Estimating the Value of Energy Storage in Utility Applications

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Approach

Navigant Consulting, Inc. analyzed the opportunities for implementing energy storage in various utility applications. As shown in Table 1, these opportunities include: Renewable Generation Integration, Peak Load Shifting, Grid Operational Support, or Grid Stabilization functions. Depending on the location within the grid, the storage owner, and the regulatory structure, these applications can be combined to create value streams that maximize the benefits of individual energy storage projects with primary and secondary applications.

Table 1. Energy Storage Value Streams Identified

Function	Application	Location*	Owner**	Value Stream***						
				#1 Wind Shifting	#2 Energy Market	#3 Retail Market	#4 Capacity Enhancement	#5 Frequency Regulation	#6 Backup Power	#7 Bridging Power
Renewable Generation Integration										
	Wind Smoothing/Ramping	T,D,E	NU, U	S						
	Wind Shifting	T,D,E	NU, U	P						
Peak Load Shifting										
	Energy Market	T	NU, U		P		S			
	Retail Market	E	NU			P				
	Capacity Enhancement	T,D	U				P			
Grid Operational Support										
	Frequency Regulation	T	NU, U					P		
	Load Following	T	NU, U		S					
	Operating Reserve	T	NU, U	S	S			S		
	Black Start	T	NU, U	S						
Grid Stabilization										
	Backup Power	E	NU	S		S			P	
	Bridging Power	E	NU							P

*T=Transmission; D=Distribution; E=End Use ** U=Utility; NU=Non Utility (generator or energy service company) ***P=Primary; S=Secondary

Table 2 presents the benefits that can accrue to utility/ratepayers, consumers, or society and can be categorized as economic, reliability, or environmental. If desired, all of these benefits can be monetized. A positive business case can be developed for several of the applications in the short term (e.g., frequency regulation or capacity upgrade deferral), while others may become more attractive in the long term (e.g., wind shifting). This analysis was conducted regionally and aggregated to the entire U.S. with market penetration estimated over 20 years. The impact of several scenarios (e.g., high renewable generation and high fuel prices) on the overall size and value of the opportunity was investigated.

While each of the value streams provides opportunities, there are multiple barriers to implementation including:

- **Technical -** Technical barriers may involve the ability of specific energy storage technologies to provide sufficient power/energy or the requirement for site-specific conditions (such as for pumped hydro storage).
- **Economic -** Economic barriers may be attributed to the current cost of energy storage technologies but may also be a function of who receives benefits versus who incurs costs.
- **Market –** One of the most discussed issues is whether the variability attributed to renewable energy will be the responsibility of the renewable energy resource or of the grid operator. For example, most long-term power purchase agreements between wind farms and utilities today do not provide incentives for the wind farm

developer to deliver firm capacity, smooth power, load shifting, or controlled ramping. The variability may be accounted for by the system operator or utilities procuring additional ancillary services.

Table 2. Benefits Resulting from Energy Storage Value Streams

Benefit			Value Stream						
			#1 Wind Shifting	#2 Energy Market	#3 Retail Market	#4 Capacity Enhancement	#5 Frequency Regulation	#6 Backup Power	#7 Bridging Power
Economic	Market Revenue	Arbitrage Revenue	✓	✓					
		Capacity Market Revenue							
		Ancillary Services Revenue					✓		
		Reduced Energy Cost	✓		✓	✓			
	Power System Savings	Reduced Peak Demand	✓		✓	✓			
		Reduced Peak Losses	✓		✓	✓			
		Reduced Reserve Margin Req.	✓		✓	✓			
		Reduced Congestion Costs	✓	✓	✓	✓			
		Reduced Ancillary Service Costs	✓			✓			
		Improved System Performance	✓			✓			
	Capital Savings	Deferred Transmission Inv.		✓		✓			
		Deferred Distribution Inv.		✓	✓	✓			
	O&M Savings	Reduced O&M Cost		✓		✓			
		Reduced Energy Cost	✓			✓			
	Energy Efficiency	Reduced Electricity Losses	✓		✓	✓			
Reliability	Power Interruptions	Reduced Sustained Outages			✓	✓		✓	
		Reduced Major Outages	✓		✓	✓			
		Reduced Unserved Energy	✓			✓		✓	
		Reduced Restoration Cost	✓			✓			
	Power Quality	Reduced Momentary Outages				✓		✓	✓
		Reduced Sags and Swells							
Env.	Emissions	Reduced CO_2, SO_x, NO_x, PM-10	✓	✓	✓	✓	✓	✓	✓

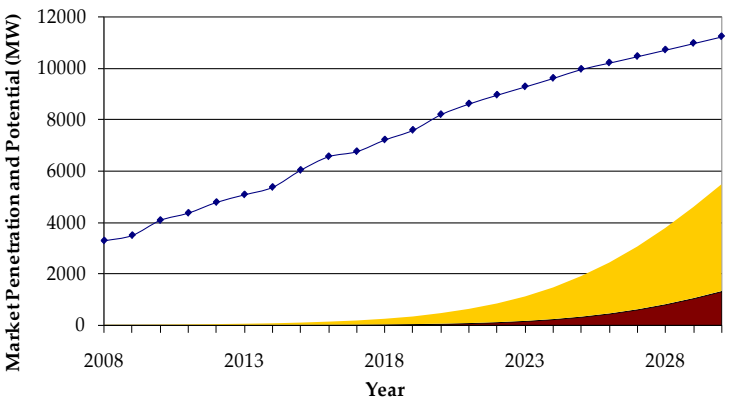
Value Stream #1 Wind Shifting

The primary application for this value stream is Wind Shifting. Wind power generated during off-peak hours can be stored and discharged during peak hours. Discharge durations of 4 hours are needed for the storage device to qualify for capacity payments, so it was assumed that the storage device will charge for 4 hours during off-peak hours and discharge for 4 hours during peak hours. The application of smoothing and ramping to address wind variability can be conducted by a storage device at the wind farm, but since frequency regulation and load following services are procured on a system-wide level, the impact of wind variability is addressed in the Frequency Regulation value stream. For projects located at the transmission and distribution level, secondary applications included smoothing/ramping, operating reserve, and black start. Backup power is a secondary application for projects located at the end user's facility. The monetary benefits of using energy storage for Wind Shifting are based on the price differential between peak and off-peak energy prices and the roundtrip efficiency of the storage device. In addition, revenue can be generated through capacity payments if storage meets the technical requirements.

The market potential for this value stream was based on the forecast of wind penetration in each state and differs between regulated and deregulated states. (See Figure 1.) A forecast for installed wind capacity in the U.S. out to 2030 was developed by comparing existing installed wind capacity to state renewable portfolio standards and assuming that wind would fulfill a certain percentage of each state's portfolio standard. The associated energy storage potential was assumed to be 20% of the wind penetration. The penetration of storage for this application was estimated to be relatively low since wind capacity is a very small percentage of total generating capacity in today's U.S. market, and 20% wind penetration is believed to be the threshold at which grid stability will become a major concern. In this analysis, 20% wind penetration is reached by 2030 only in the High Renewables scenario. The forecasted penetration of energy storage for wind shifting was particularly low in deregulated states. In most cases,

utilities cannot own generation assets and it is not clear whether the public utility commissions will consider energy storage used in this capacity as a generation assets, leaving the market to non-utility owners. Since most of the wind power in the U.S. is sold via power purchase agreements (PPAs) that do not specify when power must be delivered, there is little incentive for operators of wind farms with PPAs to install storage to shift wind to peak times when market prices are higher. A merchant wind power plant, however, could benefit from shifting and smoothing. The market potential for energy storage in deregulated states was estimated at 20% of merchant wind capacity. [1] Currently, 1% of the Northeast Power Coordinating Council (NPCC) and 13% of wind capacity in Texas sells directly to the market, while other regions have a negligible amount of merchant wind projects. [2]

Figure 1. Market Penetration for Wind Shifting Value Stream



Source: Navigant Consulting, Inc.

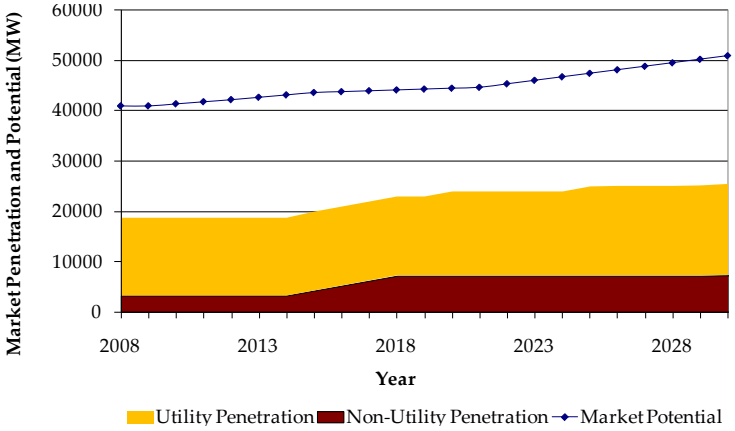
It should be noted that wind capacity that is installed with power purchse agreements (PPAs) does affect grid stability, but the wind variability is accommodated by the grid and corrected through frequency regulation and load following with traditional generation units. Therefore, the impact of wind integration on frequency regulation is modeled under the Frequency Regulation value stream.

In regulated markets, where vertically integrated utilities operate and are able to own generation assets, energy storage may be a more attractive investment for wind integration. Storage may be a more attractive investment when a single utility has the responsibility to transport electricity reliably and efficiently from generation to end-use. Utilities in regulated states would have an incentive to invest in energy storage in order to shift energy for use in peak times. Therefore, in these states, the market potential for storage was estimated as 20% of all installed wind, both with and without PPA's.

Value Stream #2 Energy Market

The primary application for this value stream is the "Wholesale Market" (arbitrage) in deregulated states and "Energy Cost Optimization" in regulated states. The secondary applications are operating reserve and load following at the transmission level.

Figure 2. Market Penetration for Energy Market Value Stream



Source: Navigant Consulting, Inc.

The market penetration is driven by the economics of building or installing storage, and the majority of the benefits flow to the owner of the storage device. It should be noted that depending on the region's off-peak generation mix, the use of energy storage may increase emissions, which can have a significant impact on the net benefits of the value streams. If a storage owner can arrange a clean source of energy as its fuel, then a positive emissions impact can be achieved.

The market potential for the Energy Market value stream is based on each region's generation mix. (See Figure 2.) Existing pumped hydro storage capacity makes up the existing market penetration for arbitrage in deregulated

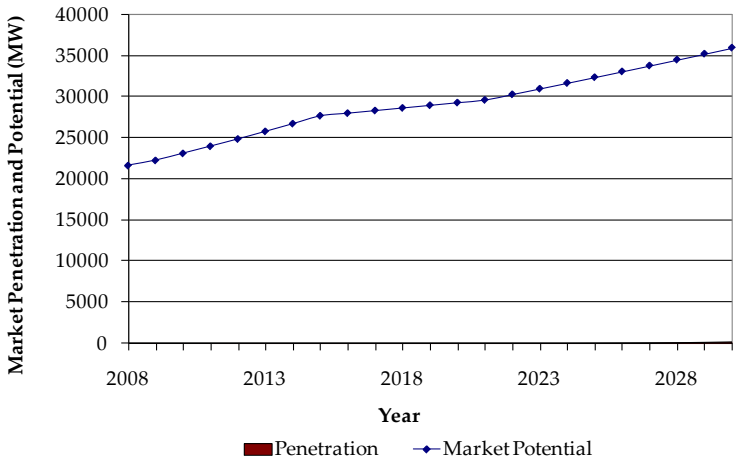
markets and energy cost optimization in regulated markets. The forecast of this market penetration increases by approximately 6 GW by 2030 based on discussions with industry stakeholders.

Value Stream #3 Retail Market

The Retail Market value stream is based on the same concept as the Energy Market value stream which is to charge off-peak and discharge on-peak. The main difference is that this value stream applies to end-use customers who wish to take advantage of the difference in dynamic pricing rates. Dynamic pricing rates exist to encourage customers to shift their electricity usage to off-peak hours, reducing the cost of electricity for the customer and peak demand for the utility. The customer could install an energy storage device to effectively decrease electricity consumption during peak hours and supply their energy demand with cheaper, off-peak power. The primary application for this value stream is the Retail Market and the secondary application is backup power, which would only be needed during sustained or major outage events and may often overlap with normal daily use of the device for the primary application.

The market potential for this value stream was determined by assuming that 90% of all industrial and commercial customers will have time-of-use rates by 2030 and that 75% of energy sales are to entities subject to time-of-use rates today. A very long adoption rate is expected due to the current cost of electricity storage. (See Figure 3.)

Figure 3. Market Penetration for Retail Market Value Stream



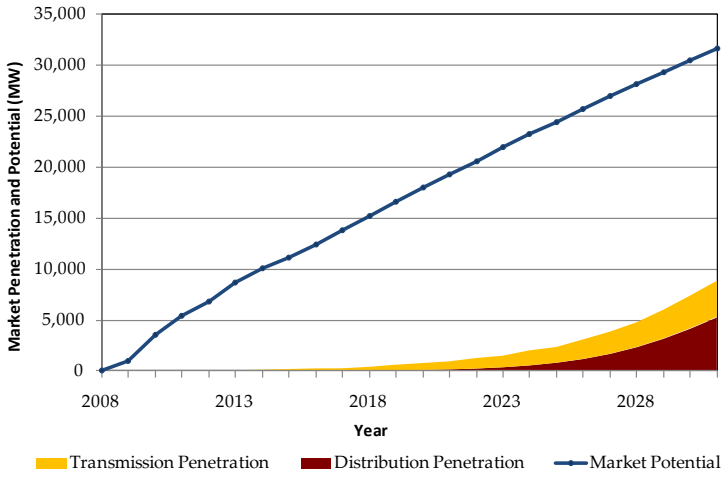
Source: Navigant Consulting, Inc.

Value Stream #4 Capacity Enhancement

Energy storage can be used to defer transmission and distribution upgrades and/or alleviate transmission congestion. Using energy storage for capacity enhancement could provide additional stability to the grid as more distributed energy generation is installed. A storage device that is primarily used for Capacity Enhancement at the transmission level can also be used for Energy Cost Optimization or for Black Start. A storage device that is primarily used for Capacity Enhancement at the distribution level can also be used for Energy Cost Optimization. It is important to consider the applicability of the secondary application, energy cost optimization, for a given state (regulated v. deregulated). For this analysis, it was assumed that all projects can take advantage of energy cost optimization.

The market potential for transmission capacity deferral is based on a published study that projected transmission and distribution investments through 2030 based on data collected by the North American Electric Reliability Corporation (NERC) and on an Edison Electric Institute (EEI) survey of 60 shareholder-owned electric utilities.[3] Market penetration would increase in a stepwise manner because transmission upgrades are large and would likely require >50MW of storage capacity to defer each upgrade. (See Figure 4.) The market for distribution capacity deferral is also based on the same report for distribution investment through 2030. This value stream reaches a higher market penetration because these upgrades can be made with small increments of energy storage, making it more feasible to use storage for Capacity Enhancement -

Figure 4. Market Penetration for Capacity Enhancement Value Stream



Source: Navigant Consulting, Inc.

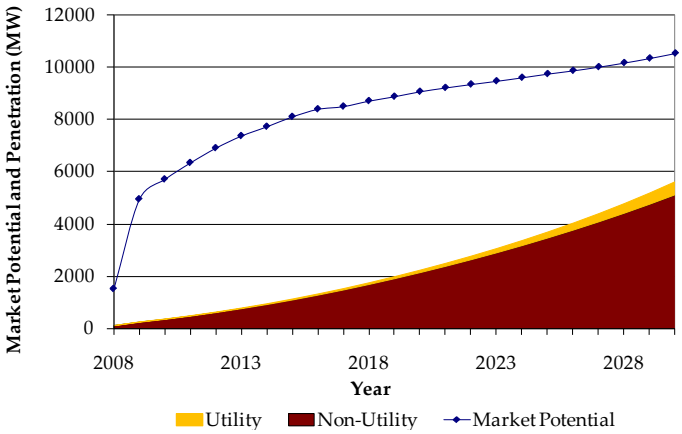
Distribution.

Value Stream #5 Frequency Regulation

Energy storage can be used to provide frequency regulation to the grid. The secondary applications for this value stream include load following and short term operating reserve if the technology used has sufficient energy and power (e.g. pumped hydro storage).

The market potential for the Frequency Regulation value stream in the U.S. shown in Figure 5 is based on the current requirement for frequency regulation services, defined as 1% of peak load by NERC standards. This requirement was then increased over time to account for additional wind penetration.

Figure 5. Market Penetration for Frequency Regulation Value Stream



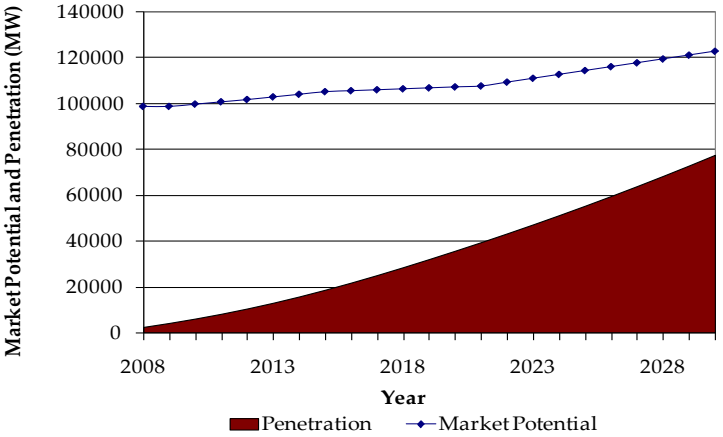
Source: Navigant Consulting, Inc.

Value Stream #6 Backup Power

Energy storage can be used to provide backup power during outages. This value stream assumes that the energy storage device is 100% dedicated to reducing outage events, thus no secondary applications are applicable.

The market penetration from 2009-2013 for backup power is based on the Frost and Sullivan sales forecast of 200+kVA devices, the applicable size for commercial and industrial customers. [4] The market was then projected through 2030 with approximately a 1% growth rate. Finally, total U.S. market penetration was estimated for each region based on the ratio of industrial and commercial load, as a percent of total U.S. industrial and commercial load. Economic potential was not estimated for this value stream, though theoretical potential was assumed to be peak demand of all commercial and industrial customers that require backup power. (See Figure 6.)

Figure 6. Market Penetration for Backup Power Value Stream

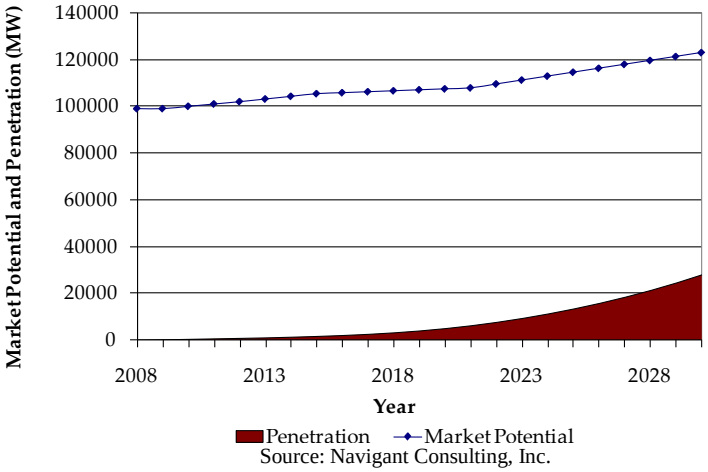


Source: Navigant Consulting, Inc.

Value Stream #7 Bridging Power

Energy storage can provide power quality in order to reduce momentary outages, including sags and swells, at the end-user location. This application is similar to the backup power but is assumed to operate for <15 seconds at a time. This value stream requires a 100%-dedicated device so there are no secondary applications.

Figure 7. Market Penetration for Bridging Power Value Stream



Source: Navigant Consulting, Inc.

The market penetration for Bridging Power shown in Figure 7 is based on a 2007 Frost and Sullivan report and the static UPS market penetration developed in the Backup Power market value stream. [5] These growth projections were then extrapolated out to 2030. As mentioned above, the market for the Bridging Power value stream is limited to the rotary UPS market in order to draw a clear distinction from the Backup Power market, which focuses on static UPS devices. Similar to the Backup Power Market, the total technical market is confined to 200 kVA+ systems, which are more applicable for larger-scale commercial and industrial applications.

Results and Conclusions

Value Stream #5 Frequency Regulation is one of the most attractive emerging opportunities for energy storage in the near term, especially given the assumption that the need for regulation services is expected to increase to account for variability associated with higher wind penetration. New York Independent System Operator (NYISO) is currently the most promising deregulated market due to its high frequency regulation price that averaged ~$60/MWh in 2007.

Value Stream #4 Capacity Enhancement is feasible in the near term for distribution deferral, though it is limited to upgrades where incremental capacity need is small in comparison to the upgrade cost. Additionally, the attractiveness of distribution deferral with energy storage increases dramatically with the number of years the upgrade can be deferred or the number of locations that a single storage device can service over its lifetime. Capacity Enhancement at transmission is only attractive in niche applications.

Given the policy goals for renewable energy in the coming years, Value Stream #1 Wind Shifting holds the greatest potential for energy storage. However, market barriers significantly hinder the penetration of energy storage for wind shifting and smoothing/ramping, especially in deregulated states. This could be a leading value stream given the appropriate incentives and market rules that encourage developers to invest in storage.

The other value streams were less attractive opportunities for energy storage.

- Value Stream #2 Energy Market – Existing PHS facilities account for the large projected value over 20 years. But market growth is limited because increased storage penetration may flatten the load curve and decrease price differentials, thus making storage less profitable.
- Value Stream #3 Retail Market – The cost of energy storage is the major roadblock to market penetration in the Retail Market value stream. Retail customers have several alternative opportunities to curve peak demand and energy cost that do not require capital investments, and until the cost of energy storage declines significantly or other factors drive investment, a very long adoption rate is expected.
- Value Stream #6 Backup Power –The backup power value stream has one of the largest net values in this analysis, since lead acid UPS devices are a mature storage technology with existing market penetration. Growth will likely be seen in data centers and the telecommunication industry.
- Value Stream #7 Bridging Power – The bridging power value stream focuses on rotary UPS systems, which are expected to grow in market share compared to lead acid UPS systems.

References

[1] Electricity Advisory Committee. Bottling Electricity: Storage as a Strategic Tool for Managing Variability and Capacity Concerns in the Modern Grid. Office of Electricity, U.S. Department of Energy. December 2008.
[2] American Wind Energy Association Project Database, Q3 of 2008.
[3] "Mark Chupka, Robert L. Earle, Peter S. Fox-Penner, and Ryan Hledik. Transforming America's Power Industry: The Investment Challenge 2010-2030. *The Edison Foundation*. November 2008.
[4] Frost & Sullivan. World Static UPS Market Report. 2006.
[5] Frost and Sullivan sales forecast out to 2013 in *3-Phase North American UPS Market Report*. 2007.