Grid Applications for Energy Storage

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Referencing a Recent Sandia Study,* This Talk Will:

Describe and illustrate selected grid applications for energy storage

- Time-of-use energy cost management
- Demand charge management
- Load following
- Area Regulation
- Renewables energy time shift
- Renewables capacity firming

Compare Sandia's estimates of the economic value of these applications to the Electricity Storage Association's estimates of the capital costs of energy storage technologies

*Eyer, J. and G. Corey. *Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide.* February 2010. SAND2010-0815

A Recent Sandia Study Estimates the Economic Value of 17 Grid Applications for Energy Storage

#	Benefit Type	Discharge Duration*		Capacity (Power: kW, MW)		Benefit ($/kW)**		Potential (MW, 10 Years)		Economy ($Million)†	
		Low	High	Low	High	Low	High	CA	U.S.	CA	U.S.
1	Electric Energy Time-shift	2	8	1 MW	500 MW	400	700	1,445	18,417	795	10,129
2	Electric Supply Capacity	4	6	1 MW	500 MW	359	710	1,445	18,417	772	9,838
3	Load Following	2	4	1 MW	500 MW	600	1,000	2,889	36,834	2,312	29,467
4	Area Regulation	15 min.	30 min.	1 MW	40 MW	785	2,010	80	1,012	112	1,415
5	Electric Supply Reserve Capacity	1	2	1 MW	500 MW	57	225	636	5,986	90	844
6	Voltage Support	15 min.	1	1 MW	10 MW	400		722	9,209	433	5,525
7	Transmission Support	2 sec.	5 sec.	10 MW	100 MW	192		1,084	13,813	208	2,646
8	Transmission Congestion Relief	3	6	1 MW	100 MW	31	141	2,889	36,834	248	3,168
9.1	T&D Upgrade Deferral 50th percentile††	3	6	250 kW	5 MW	481	687	386	4,986	226	2,912
9.2	T&D Upgrade Deferral 90th percentile††	3	6	250 kW	2 MW	759	1,079	77	997	71	916
10	Substation On-site Power	8	16	1.5 kW	5 kW	1,800	3,000	20	250	47	600
11	Time-of-use Energy Cost Management	4	6	1 kW	1 MW	1,226		5,038	64,228	6,177	78,743
12	Demand Charge Management	5	11	50 kW	10 MW	582		2,519	32,111	1,466	18,695
13	Electric Service Reliability	5 min.	1	0.2 kW	10 MW	359	978	722	9,209	483	6,154
14	Electric Service Power Quality	10 sec.	1 min.	0.2 kW	10 MW	359	978	722	9,209	483	6,154
15	Renewables Energy Time-shift	3	5	1 kW	500 MW	233	389	2,889	36,834	899	11,455
16	Renewables Capacity Firming	2	4	1 kW	500 MW	709	915	2,889	36,834	2,346	29,909
17.1	Wind Generation Grid Integration, Short Duration	10 sec.	15 min.	0.2 kW	500 MW	500	1,000	181	2,302	135	1,727
17.2	Wind Generation Grid Integration, Long Duration	1	6	0.2 kW	500 MW	100	782	1,445	18,417	637	8,122

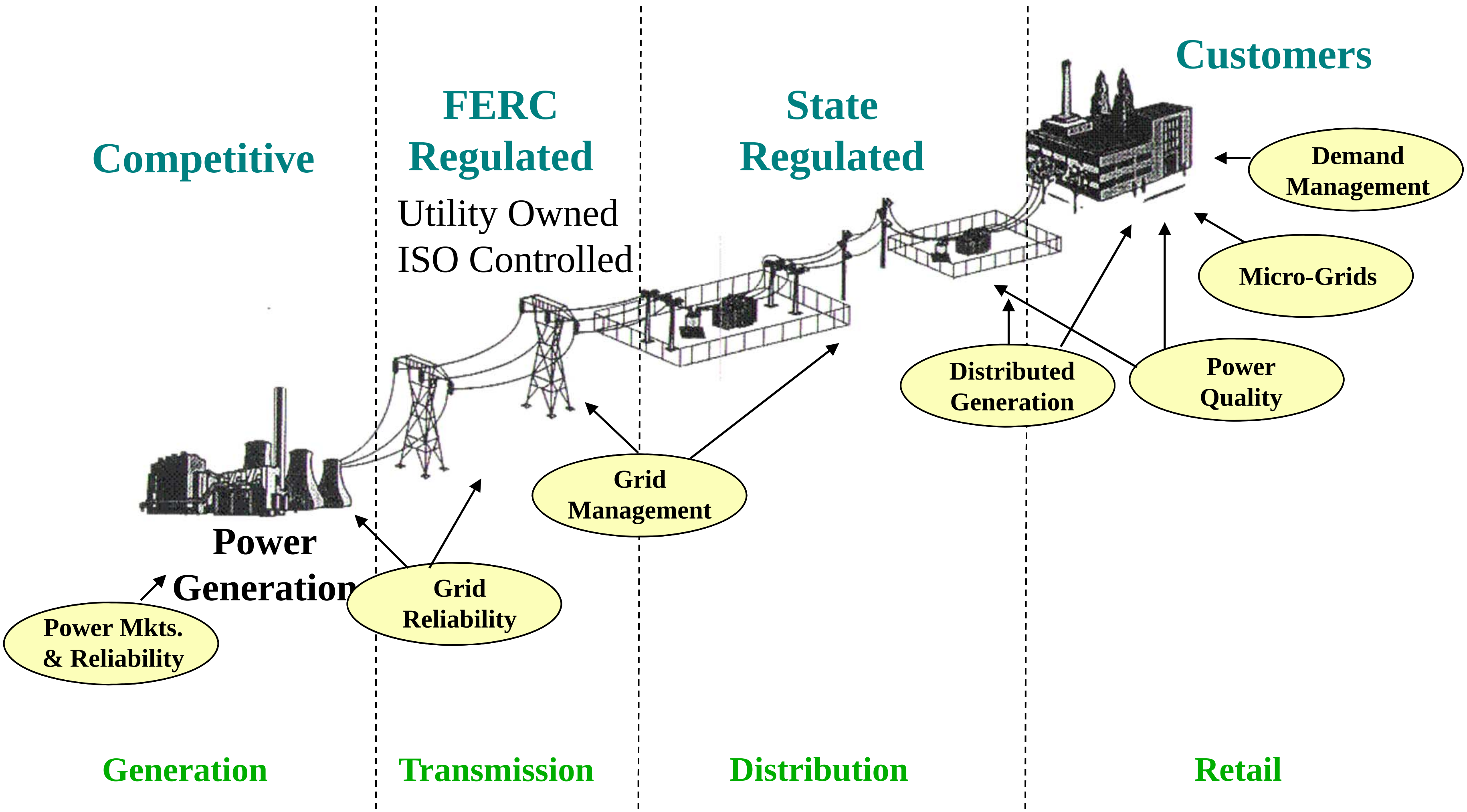
*Hours unless indicated otherwise. min. = minutes. sec. = seconds.

**Lifecycle, 10 years, 2.5% escalation, 10.0% discount rate.

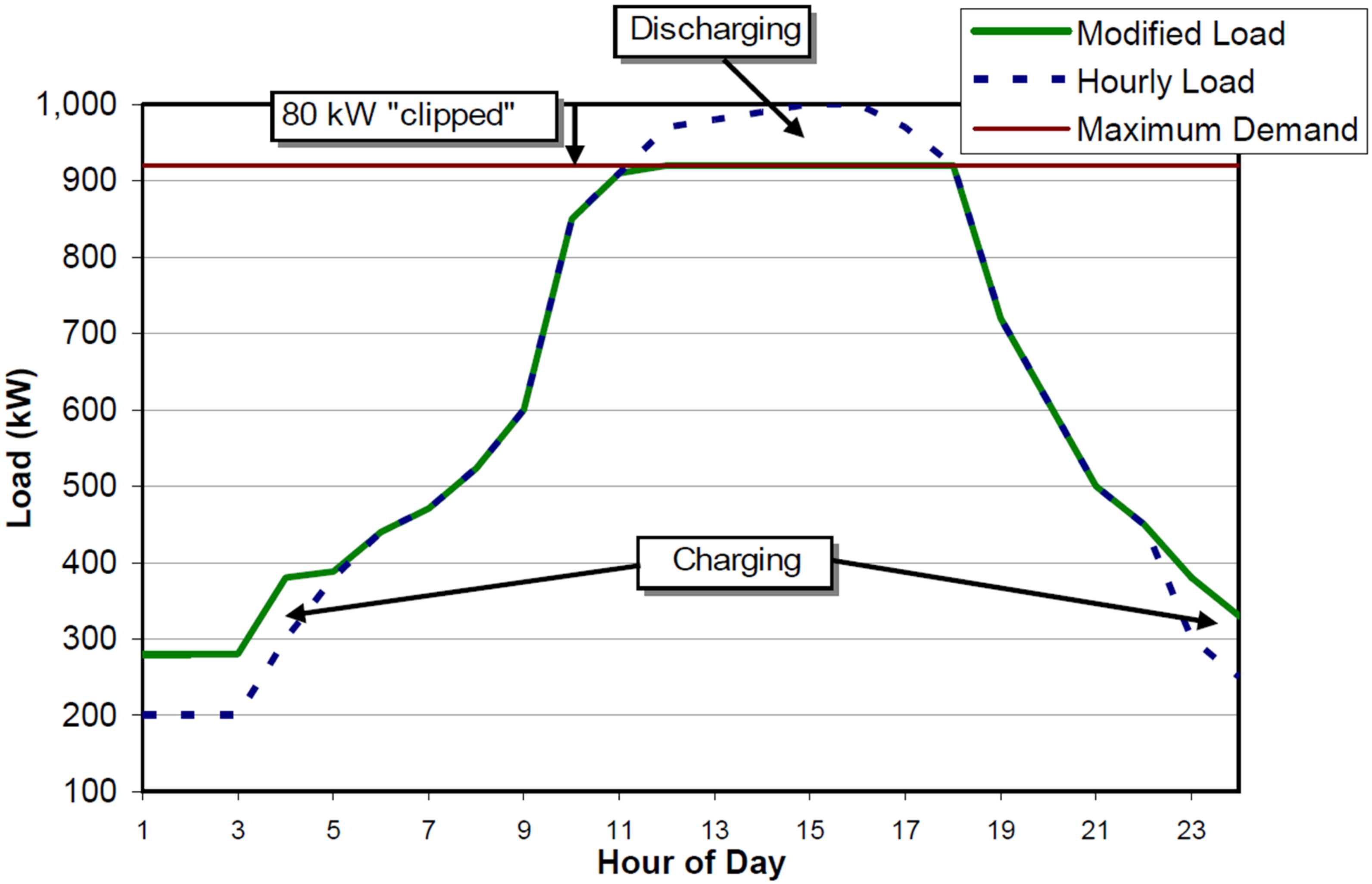
†Based on potential (MW, 10 years) times average of low and high benefit ($/kW).

†† Benefit for *one year*. However, storage could be used at more than one location at different times for similar benefits.

Competitive Electric Market Structure

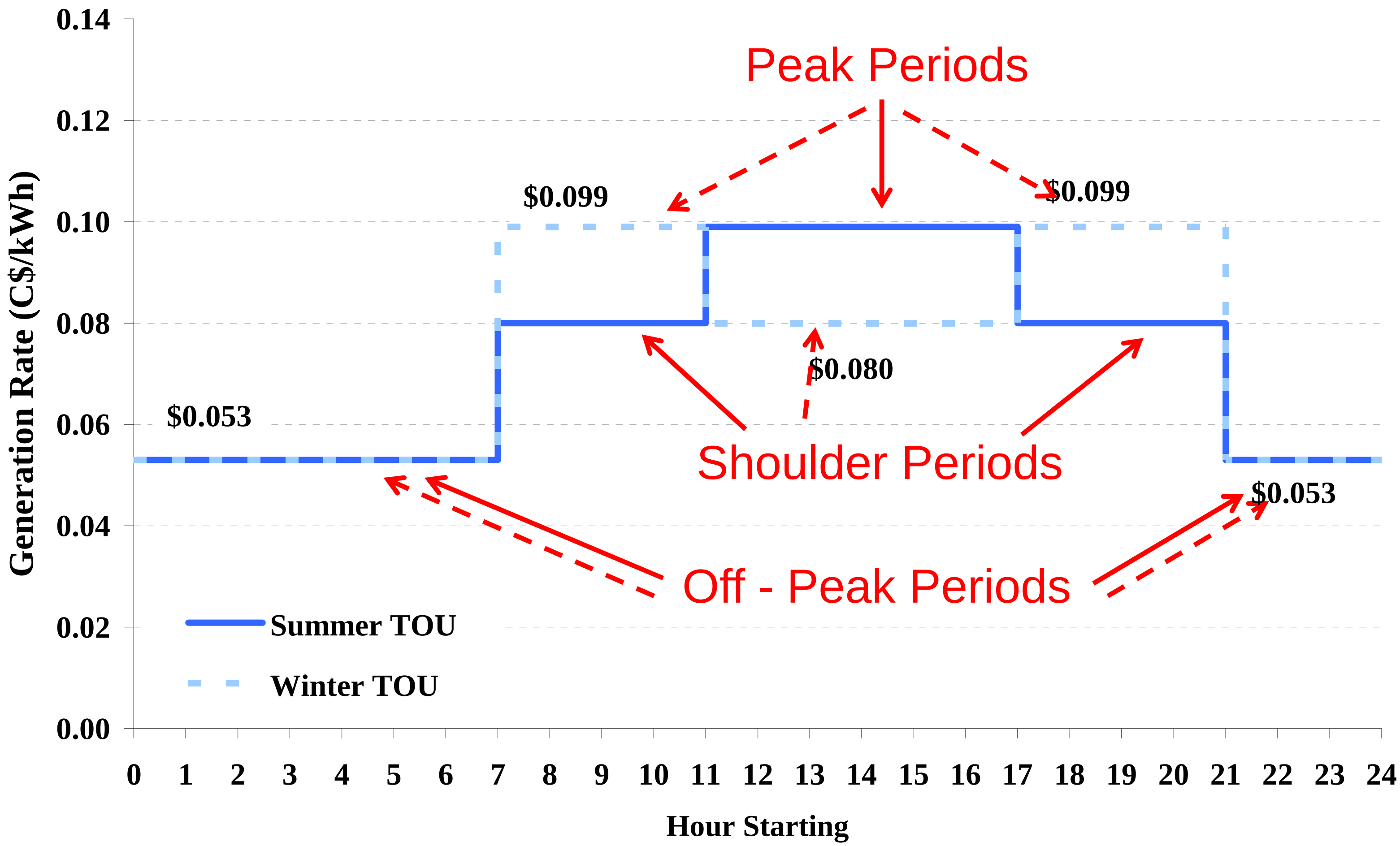


TOU Energy Cost Management and *Demand Charge Management* are Both Forms of Energy Arbitrage



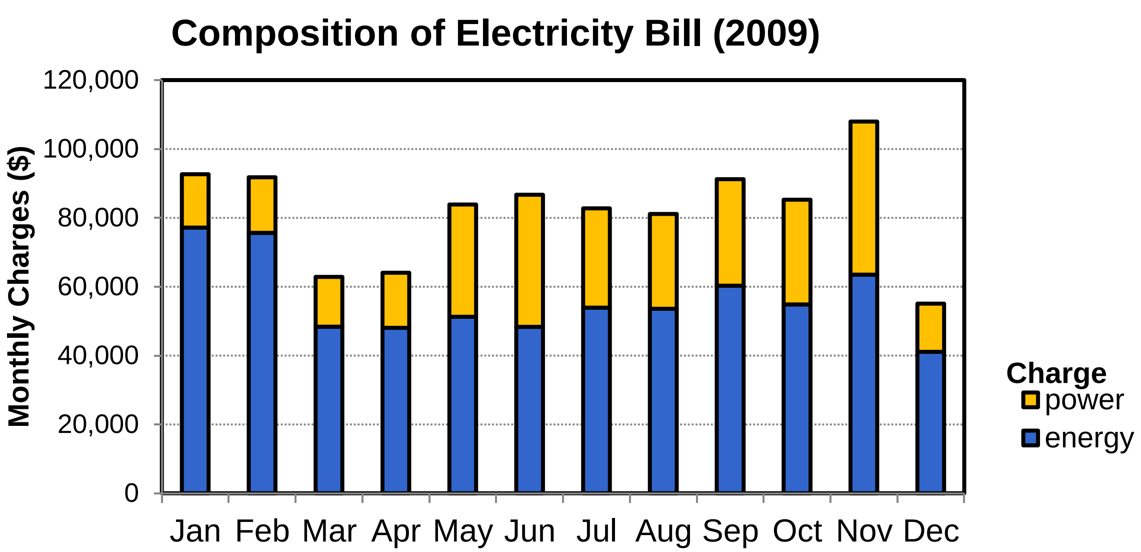
Source: Eyer, J., and R. Brown. Guide to Estimating Benefits and Market Potential for Electricity Storage in New York (with an Emphasis on New York City). NYSERDA. Final report 07-06. March 2007

Anatomy of a Time of Use Rate

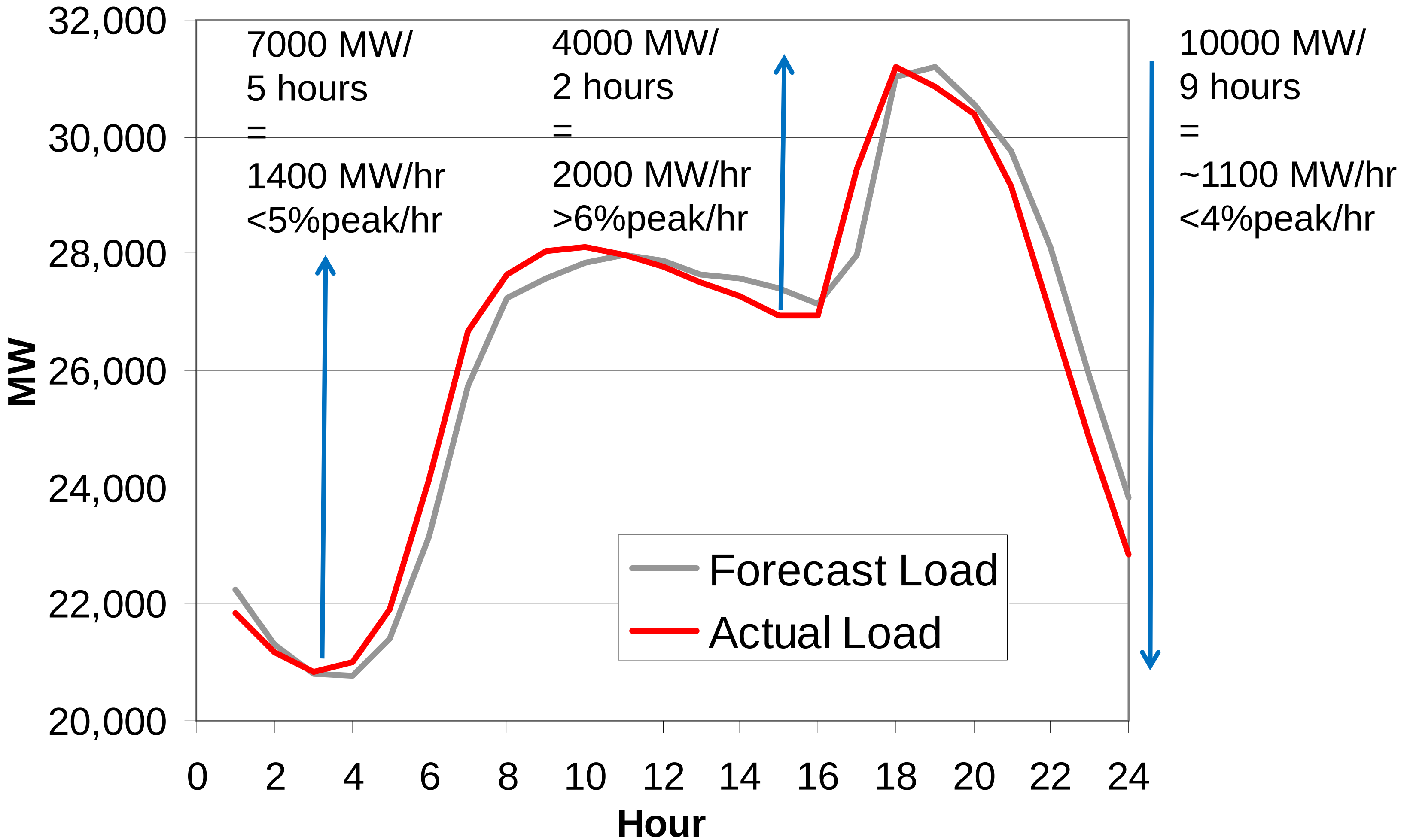


Pacific Gas & Electric E-20 TOU Tariff

Charge Type		power	energy	Duration
Summer	Max Peak	$11.04	$0.14040	12:00-18:00, M-F
	Part-Peak	$2.59	$0.09807	8:30-12:00, 18:00-21:30, M-F
	Off-Peak	-	$0.07992	21:30-8:30, M-F; Weekends
	Maximum	$7.45	-	
Winter	Part-Peak	$0.82	$0.08585	8:30-21:30, M-F
	Off-Peak	-	$0.07664	21:30-8:30, M-F; Weekends
	Maximum	$7.45	-	
		[$/kW]	[$/kWh]	

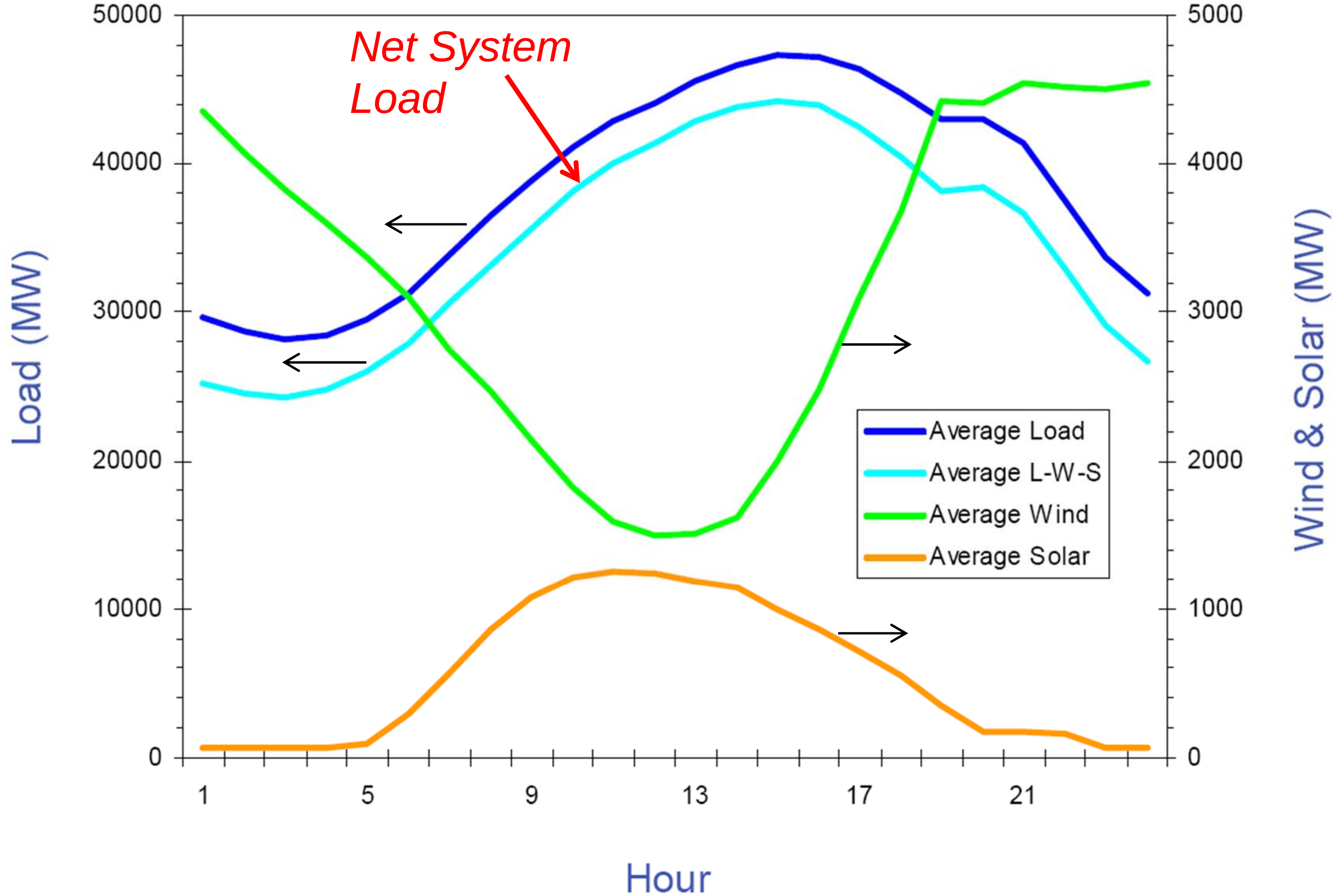


Typical December Load Following Requirements for CAISO



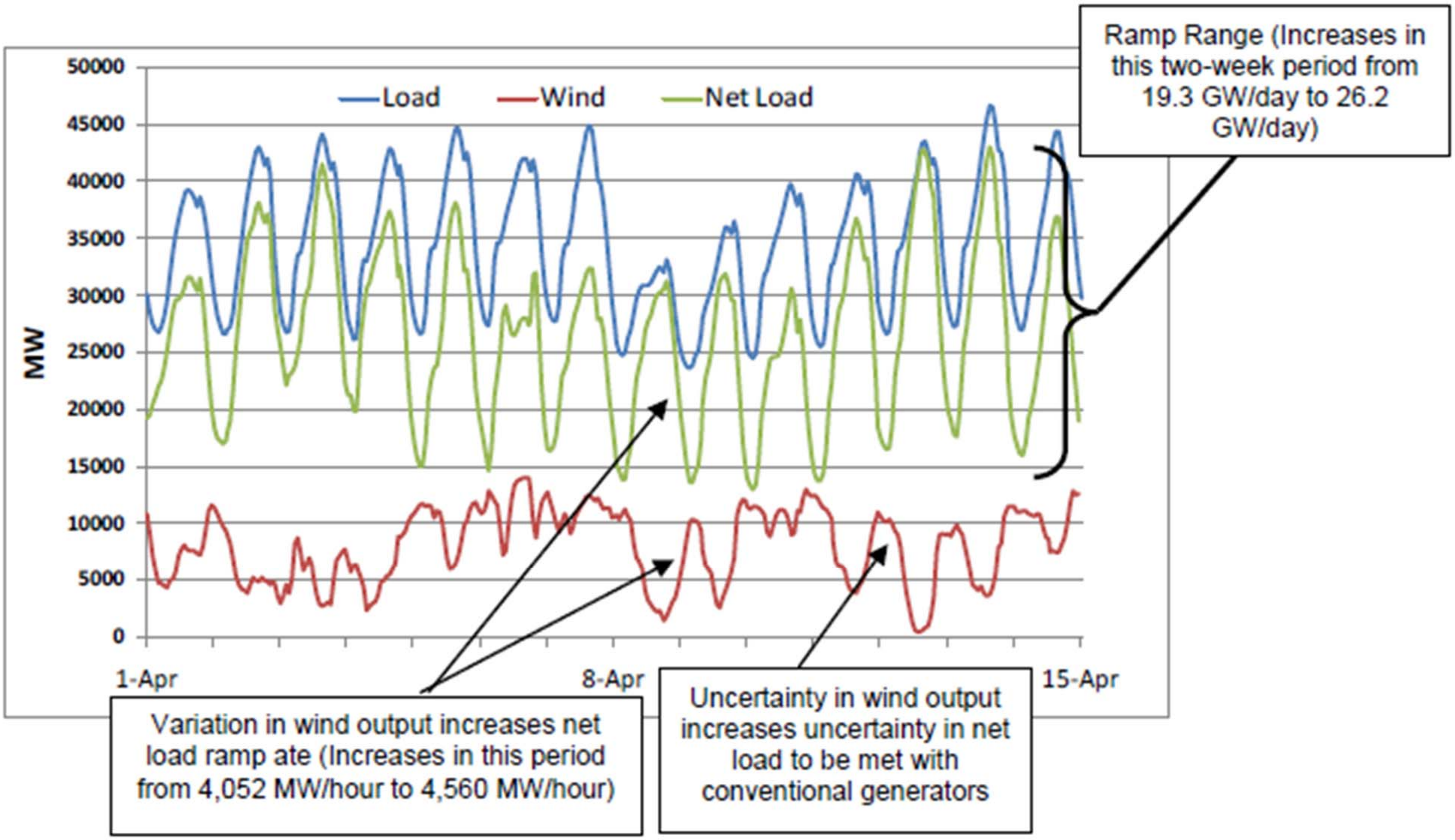
Source: Undrill, J. *Power and Frequency Control as it Relates to Wind Generation.* Lawrence Berkeley National Laboratory. December 2010. LBNL-4143E.

Net System Load is the Residual Load that is Left After Subtracting Variable Renewable Generation



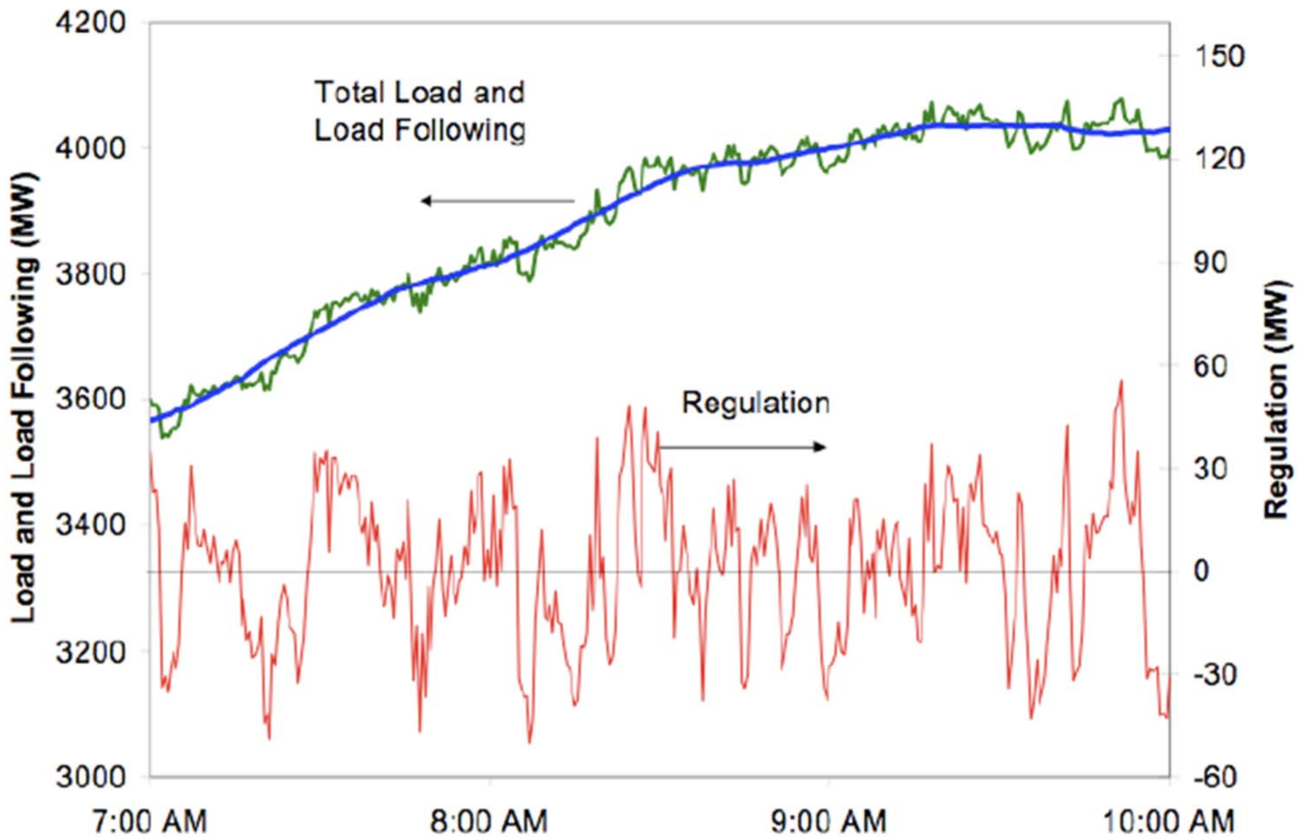
Source: NERC. *Special Report: Accommodating High Levels of Variable Generation.* http://www.nerc.com/files/IVGTF_Report_041609.pdf 2009

Increased Variable Renewable Generation will Increase Load Following Requirements



Source: Denholm, P., E. Ela, B. Kirby, and M. Milligan. *The Role of Energy Storage with Renewable Electricity Generation*. National Renewable Energy Laboratory. Jan. 2010. NREL/TP-6A2-47187.

Load Following vs. Regulation



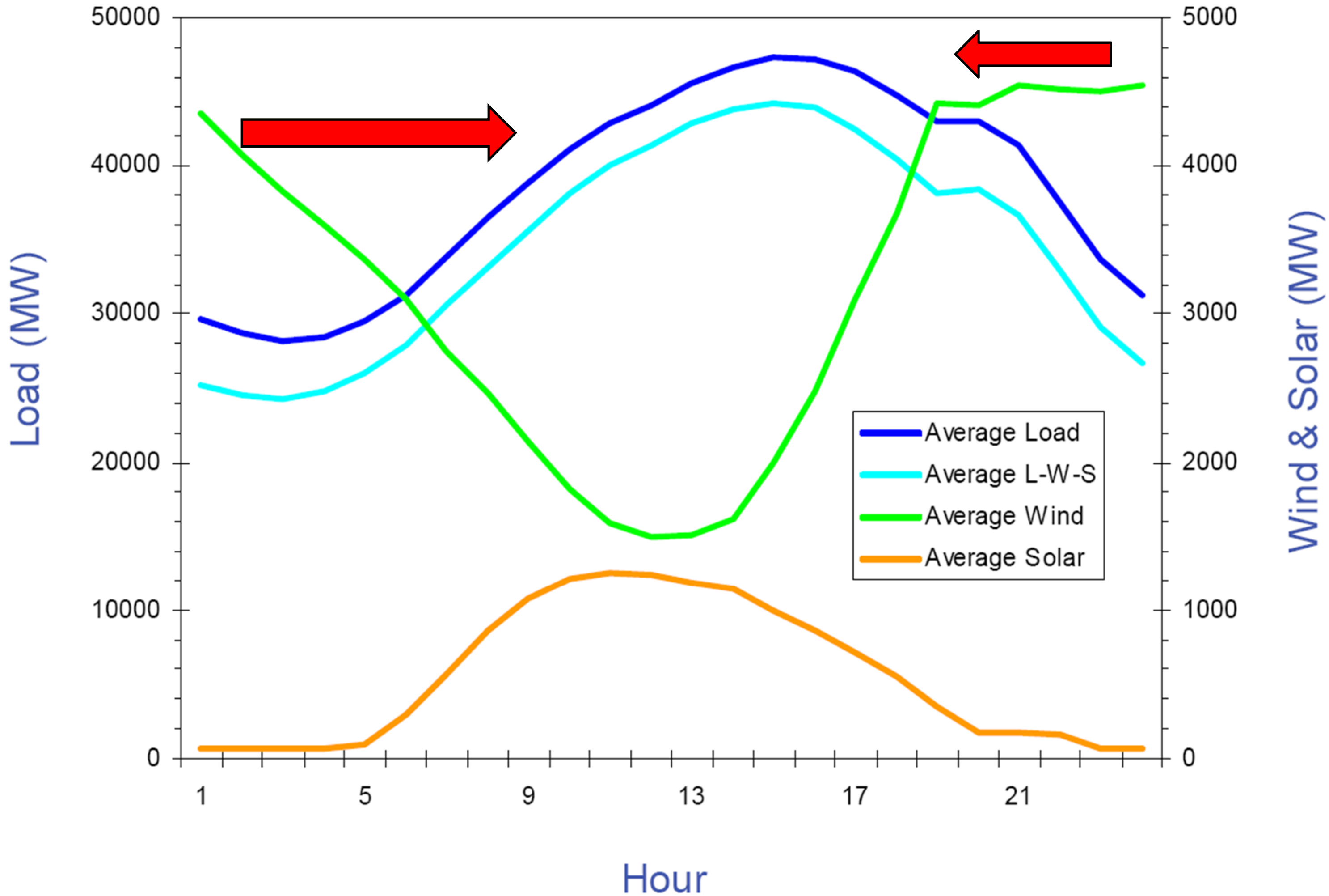
Source: Kirby, B. *Frequency Regulation Basics and Trends*. Oak Ridge National Laboratory, December 2004, ORNL/TM 2004/291.

Increased Variable Renewable Generation is Expected to Increase Requirements for Load Following and Regulation

Area	Wind in Base Scenario (MW)	Highest Wind Scenario Studied (MW)	Regulation	Load Following
			Change in Requirements (%)	Change in Requirements (%)
NYISO (GE 2005)	0	3,300	95%	6%
(EnerNex 2006)	1,049	5,688	15%	5%
Avista (EnerNex 2007)	0	600	Not studied	123%
CAISO (CAISO 2007)	2,648	6,688	92%/200%	30%/24%
ERCOT (GE 2008)	5,000	15,000	23%/21%	20%/39%
BPA (PNNL 2008)	2,700	6,300	233%/383%	170%/47%

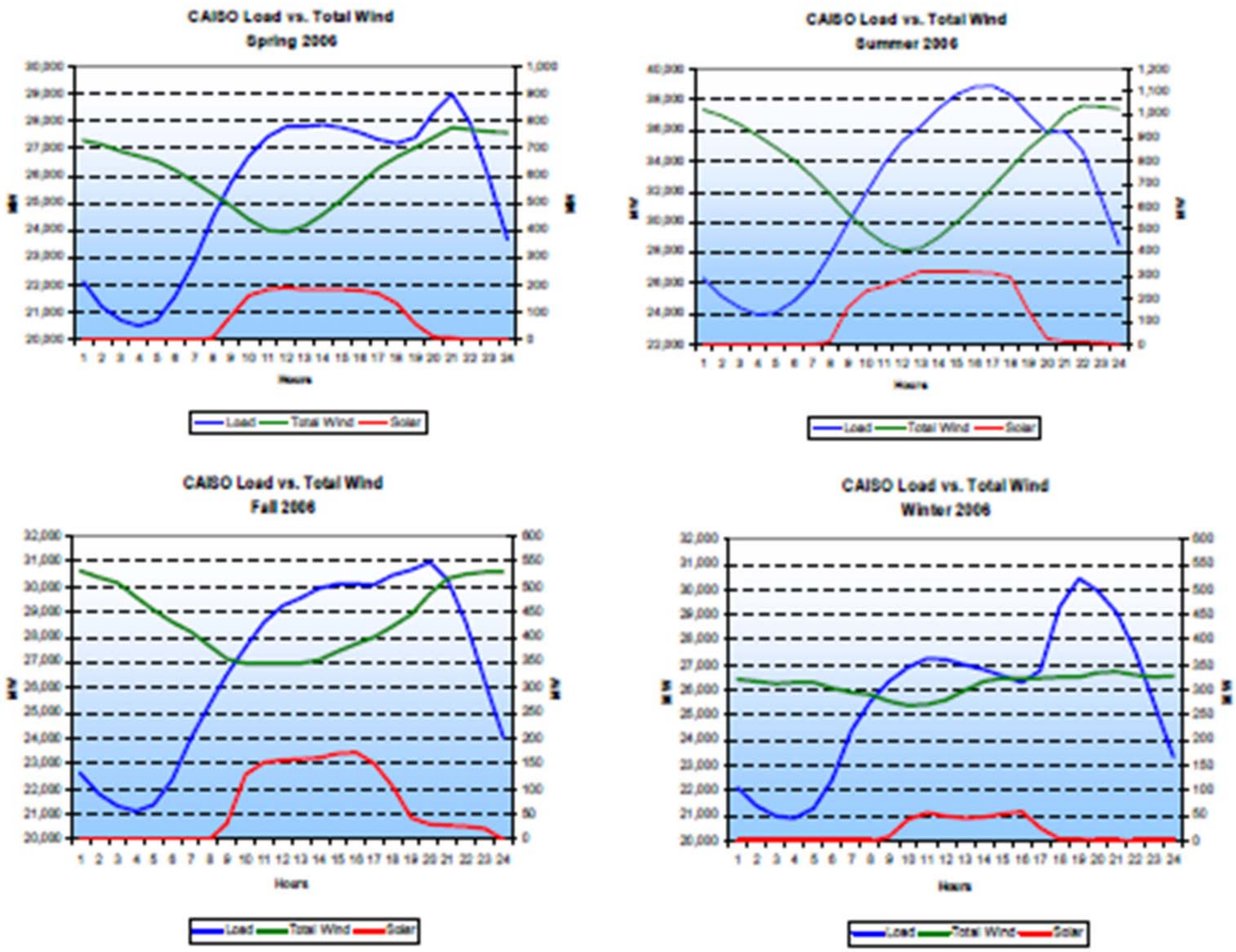
Source: Eto, J. H., J. Undrill, P. Mackin, R. Daschmans, B. Williams, B. Haney, R. Hunt, J. Ellis, H. Illian, C. Martinez, M. O'Malley, K. Coughlin, K. H. LaCommare. 2010. Use of Frequency Response Metrics to Assess the Planning and Operating Requirements for Reliable Integration of Variable Renewable Generation. LBNL-4142E. Berkeley: Lawrence Berkeley National Laboratory.

Renewable Energy Time Shift Injects Renewable Energy at Times when System Value is High



Source: NERC. *Special Report: Accommodating High Levels of Variable Generation.* http://www.nerc.com/files/IVGTF_Report_041609.pdf 2009

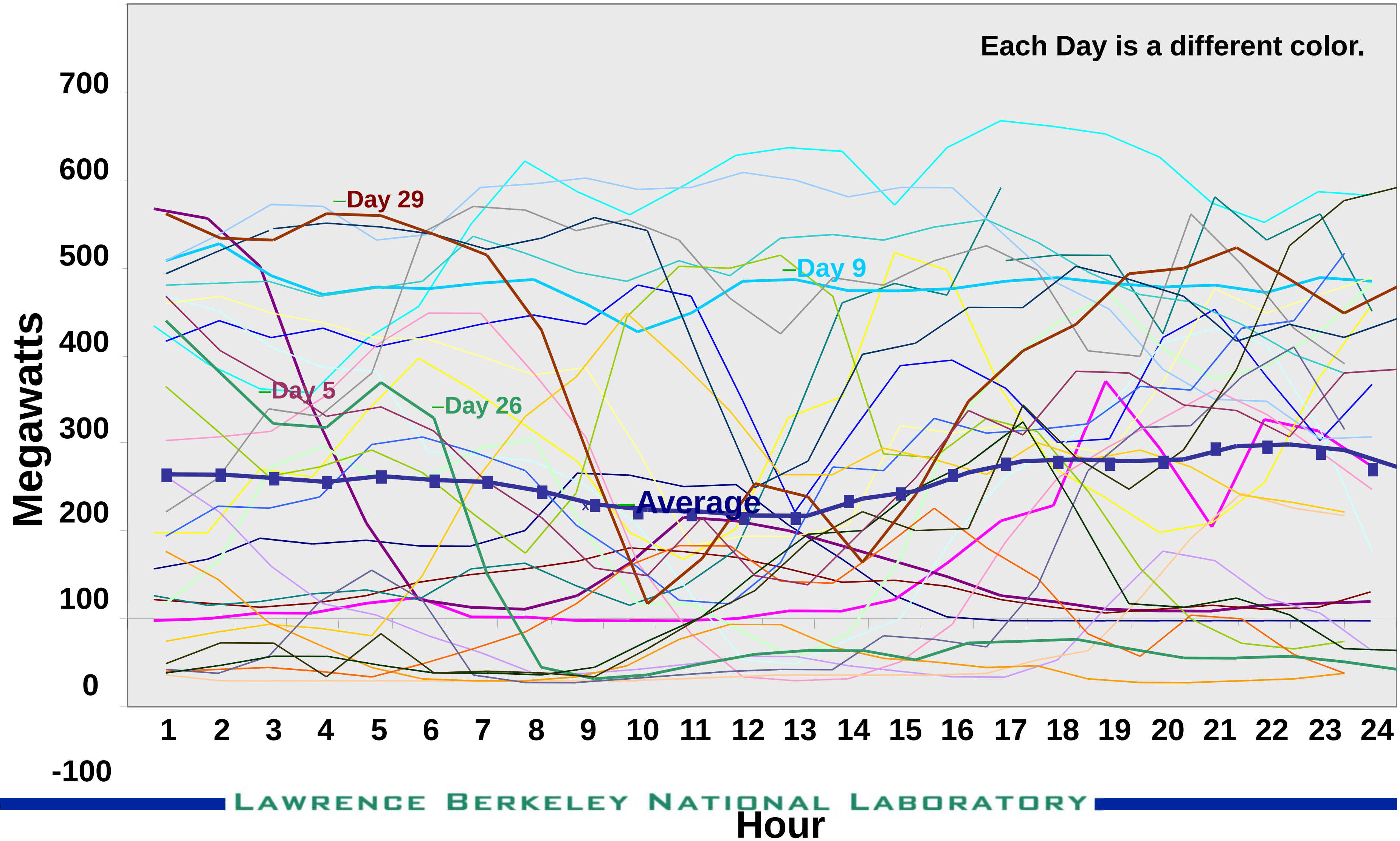
The Opportunities for Renewable Energy Time Shift Vary Seasonally and Daily



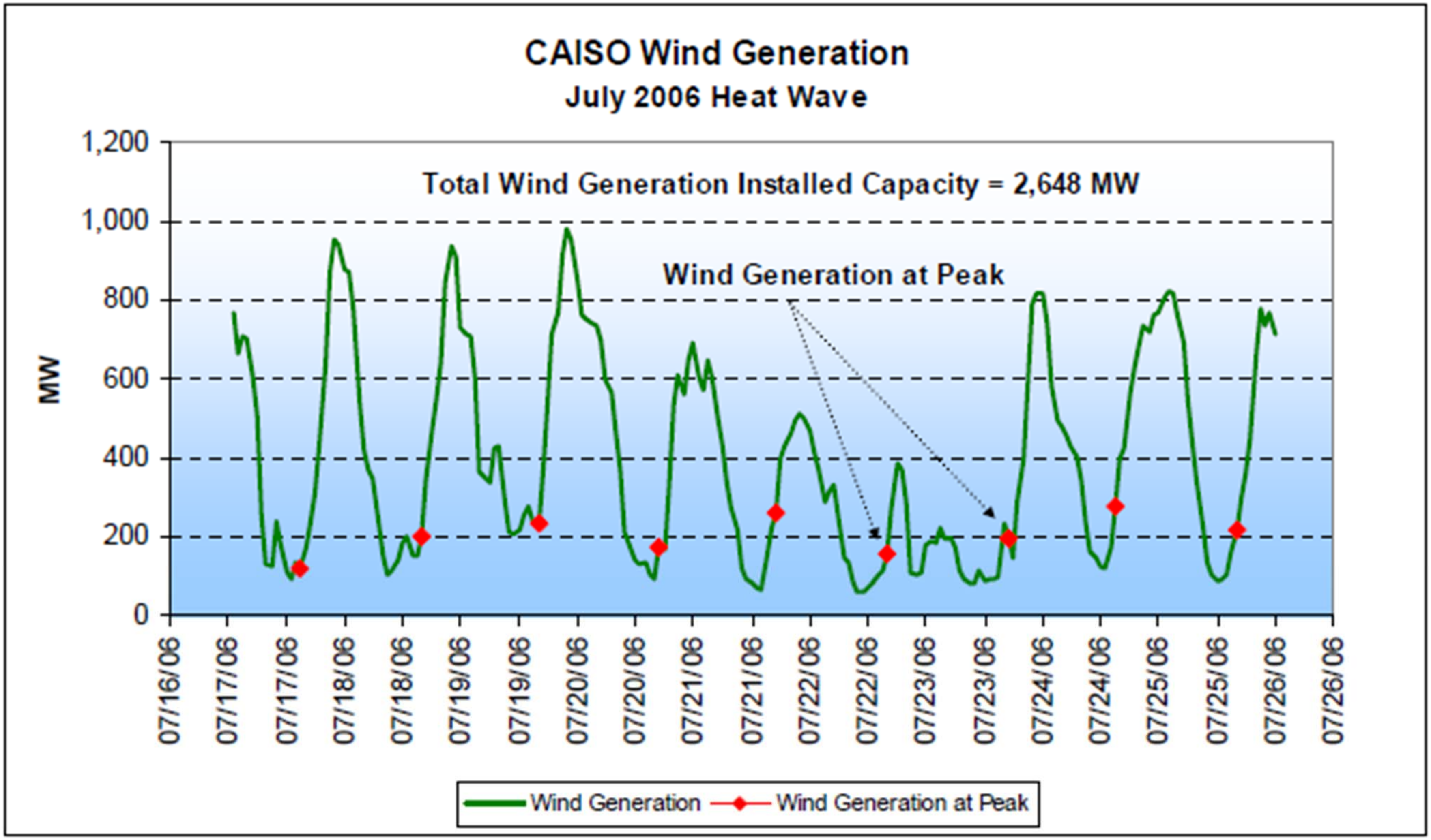
Source: California ISO 2007 Intermittent Renewables Integration Report

Renewable Energy Firming "smoothes out" Daily and Hourly Variability in Variable Renewable Generation

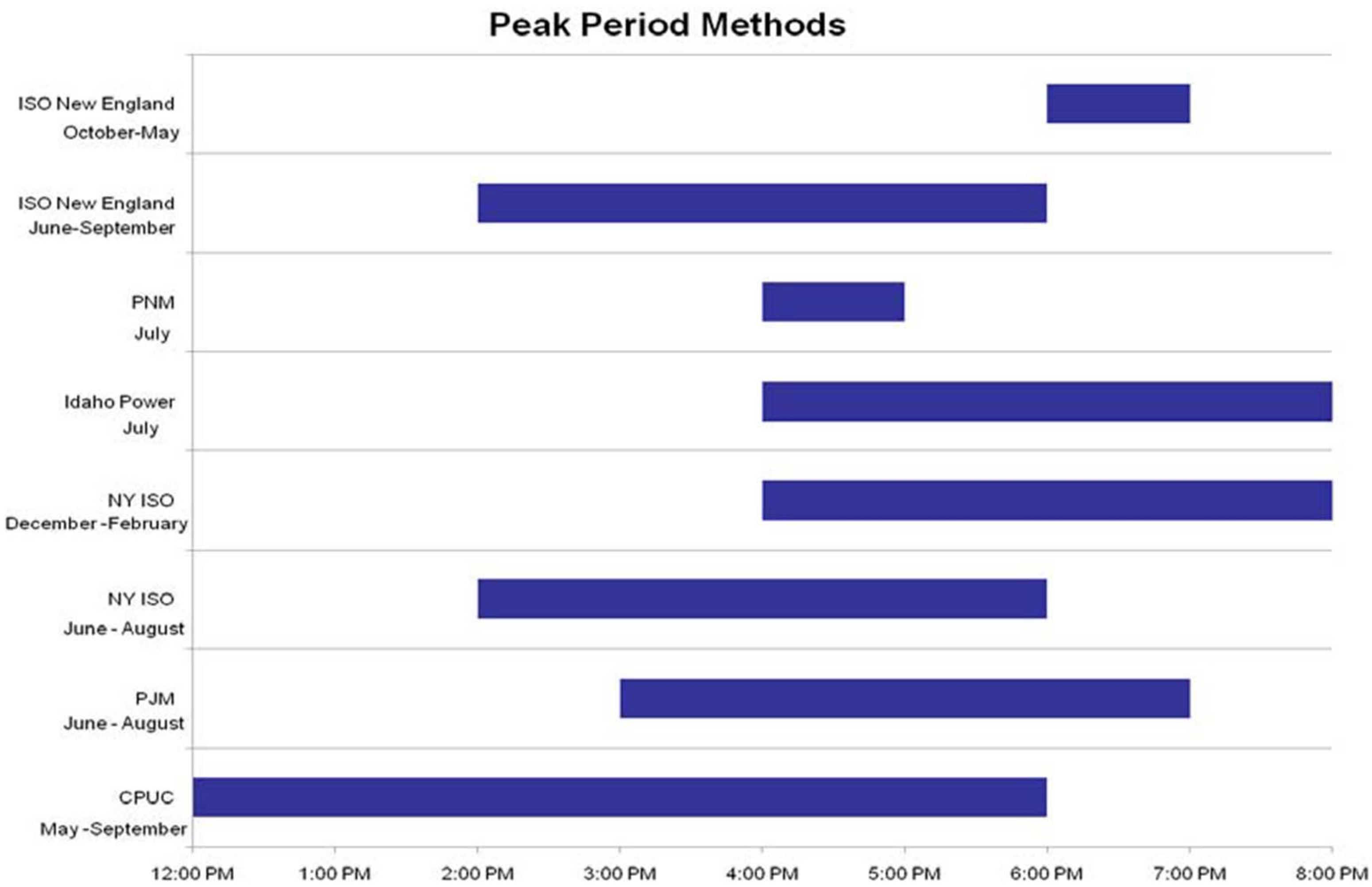
Tehachapi Wind Generation in April – 2005 Source: CAISO



The Capacity Value of FirmingVariable Renewable Generation Depends on its Contribution to Meeting System Peak Demands

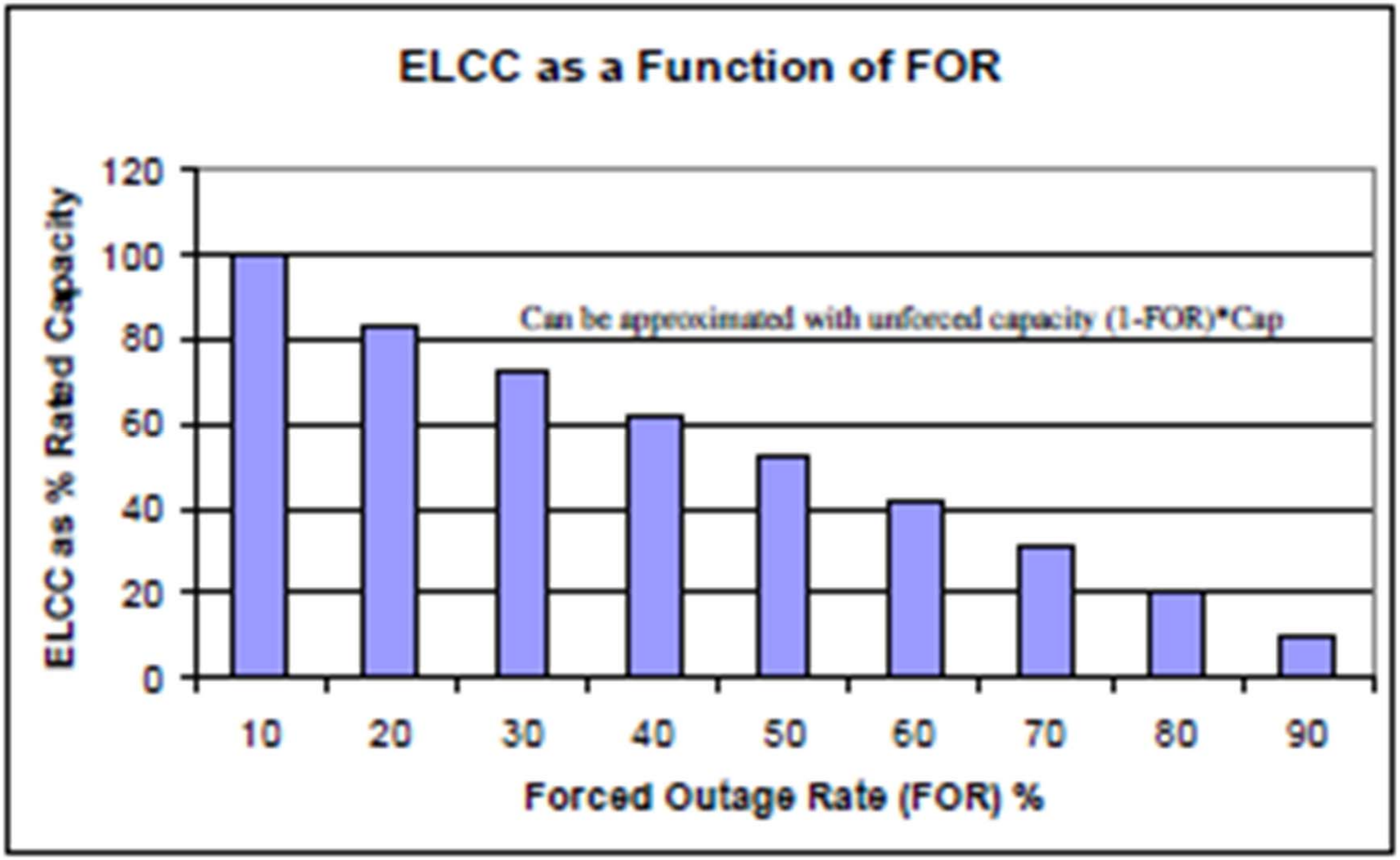


The Means for Establishing the Value of Capacity Firming is System Dependent



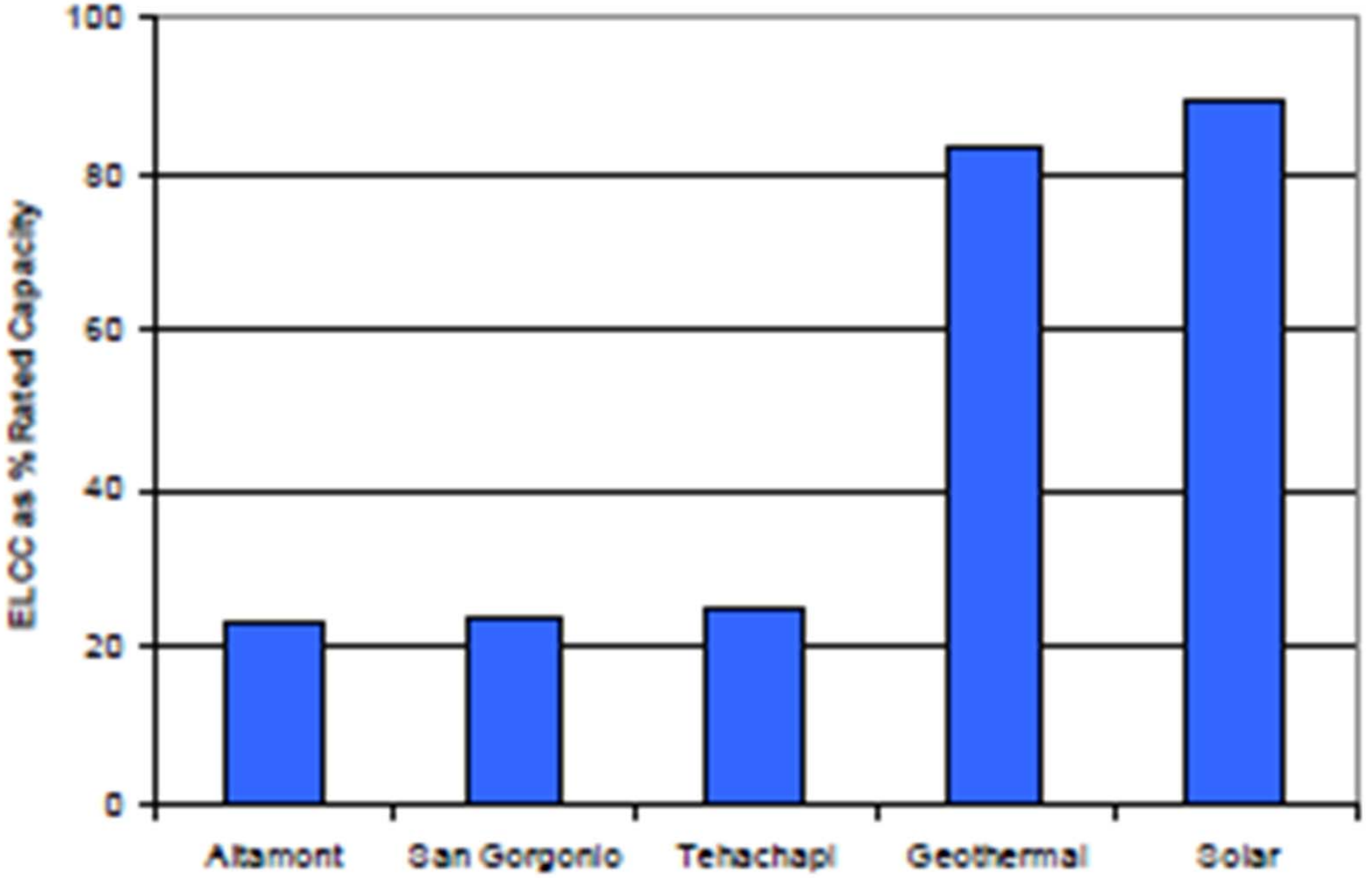
Source: NERC. *Special Report: Accommodating High Levels of Variable Generation.* http://www.nerc.com/files/IVGTF_Report_041609.pdf 2009

Equivalent Load Carrying Capability (ELCC) is a Measure of a Technology's Capacity Firming Value



Source: Milligan, M. and K. Porter. *Determining the Capacity Value of Wind: A Survey of Methods and Implementation.* WINDPOWER 2005. Denver, CO. May 15-18, 2005

Wind Generation Tends to Have a Low ELCC Compared to Other Variable Renewable Sources



Source: Milligan, M. and K. Porter. *Determining the Capacity Value of Wind: A Survey of Methods and Implementation.* WINDPOWER 2005. Denver, CO. May 15-18, 2005

Sandia Estimated the Economic Value of the Five Energy Storage Applications

Time-of-use energy cost management - 1226 $/kW

Renewables capacity firming - 709-915 $/kW

Load following - 600-1000 $/kW

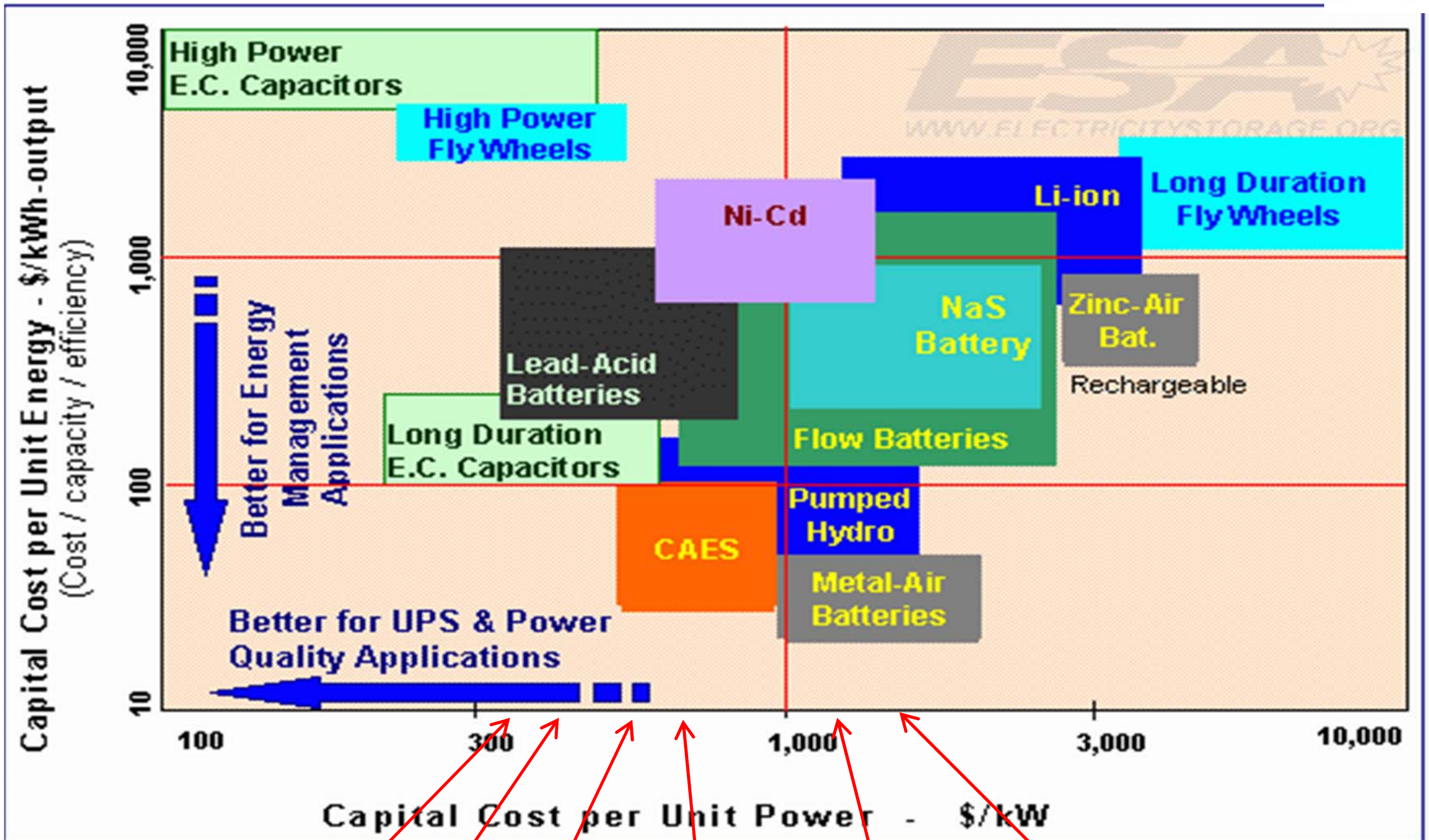
Area regulation – 785-2010 $/kW

Demand charge management - 582 $/kW

Renewables energy time shift - 233-389 $/kW

Question: Are these lifecycle economic values sufficient to warrant investment in an energy storage technology?

The Electricity Storage Association's Estimates of the Capital Cost of Energy Storage Technologies



Source: Electricity Storage Association. 2010.

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From SAND2010-0815

Some Concluding Observations

There are a variety of promising grid applications for energy storage

Currently the economic case for these applications appear to be marginal when comparisons are made to current estimates of storage technology costs

More importantly, the economic case for new technologies varies greatly based on local circumstances and often understates (or rather does not take into account) non-economic factors that affect technology adoption

Examples include the absence of meaningful markets through which these values would be captured by developers and related regulatory/institutional barriers