Energy Storage - a Cheaper and Cleaner Alternative to Natural Gas-Fired Peakers

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Storage is vital in all efficiently functioning commodity markets—storage smoothes the fluctuations in supply and demand and ensures availability during critical periods of high demand. Energy storage systems store energy for use at a later time, when electric power is most needed and most valuable, such as on hot summer afternoons. Energy storage helps integrate intermittent renewable sources, can supplant the most polluting power plants, and enhances grid reliability. There are many ways to store energy, including chemically (batteries), mechanically (flywheels) and thermally (ice).[1]

Due to insufficient energy storage for the electric power grid, utilities must size their generation and transmission systems to deliver the full amount of electricity that consumers demand (or might demand) at any given moment of the year. Owning and operating sufficient assets to serve peak demand - only 5% or less of the hours per year - results in increased emissions and costs to electricity customers.

Energy storage has the unique potential to transform the electric utility industry by improving existing asset utilization, avoiding the building of new power plants, and avoiding or deferring upgrades to existing transmission and distribution networks. Scientists, utility CEO's, and policy makers frequently refer to energy storage as the "Holy Grail" for the electric power industry.

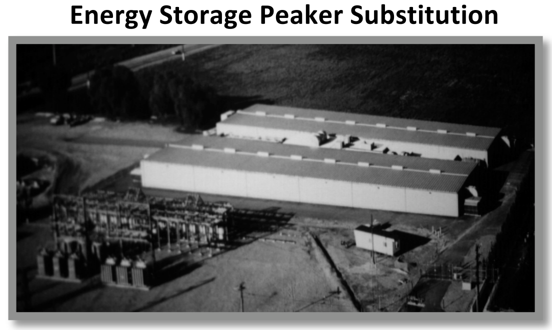
More recently, energy storage has achieved recognition as a foundational element of the Smart Grid[2], and the technical community speaks of energy storage as a key enabling resource to facilitate the transition away from a fossil fuel dominated generation fleet to one that is cleaner, more reliant on renewables, "smarter," and able to accelerate the electrification of the transportation sector.

To help illustrate the cost effectiveness of energy storage as an alternative to natural gas-fired peakers, we compared the cost of a kilowatt-hour (kWh) of electricity generated on-peak by a gas-fired peaker, with the cost of a kWh of electricity provided on-peak by an energy storage system. For simplicity, this comparison selected a commercially available energy storage technology – lead-acid batteries – and used the cost and specifications similar to the large lead-acid energy storage peaking facility shown below. Located in Chino, California, this 10 megawatt (MW), 4 hour duration system successfully demonstrated energy storage's ability to manage peak load from 1988 through 1996.[3, 4]

Energy Storage Technologies Today Can Deliver On-Peak Electricity at a Lower Cost than Gas-Fired Peakers

Gas-Fired Turbine Peaker Plant

Energy Storage Peaker Substitution



[1] Pumped hydro energy storage, which has been in wide use for many years, is another form of mechanical, or kinetic, energy storage
[2] Title XIII of the Energy Independence and Security Act of 2007 described the Smart Grid as including "deployment and integration of advanced electricity storage and peak-shaving technologies, including plug-in electric and hybrid electric vehicles, and thermal-storage air conditioning"
[3] Energy storage performance specifications based on commercially deployed lead-acid grid storage projects, including the EPRI–funded grid level energy storage demonstration project in Chino, California
[4] EPRI Chino Study TR-101787, *Chino Battery Energy Storage Power Plant: Engineer-of-Record Report* (December 1992)

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Assumptions for the gas-fired peaker were taken directly from the CEC's *Comparative Cost of California Central Station Electricity Generation Technologies* model. To calculate the cost per kWh of electricity discharged by an energy storage system, the same 20-year project time horizon and 5% capacity factor were used. Below is a detailed overview of the analysis methodology:

Gas-Fired Peaker Plant[5]

General Assumptions	
Technology:	Simple Cycle Combustion Turbine
Plant Size	49.9MW
Efficiency	37% (9,266 Btu/kWh Heat Rate)
Ownership	POU Owned/Financed
Project Life	20 years
Capacity Factor	5%
Plant, T&D Losses	6% (Centralized Plant)

Costs	Assumptions	LCOG ($/MWh)	LCOG ($/kW-yr)
Fixed O&M	$24/kW/yr	$69	$29
Corp. Taxes	0%	$0	$0
Insurance	0.6% of CAPEX	$23	$10
Property Tax	1.1% of CAPEX	$29	$12
Natural Gas Fuel	$61/MWh	$100	$41
Variable O&M	$0.04/kWh	$5	$2
Subtotal		$227	$93

Costs	Assumptions	LCOG ($/MWh)	LCOG ($/kW-yr)
Installed Cost	$1,394/kW	$265	$109
Grand Total		$492	$203

Energy Storage Peaker Substitution[6]

General Assumptions	
Technology:	Lead-Acid Battery
Plant Size	49.9MW (4h duration)
Efficiency	84% (AC to AC Roundtrip)
Ownership	POU Owned/Financed
Project Life	20 years
Capacity Factor	5%
Plant, T&D Losses	6% (Centralized Plant)

Costs	Assumptions	LCOG ($/MWh)	LCOG ($/kW-yr)
Fixed O&M	$6/kW/yr	$17	$7
Corp. Taxes	0%	$0	$0
Insurance	0.6% of CAPEX	$22	$9
Property Tax	1.1% of CAPEX	$28	$12
Off-Peak Grid Charging	$24/MWh[7]	$48	$20
Variable O&M	$0.04/kWh	$5	$2
Subtotal		$121	$50

Costs	Assumptions	LCOG ($/MWh)	LCOG ($/kW-yr)
Installed Cost	$1,351/kW[8] ($338/kWh)	$256	$105
Grand Total		$377	$155

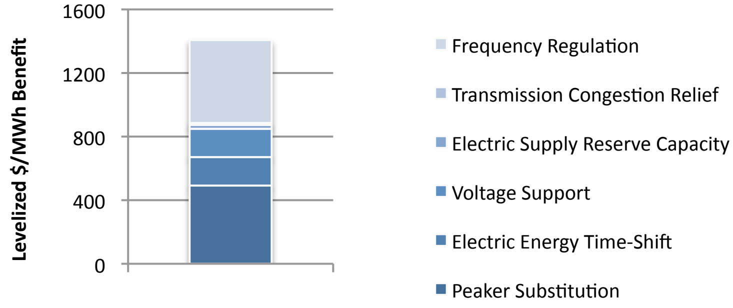
Levelized Cost of Generation for Energy Storage is Less Than a Simple Cycle Gas-Fired Peaker

Energy Storage Has the Ability to Deliver More than Peaker Substitution Value to the Grid

In addition to cost savings for electricity consumers, energy storage provides multiple value streams above and beyond peaker substitution, making the economic case for energy storage even stronger. For example, by their nature, gas-fired peaker plants cannot be economically sized below 50 MW and therefore are not easily installed in a distributed footprint. Energy storage systems do not have this limitation, opening up the potential for many technical and economical benefits available to distributed energy resources such as reduction of transmission and distribution losses. Additional benefits include electric energy time-shift, voltage support, electric supply reserve capacity, transmission congestion relief, and frequency regulation. Ranges for each of these value streams have recently been quantified by Sandia National Laboratories, and are presented in the chart below in terms of additional benefits per MWh delivered on-peak.

[5] Source: *CEC 2009 Comparative Cost of California Central Station Electricity Generation Technologies* (CEC_COG_Model_Version_2.02-4-5-10)
[6] Source: StrateGen Consulting, Levelized Cost of Generation Model
[7] Assumes most recent sample of average summer off-peak wholesale price from CAISO OASIS database
[8] EPRI Chino Study TR-101787, *Chino Battery Energy Storage Power Plant: Engineer-of-Record Report* (December 1992)

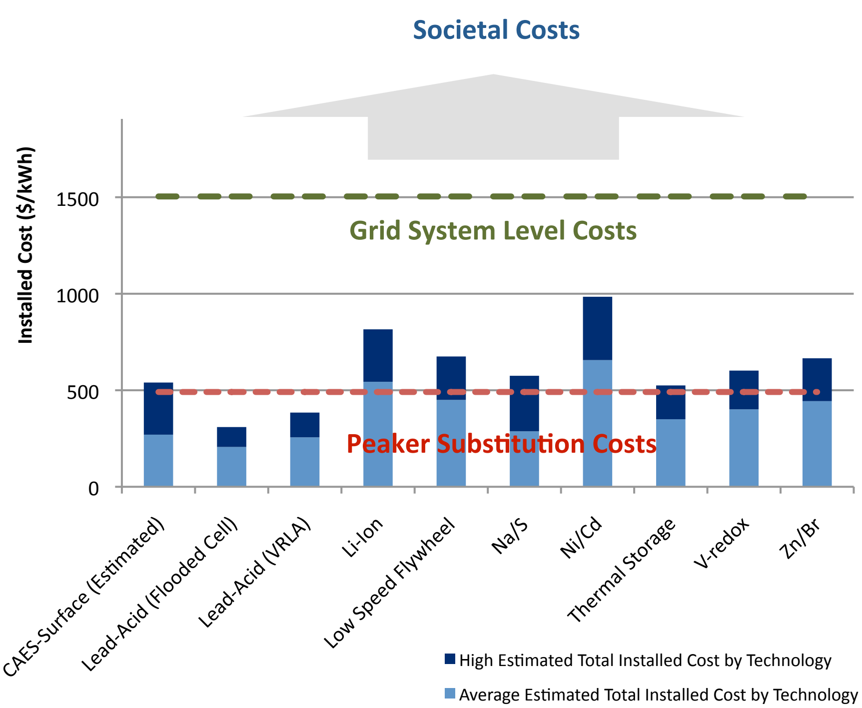
Additional System Benefits of Energy Storage[9]



Energy Storage is the Most Cost-Effective Resource

When these benefits are factored in and compared to the total installed cost for a range of energy storage technologies, energy storage emerges as a comprehensive, cost-effective system resource.

Fossil Fuel Societal, Grid, and Peaking Costs vs. Energy Storage Costs[10,11]



Avoided Costs Realized

Societal Level:
- GHG & Air Quality
- Renewables Integration
- Smart Grid Implementation
- Streamlined Permitting

Grid System Level:
- Electric Energy Time-Shift
- Voltage Support
- Electric Supply Reserve Capacity
- Transmission Congestion Relief
- Frequency Regulation

Peaker Level:
- Peaker Plant Substitution

The bars in the chart above represent the total installed cost per kWh of energy storage capacity by major storage technology, assuming four hours of capacity for each. The red dashed line indicates where storage costs

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[9] Source: SANDIA Report SAND2010-0815, *Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide*, Jim Eyer & Garth Corey (February 2010)

[10] Assumptions: All energy storage technology costs shown are normalized for a four-hour duration; Technology comparison is for modern energy storage systems only, but does not include pumped hydro or high-speed flywheels which are not designed for long-duration peaking applications

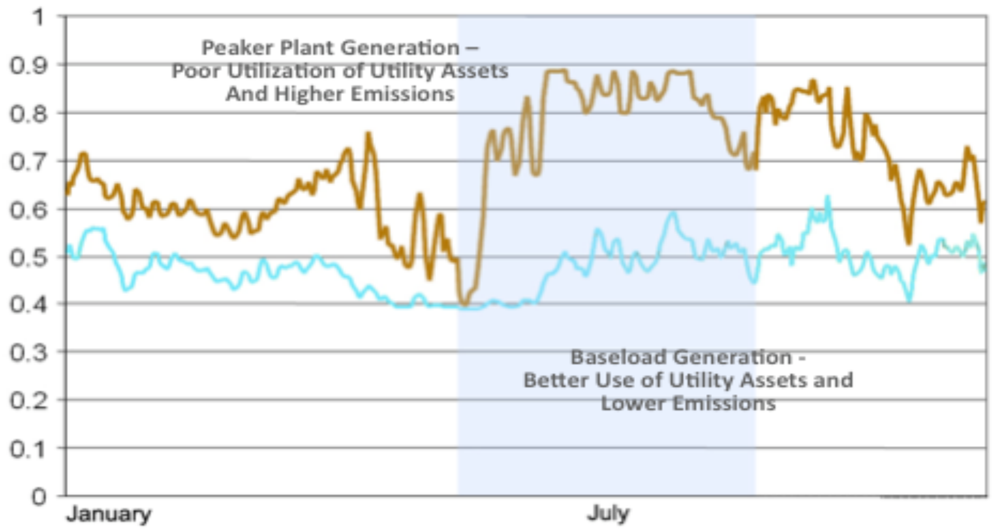
[11] Source: Average estimated total installed cost estimate from: Sandia Report SAND2008-0978, Susan M. Schoenung and Jim Eyer, *Benefit/Cost Framework for Evaluating* (February 2008)

are at cost parity with a natural gas-fired peaker. The green dashed line indicates the grid system level costs avoided with energy storage – in other words, this line is representative of other real system costs that are borne by electricity customers. Finally, the blue arrow represents the total societal cost avoided by energy storage, including its ability to help achieve a smart grid, accelerate and facilitate renewables integration, and avoid GHG emissions.

Energy Storage is a Cleaner Alternative to Natural Gas-Fired Peakers

Grid storage displaces less efficient, dirtier peaker generation by time-shifting more efficient, cleaner base-load generation to peak periods. This results in substantial system-wide air quality benefits. The chart below compares actual carbon dioxide (CO_2) emissions of peak vs. off peak generation in Southern California Edison's service territory. Peaker plant generation produces far more CO_2 emissions per MWh than base load generation, especially during the summer months. This is true of California's other utilities as well.

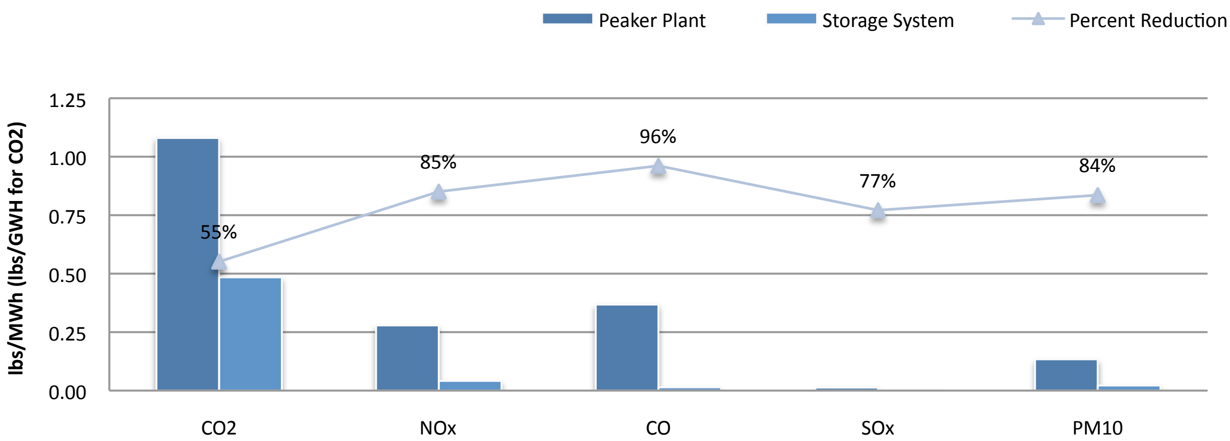
Peak vs. Off-Peak CO_2 Emission Rate (Tons/MWh)[12]



Energy storage usage results in significant air quality benefits. Assuming Pacific Gas and Electric's base load electric mix as the off-peak source of electricity, energy storage would provide 55% CO_2 savings, 85% NOx savings, and up to 96% savings of CO per MWh of on-peak electricity delivered (shown in the chart below). These emissions benefits increase as more off-peak renewable generation comes on-line. Energy storage will also help optimize the use of existing transmission and distribution capacity, enabling the deployment of more renewable energy. Finally, because of its ability to store locally generated power and be remotely dispatched, energy storage is an indispensable component of a more affordable, secure and reliable smart grid.

[12] Source: 2006 CPUC Update for Energy Efficiency Proceeding (Brian Horii, E3)

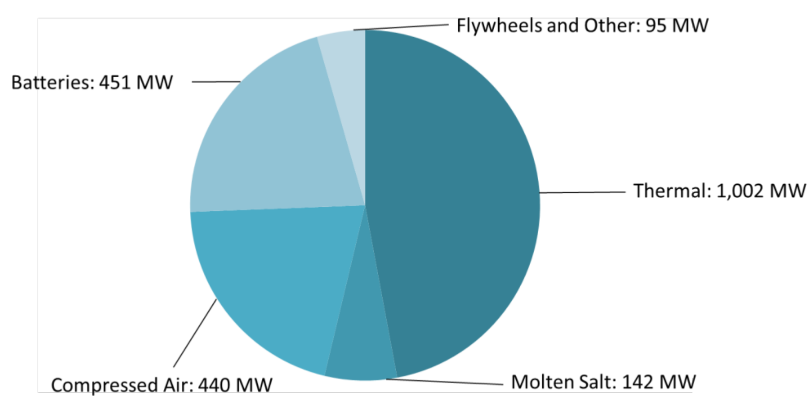
Energy Storage is a Cleaner Alternative to Gas Peakers[13]



Smart, Clean, Cost-Effective Energy Storage: Ready for Deployment

Modern energy storage technologies, some of which have been in existence for decades, cover a wide range of sizes, power (measured in MW), and discharge durations (measured in hours). An energy storage system can be either centralized or distributed and can be utility-owned, customer-owned or third-party owned. Today, there are more than 2,000 MW of installed grid connected energy storage technologies deployed worldwide with a comparable amount under development.[14]

Current Estimated Worldwide Installed Advanced Energy Storage Capacity (2128 MW as of 2010)



Why Isn't Energy Storage Being Widely Used in California?

Current California policy has not kept pace with advances in energy storage, yet energy storage can cost-effectively help address California's many energy policy challenges, such as green house gas emissions reduction, renewables integration, transmission and distribution constraints, increasing peak demand and

[13] Assumptions from CEC Cost of Generation Model for simple cycle peaker and standard combined cycle for off-peak base load; generation mix based on annual report of actual electricity purchases for Pacific Gas and Electric in 2008

[14] Source: StrateGen and CESA research. Excludes pumped hydro capacity, estimated at ~123 GW

enabling electric vehicles. Energy storage is particularly relevant, as many of these complex challenges need to be addressed in the near term, and storage technology is currently available and deployable on a large scale.

Energy storage technologies are well established in other industries and market applications, such as the transportation and consumer electronic industries. Grid storage, a key component of the electric power industry, represents a large new market application for both existing and emerging energy storage technologies. Unfortunately, the electric power industry is a highly regulated industry that has historically overlooked using storage for grid optimization. As a result, current market structure does not allow for the buyer of the storage equipment to easily capture all the value streams provided by storage across the entire electric power system.

The barrier is neither the availability of a reliable energy storage technology nor its cost; the barrier is the current accounting of disaggregated benefits in a regulated utility industry and lack of clear policy direction to utilities that energy storage is a superior alternative to gas-fired peakers. Thus, while energy storage presents compelling social and economic benefits, California's current market structure has led to underinvestment.

Key State and Federal Policy Recommendations to Realize the Benefits of Energy Storage:
Energy storage can cost-effectively help address California's many near term, complex and inter-related energy policy challenges, such as green house gas emissions reduction, renewables integration, transmission and distribution constraints, increasing peak demand and enabling electric vehicles.

State Recommendations

1) Require utilities to evaluate procurement targets for cost-effective storage deployment (e.g., AB 2514)
2) Encourage diversity in energy storage technology deployment, including market application and ownership options to foster utility, third party, and customer-owned applications
3) Fully implement SB 412 to provide Self Generation Incentive Program (SGIP) incentives for energy storage coupled with solar and used standalone on the customer side of the meter
4) Implement energy-storage focused rulemaking, require consideration of energy storage as a valued system resource in all regulatory proceedings (e.g. distributed generation, smart grid, renewables, and demand response/permanent load shifting)
5) Include energy storage in a standardized cost-effectiveness methodology applicable to all resources
6) Require utilities to include energy storage as a bidding option in peaking capacity Requests for Offers (RFOs)
7) Require storage as part of long term procurement process, including pursuing standard offers for permanent load shifting
8) Explore tariff design that encourages load shifting
9) Increase Feed-in-Tariff price for renewables firmed/shifted with energy storage
10) Accelerate the CAISO's stakeholder processes to achieve comparability of energy storage (implementation of FERC Orders 890 and 719)
11) Consider peak reduction standard for state agency power purchases
12) Clarify net metering rules for renewable energy projects with storage

Federal Recommendations

1) Support extension of the existing federal investment tax credit to energy storage systems (e.g., S.1091)
2) Add energy storage as its own category in the FERC's Uniform System of Accounts

APPENDIX

GLOSSARY[15,16]

Levelized Cost of Generation: According to the CEC, levelized cost of generation of a resource represents a constant cost per unit of generation computed to compare one unit's generation costs with other resources over similar periods. This is necessary because both the costs and generation capabilities differ dramatically from year to year between generation technologies, making spot comparisons using any year problematic. The levelized cost formula used in this model first sums the net present value of the individual cost components and then computes the annual payment with interest (or discount rate) required to pay off that present value over the specified period. These results are presented as a cost per unit of generation over the period under investigation. This is done by dividing the costs by the sum of all the expected generation over the time horizon being analyzed. The most common presentation of levelized costs is in dollars per megawatt-hour ($/MWh) or cents per kilowatt-hour (¢/kWh).

Capacity Factor: The capacity factor is specified as a percentage and is a measure of how much the power plant operates. More precisely, it is equal to the energy generated by the power plant during the year divided by the energy it could have generated if it had run at its full capacity throughout the entire year (Gross MW x 8,760 hours). For the purposes of this analysis, specifically for energy storage, the capacity factor is measured using the number of hours discharged only and does not include the number of hours used to charge the storage system.

Electric Energy Time-Shift: Electric energy time-shift involves purchasing inexpensive electric energy, available during periods when the price is low, to charge the energy storage plant so that the stored energy can be used or sold at a later time when the price is high. This is also sometimes referred to as "arbitrage."

Voltage Support: An important technical challenge for electric grid system operators is to maintain necessary voltage levels with the required stability. In most cases, meeting that challenge requires management of a phenomenon called "reactance." Reactance occurs because equipment that generates, transmits, or uses electricity often has or exhibits characteristics like those of inductors and capacitors in an electric circuit. To manage reactance at the grid system level, grid system operators rely on an ancillary service called "voltage support." The purpose of voltage support is to offset reactive effects so that grid system voltage can be restored or maintained.

Electric Supply Reserve Capacity: Prudent operation of an electric grid includes use of electric supply reserve capacity ("reserve capacity") that can be called upon when some portion of the normal electric supply resources become unavailable unexpectedly. In the electric utility realm, this reserve capacity is classified as an ancillary service.

Transmission Congestion Relief: In many areas, transmission capacity additions are not keeping pace with the growth in peak electric demand. Consequently, transmission systems are becoming congested during periods of peak demand, driving the need and cost for more transmission capacity and increased transmission access

[15] Source: CEC 2009 Comparative Cost of California Central Station Electricity Generation Technologies Report

[16] Source: SANDIA Report SAND2010-0815, Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide, Jim Eyer & Garth Corey (February 2010)

charges. Additionally, transmission congestion may lead to increased use of congestion charges or locational marginal pricing for electric energy.

Frequency Regulation: regulation is used to reconcile momentary differences between supply and demand. That is, at any given moment, the amount of electric supply capacity that is operating may exceed or may be less than load. Regulation is used for damping of that difference.

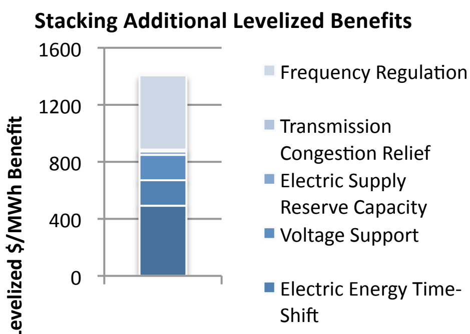
ANALYSIS METHODOLOGY: PEAKER VS. ENERGY STORAGE

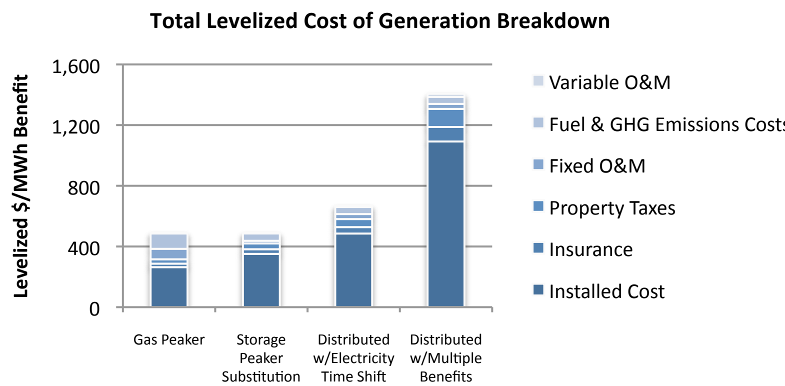
For further examination of the analysis above and access to the spreadsheet model used for the above analysis, see the following website: http://storagealliance.org/work-presentations.html

ANALYSIS METHODOLOGY: ADDITIONAL BENEFITS

Unlike a single-use centralized peaker plant, energy storage can be used for a multitude of applications beyond those of simple peaker plant substitution. When reasonable and "stackable" additional benefits are factored into the maximum allowable installed cost, energy storages' 'cost effective' price point increases. This means that energy storage technologies that are technically capable of capturing these additional benefits should be cost effective even at higher installed costs.

To help illustrate the impact of additional value streams to the maximum allowed installed cost of grid-integrated storage, we utilized the midpoint of the Sandia report benefit estimate for each value stream[17], and utilized the same 20 year time horizon and targeted return for investors and solved for the maximum *increase* in installed cost of the storage system resulting from these added benefits. The incremental allowable installed cost for energy storage was then added to the maximum allowable installed cost per kWh of energy storage capacity calculated for the peaker substitution. To be conservative, we further adjusted operating assumptions for each benefit to allow for increased transaction and maintenance costs for distributed systems to arrive at the final installed cost/kWh capacity of the energy storage system, as indicated in the chart below.





[17] Source: SANDIA Report SAND2010-0815, Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide, Jim Eyer & Garth Corey (February 2010)