.C. 132, 142 (1942) (footnote omitted) ("*CL&P*"), *aff'd sub nom. Conn. Light & Power Co. v. Federal Power Comm'n*, 141 F.2d 14 (D.C. Cir. 1944), *rev'd in part*, 324 U.S. 515, 533 (1945). The Supreme Court reversed and remanded for further consideration the Commission's determination that the dividing line between transmission and distribution fell on the load side of CL&P's step-down transformer. It did not, however, disturb the Commission's holding that transmission extends from the generator to the point, wherever it may be located, at which distribution begins. The Supreme Court later expressly adopted that holding. *United States v. Pub. Utils. Comm'n*, 345 U.S. 295, 316 (1953).

[136] *CL&P* at 142.

[137] *Promoting Wholesale Competition Through Open Access Non-discriminatory Transmission Services by Public Utilities; Recovery of Stranded Costs by Public Utilities and Transmitting Utilities*, 60 Fed. Reg. 17,662, 17,717 (proposed Apr. 7, 1995), FERC Stats. & Regs. ¶ 32,514, at 33,144 (proposed 1995).

conversion from electricity to another form is not performed for any reason other than to enable the subsequent production of electricity from the same energy. Accordingly, as explained in the introduction above, the entire sequence serves only to connect generation to subsequent load. It does so not over measurable periods of time but nearly instantaneously, but no reference to the speed of light appears in the FPA's jurisdictional provisions.

Under this construct, the terms on which energy is sold to the storage facility for charging amount in substance to a portion of the terms through which the storage facility charges for its transmission service, much as "buy-sell" transactions have been held to constitute a bundling of FERC-jurisdictional transmission service.[138] Note, however, that this construct assumes the storage facility is located on the "transmission" rather than "distribution" portion of the overall system. If a storage facility dedicated to the end user(s) to which it sells output is located on the same distribution system as the end user(s), as is envisioned for Community Energy Storage Systems and the like, then the delivery of energy through the storage facility would likely be considered to be distribution, not transmission.[139]

Second, the storage facility can reasonably be considered as one that enables the primary generator to sell at wholesale, either directly or through intermediaries, to the load-serving entities (retail sellers) who receive the energy discharged from the storage facility. Under this construct, the storage facility is a facility for jurisdictional wholesales. On that view, where the charging energy is sold to the storage facility owner, those sales constitute sales from one FERC-jurisdictional public utility to another, for eventual resale rather than consumption, and thus constitute jurisdictional wholesales.

Founding FERC jurisdiction over deliveries to storage facilities on either of the bases articulated above rather than that articulated in *Norton* is not a purely academic matter. One can conceive of arrangements under which the presence or absence of federal jurisdiction would turn on the difference. For example, suppose a storage facility is installed right where a high-voltage transmission line is tapped to feed a load center (*e.g.*, in order to provide backup for an industrial park in case the line trips out of service). Under *Norton*, federal jurisdiction over transfers of

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[138] *See Promoting Wholesale Competition Through Open Access Non-Discriminatory Transmission Services by Public Utilities; Recovery of Stranded Costs by Public Utilities and Transmitting Utilities*, Order No. 888, 61 Fed. Reg. 21,539, 21,620 & n.519 (May 10, 1996), FERC Stats. & Regs. ¶ 31,036, at 31,771 & n.519 (1996) ("Order 888"), *clarified*, 76 FERC ¶ 61,009 (1996), *modified*, Order No. 888-A, 62 Fed. Reg. 12,274 (Mar. 14, 1997), FERC Stats. & Regs. ¶ 31,048 (1997), *order on reh'g*, Order No. 888-B, 62 Fed. Reg. 64,688 (Dec. 9, 1997), 81 FERC ¶ 61,248 (1997), *order on reh'g*, Order No. 888-C, 82 FERC ¶ 61,046 (1998), *aff'd in part and remanded in part sub nom. Transmission Access Policy Study Group v. FERC*, 225 F.3d 667 (D.C. Cir. 2000), *aff'd sub nom. New York v. FERC*, 535 U.S. 1 (2002).

[139] *See generally Revision to Electric Reliability Organization Definition of Bulk Electric System*, Order No. 743-A, 134 FERC ¶ 61,210 (Mar. 17, 2011) (Docket No. RM09-18) (describing difference between distribution and transmission and re-affirming a NERC reliability registry process to delineate facilities constituting transmission); *Duke Power Company v. FPC*, 401 F.2d 930, 950-51 (D.C. Cir. 1968) (distribution facilities are not FERC-jurisdictional).

charging energy might be avoided by billing retail consumers in that load center for charging energy, deeming the energy held in the storage facility to be their common property, and not billing them for energy purchases when the line trips and the stored energy is discharged and delivered. If the *Norton* jurisdictional analysis were applied to such a scenario, the transactions through which they purchase charging energy would not appear to be FERC-jurisdictional wholesales, because there is no downstream resale. But if jurisdiction over deliveries to storage facilities is founded instead on the conclusion that storage represents a stage of transmission, then deliveries to this storage facility would appear to fall under FERC's transmission jurisdiction, which extends to retail transmission.[140] And if jurisdiction over sales to storage facilities is founded on the conclusion that such sales are sales for resale, then FERC's jurisdiction over wholesale sales would obviously attach.

The broader point here is that jurisdictional delineations based on whether electricity is resold are susceptible to being avoided in the context of storage, by structuring transactions to mask their economic substance. Jurisdiction based on either of the above bases would avoid such gaming.

To be clear, characterization of storage as transmission for jurisdictional purposes does not imply that its costs should be recovered from all transmission customers through cost-of-service regulated rates. Some jurisdictional transmission facilities serve only a subset of customers and are appropriately either allocated to a subset of transmission customers or left for recovery under market-based generator sales prices. *Compare, e.g.*, *Utah Power & Light Co. v. Pfost*, 286 U.S. 165, 181 (1932) (in a constitutional sense, transmission in interstate commerce, *i.e.*, "the process of transferring, as distinguished from that of producing" begins "at the generator") *and CL&P* at 142-43 (following *Pfost*, federal jurisdiction over transmission in interstate commerce includes generator step-up transformers, which "are used to make the transmission of electric energy in bulk over a distance commercially feasible") *with Kentucky Utils. Co.*, 85 FERC ¶ 61,274, at 62,111 (1998) (for ratemaking functionalization purposes, generator step-up transformers are part of the generator).

2. State jurisdiction

State commission jurisdiction is difficult to address generically, because state regulatory statutes are not uniform. However, they generally provide that entities, and their electric-industry activities, are subject to state commission regulation as "public utilities" if they furnish electricity to the public. For example, consider the statutory definitions of "public utility" status as enacted by California, Georgia, and Wisconsin, three of the earliest[141] states to regulate public

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[140] *See New York v. FERC*, 535 U.S. 1 (2002).

[141] *See* Werner Troesken, "Regime Change and Corruption. A History of Public Utility Regulation," published as chapter in National Bureau of Economic Research, *Corruption and Reform: Lessons from America's Economic History* 259 (Edward L. Glaeser and Claudia Goldin eds. 2006) (*available at* http://www.nber.org/chapters/c9986). Massachusetts legislated even earlier, *id.*, but its electricity-related statutory provisions were so thoroughly revised by that state's 1997 restructuring legislation that its currently effective statute is not representative of

utilities at the state rather than local level. California defines "public utility" to include every "electrical corporation . . . where the service is performed for, or the commodity is delivered to, the public or any portion thereof."[142] Similarly, Georgia has empowered its state regulatory commission to regulate "gas and electric light and power companies, or persons owning, leasing, or operating public gas plants or electric light and power plants furnishing service to the public."[143] And Wisconsin reaches any non-exempt "corporation, company, individual [*etc.*] that may own, operate, manage or control . . . all or any part of a plant or equipment, within the state, for the production, transmission, delivery or furnishing of heat, light, water or power either directly or indirectly to or for the public."[144] Such formulations of state commission jurisdiction indicate that a business holding itself out as offering to store electricity for the public broadly would thereby become subject to state regulation as a public utility,[145] whereas an entity that stores electricity for only a small, geographically defined set of local customers (*e.g.*, an apartment owner storing electricity for its tenants) would not.

In any event, retail commission jurisdiction is likely to attach to at least one link in the chain of transactions that occur before grid-connected electricity is consumed for an ultimate use. Because courts and legislatures will want to ensure that an opportunity exists for state commissions to apply their expertise and protect the public interest, they will likely resist arrangements in which power would be deemed to make it all the way from the wholesale market to final consumption without passing through a stage at which state commission jurisdiction can attach. General FERC policy is in accord.[146] Accordingly, if a storage provider is not viewed as a public utility, then sales to it of electricity for charging are likely to be deemed a retail sale by a public utility to an ultimate consumer and subject as such to applicable state commission regulation.

Several recent state developments regarding plug-in vehicle charging also bear noting, although the subject they address falls outside the definition of "storage" adopted for this paper in Part II above. The California Public Utilities Commission ("CPUC") has held that plug-in vehicle charging service is not public utility service, and that entities offering that service are not thereby subject to utility commission regulation.[147] The CPUC reasoned that recent state

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other states. *See* 1997 Mass. Acts ch. 164, *available at* http://www.malegislature.gov/Laws/SessionLaws/Acts/1997/Chapter164.

[142] Cal. Pub. Utils. Act § 216(a).

[143] Ga. Code. § 46-2-21(b)(5).

[144] Wis. Stat § 196.01(5)(a).

[145] For example, even if the storage service provider is storing energy owned by others, its facility would furnish to the public the services of holding that energy and changing its form.

[146] Order No. 888, 61 Fed. Reg. at 21,650-21,651.

[147] *See* Decision In Phase 1 On Whether A Corporation Or Person That Sells Electric Vehicle Charging Services To The Public Is A Public Utility, Rulemaking No. 09-08-009 (Cal.

legislation giving it certain narrow powers to encourage plug-in vehicles implied that the legislature did not intend that its pre-existing, general powers over public utilities reach vehicle charging.[148] The Illinois and Maryland commissions have initiated investigations into the same subject.[149] Legislation that recently cleared the Washington State Senate addresses the same issue and would prohibit the Washington Utilities and Transportation Commission from regulating entities that provide such service and are not otherwise electric utilities.[150]

E. Miscellaneous other regulatory issues

The preceding discussion centers on economic regulation, traditionally the core of regulatory commission concerns. However, that is not to imply that any storage enterprise would or should be exempt from other relevant regulations. Without attempting to catalog all such generally applicable regulation, the following lists several that will likely be particularly relevant to the storage industry.

- Environmental issues, especially as to recycling and disposal of heavy metals used in batteries.

- Consumer protection and safety issues related to residential and other distributed storage. Much as with home installations of HVAC equipment or renewable energy generators and "net metering" systems, concerns will arise related to building code compliance; fair business practices; and training, credentialing, and bonding of workers who enter consumers' homes.

Pub. Util. Comm'n 2010), *available at* http://docs.cpuc.ca.gov/word_pdf/AGENDA_DECISION/121242.pdf.

148 This CPUC decision also illustrates the point made above, that sales to non-utility storage providers are likely to be viewed as retail sales. Upon holding that vehicle charging stations do not become public utilities by selling electricity to vehicle owners, the CPUC also held that "The sale of electricity by an investor-owned utility to an electric vehicle charging service provider is a retail electricity transaction." *Id.* at 26.

149 *See Initiative on Plug-In Electric Vehicles*, Illinois Commerce Commission, http://www.icc.illinois.gov/electricity/pev.aspx (last visited June 8, 2011); In the Matter of the Investigation into the Regulatory Treatment of Providers of Electric Vehicle Charging Stations and Related Services, Maryland Pub. Serv. Comm'n, Case No. 9261.

150 *See* Washington Senate Bill Report on SHB 1571 (Mar. 2011), *available at* http://apps.leg.wa.gov/documents/billdocs/2011-12/Pdf/Bill%20Reports/Senate/1571-S%20SBA%20EWE%2011.pdf.

- Privacy issues related to individual residential and business consumers' electricity time of use, much as arise in connection with "smart meters."[151]

- Technical qualification, *e.g.*, through NERC registration and compliance, to interconnect electrical equipment that interacts with the grid and may thereby affect reliability.

[151] *See, e.g.*, Sherry Lichtenberg, NRRI No. 10-17, *Smart Grid Data: Must There Be Conflict Between Energy Management and Consumer Privacy?* (2010), *available at* http://www.nrri.org/pubs/telecommunications/NRRI_smart_grid_privacy_dec10-17.pdf.

VI. Next Steps for Regulators and Practitioners

This part identifies issues for further research and provides a template for initiating a state commission investigation. It serves as the conclusion for a reason: In our dynamic society, the work of adapting regulation to emerging technologies does not end.

A. Issues for further research

The preceding discussion suggests several areas in which more work will be needed to identify effective regulatory strategies as storage technologies continue to be developed and become more widely deployed. This section will highlight a few of these issues.

One, what storage technologies best serve what functions? This is the main issue both for those seeking to develop and deploy these technologies and for regulators seeking to review deployment decisions and address the resulting rate issues.

Two, what investments slated to be made in the near term may prove to be wasteful if the promise of storage technologies is realized? U.S. utilities and regulators have already been through cancelled nuclear investment, take-or-pay gas buyouts, and electricity stranded cost cases, and it would be well to avoid a repeat performance. On the other hand, putting off investment because a speculative alternative may pan out is a recipe for paralysis. More consideration of how to steer between these extremes would be worthwhile.[152]

Three, are there any unjustified barriers to entry[153] into self-provision of storage facilities or services by (a) intermittent generators seeking to firm up their power offerings or (b) individual retail consumers or their non-utility contractors? For example, are standard transmission service terms and conditions reasonable when applied to a wind farm owner seeking to send its output to a storage facility at a location remote from the wind farm? Do they unreasonably require that both the wind farm owner and the storage facility owner pay for transmission access to deliver energy injections that ultimately serve only one load-serving

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[152] For a detailed discussions of "pre-approval" of major capital investments, *see* Scott Hempling & Scott Strauss, NRRI No. 08-12, *Pre-Approval Commitments: When And Under What Conditions Should Regulators Commit Ratepayer Dollars to Utility-Proposed Capital Projects?* (2008), *available at* http://nrri.org/pubs/electricity/nrri_preapproval_commitments_08-12.pdf.

[153] *See generally* Harold Demsetz, *Barriers to Entry*, 72 Am. Econ. Rev. 47 (1982), *available at* http://hubcap.clemson.edu/~sauerr/classes/899/readings/demsetz_barriers.pdf (describing economic limitations commonly viewed as barriers to entry, and explaining that distinguishing between barriers to entry and legitimate components of ownership involves making subjective value judgments).

entity? Or is this concern addressed by the coincident monthly peak billing determinants for network integration transmission service?[154]

Four, to what extent can storage service markets be made workably competitive, such that competition among providers of a given type of storage and between such storage and its substitutes be relied upon to keep storage prices in line with cost? Do the economically viable storage technologies have siting, intellectual property, or other inputs that are controlled by a small number of firms? Are available non-storage technologies economically substitutable for storage?

Five, are there scope economies that make ownership of storage facilities by distribution or transmission system owners a sensible extension of existing natural monopolies? How substantial are those scope economies, and do they warrant application of a cost-of-service rather than competitive pricing regime?

B. Template for state commission investigation of storage issues

Regulators can either take a proactive approach to the issues raised by emerging storage technologies or wait for interested utilities to take the initiative. Given the complexity of storage issues and the potential for incumbent utilities to under-invest in storage in order to protect their existing peaking-oriented investments, regulators would be well-advised to be proactive.

Commissions seeking to understand how emerging technologies will affect the industries they regulate and guide the deployment and regulation of such technologies in the public interest commonly initiate an investigation, notice of inquiry, advanced rulemaking, or the like. In order to assist state commission seeking to begin such an initiative with respect to storage, this paper concludes with *pro forma* questions that state commissions could pose. In these questions, "you" refers to relevant regulated entities, although other stakeholders (including comparable entities not necessarily regulated by state commissions, such as public power systems) presumably would be invited to respond as well.

1. **Load data:** What information do you collect regarding system-wide and location-specific time-stamped consumption? How fine-grained is this information (*e.g.*, hourly, by dispatch interval of *n* minutes)? For how long is this information retained? If it is retained for less than ten years, how much would it cost to retain all such data for ten years? (This information will further the identification and valuation of opportunities for storage to reduce system costs.)

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[154] One question raised here is whether (a) power transfers from a wind farm to a storage facility that holds its energy but is located elsewhere on the same transmission system, and (b) power transfers from that storage facility to load will each bear base transmission access charges. The typical billing determinant for the basic "access" charge for network integration transmission service is network service load coincident with the monthly transmission system peak (often applied as the 12-month rolling average of such monthly peaks). If that billing determinant applies, then such doubled transmission access charges should be avoidable, because the storage resource will not both charge and discharge simultaneously; presumably, at the times coincident with monthly peaks, it will only discharge.

2. **Generator data:** Same questions as above with regard to generator dispatch. (Again, this information will further the identification and valuation of opportunities for storage to reduce system costs.)

3. **Existing storage facilities:** What storage facilities do you currently own and/or operate? What are their technical characteristics in terms of energy, capacity, charging and discharging responsiveness, round-trip energy efficiency and energy losses, *etc.*? What is the estimated current annual cost of owning and operating each such facility? If this cost is recovered (explicitly or implicitly) through rates, how is it cost recovered? How is each of these facilities used? Both qualitatively and quantitatively, what costs are avoided through such operation in a representative year? (This information will provide a baseline for studying the value to consumers of storage facilities and for considering whether the cost recovery regime currently applied to them remains appropriate.)

4. **Planned storage facilities:** Same questions as above, on a projected basis, with respect to any planned storage facilities. In addition, what is the anticipated in-service date for each facility, and what are the major contingencies, if any, that might affect that timing? (This information goes to the consumer value of future storage facilities, supervision of utility system planning, and the appropriate cost recovery regime.)

5. **System planning context:** Are there any non-storage facilities that you have planned for construction within the next ten years, and which might be rendered unnecessary if storage facilities become economic substitutes? Conversely, are there any non-storage investments that you evaluated making but are not planning to make because you are anticipating that storage will make them unnecessary? (This question serves the same general purpose as the prior one.)

6. **Marginal value of storage:** If, hypothetically, you were given a battery that could hold indefinitely a MWh quantity equivalent to your system's average hourly energy sales, discharge it instantaneously, be fully recharged 24 hours later, and be sited anywhere, where would you site it, and what would be your policy for discharging it? What kinds of costs, and in what estimated amount, would such a battery enable you to avoid? (This question serves the same general purpose as the prior two, and is one way to begin identifying foregone opportunities for worthwhile storage investments.)

7. **Consumer-owned storage:** Do you have information regarding ownership of Uninterruptible Power Supply or like facilities by your retail customers? If so, please provide that information or a summary thereof. If not, provide a cost estimate for conducting a survey of such ownership through a billing insert questionnaire or the like. (This question enables utility-owned storage facilities to be considered in the context of other storage facilities that affect system planning and economics.)

8. **Regulatory policies:** Do any commission policies and/or statutory restrictions inhibit investment in storage facilities that would provide net benefits to consumers? What changes to the Commission's storage-related policies would you recommend? (This question provides an open-ended invitation for stakeholders to raise storage-related issues of concern to them.)