Energy Storage
The Missing Link in the Electricity Value Chain

An ESC White Paper

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# Table of Contents

- Executive Summary 3
- Energy Storage and the New Power Market 5
- Energy Storage Applications 10
- Public Policy 14
- Energy Storage Technologies 16
- Impact on Key Stakeholders 18
- Market Opportunities 19
- Going Forward 20
- The Energy Storage Council Charter 22
- About Pearl Street 23
Executive Summary

The continuing evolution of the U.S. electric power industry has been stymied because the electric power market is incomplete. Unlike other successful markets, it has no growing storage component. Energy markets need storage in order to successfully emerge from deregulation—witness the successful evolution of the gas industry. Without a storage component, the market will not function properly and price spikes, instability and volatility will remain chronic problems. Many of the market-based services (like tailored end-use products) that make the gas industry as flexible as it is today only became available by leveraging storage capacity.

What is Energy Storage?

At its heart, energy storage is an economic decision. Without storage, an industry must develop and maintain an entire delivery network capable of meeting the highest peak of the year at any given moment. Without storage, the industry must operate within a "just-in-time" framework that is dependent not only on variable end-use demands, but is also completely at the mercy of one of the most uncontrollable variables known: weather. With storage, the owners only must build out what is necessary to carry a heavy, but normal load—resulting in a much higher utilization of the existing equipment, and hence a higher return on their investments (ROI).

Although electricity cannot be directly stored (cheaply), it can be easily stored in other forms and converted back to electricity when necessary. The additional value of the electricity during peak demand can cover the cost of storing power produced at night. As demand continues to expand, storage can play a crucial, multi-functional role since storage facilities are designed to excel in a dynamic environment. Other factors driving the introduction of storage technologies include reduced environmental impact, solving many of the challenges regarding the increased use of renewable energy sources, and enhancing energy security measures. These issues are all key components of President George W. Bush's National Energy Policy.

How Storage Helps

Without a means to store electricity, a number of conditions will remain endemic to the industry: 1) raised volatility, 2) reduced reliability and stability, and 3) threatened security. By utilizing energy storage technologies, each of these challenges facing the industry can be greatly diminished thereby leading to a more efficient market that costs less to operate, that is more responsive to market changes, and that is more reliable in the event of a disruption.

Energy storage technologies provide a wide spectrum of capabilities that will perform a number of applications throughout the market. These capabilities can be grouped into three market roles: 1) energy management, 2) bridging power, and 3) power quality & reliability. Since the purpose is to act as a ‘shock absorber’ to the system, the incremental and beneficial impacts will accumulate as they are implemented.
**Market Role**

By supplying power when and where needed, energy storage will create a far more responsive market. It will:

1) Reduce the need for additional transmission assets,
2) Be the preferred supplier of ancillary services,
3) Provide better integration of renewables into the system,
4) Support more efficient use of existing assets,
5) Improve the reliability of electricity supply,
6) Increase the efficiency of existing power plant and transmission facilities, and
7) Reduce the investment required for new facilities.

The current power market suffers from uncertainty. The regulatory framework is incomplete, obvious market leaders have fallen, and the winning business models are still not defined. Energy storage can help by improving the economic efficiency and utilization of the existing system, not by replacing it. By optimizing the existing assets in the market and creating more opportunities, increased private industry investment will move into the market prompting greater competition and lower prices.
Energy Storage and the New Power Market

The U.S. electric power industry is stalled halfway through an epic transformation. Its challenge now is to finish changing from an industry governed by rigid command-and-control regulations to one where the competitive pressures guide the development of new products and services. So far, the results have been mixed. Unlike any other successful market, it has no storage component. Without some way to store power, the electric power market will continue to be stuck halfway, and both producers and consumers will continue to experience the results.

Energy storage is poised to play a pivotal role in the new power market. Although electricity cannot be directly stored (cheaply), it can be easily stored in other forms and converted back to electricity when necessary. The additional value of the electricity during peak demand more than makes up for the cost of storing power produced at night. The electric power market currently has five primary parts: fuel/energy source, generation, transmission and marketing, distribution, and energy services. By supplying power when and where needed, energy storage is on the brink of becoming the "sixth dimension" of the electric power market by integrating the existing segments and creating a more responsive market. Storage will improve the reliability of electricity supply, increase the efficiency of existing power plant and transmission facilities, and reduce the investment required in these facilities.

What is Storage?

Without storage, industry must develop and maintain an entire delivery network capable of meeting the highest peak of the year. With storage, the owners only need build out what is needed to carry a heavy but normal load. Storage, therefore, translates into a much higher utilization of the existing equipment and a higher return on investment (ROI). Without sufficient storage capacity in the electric power industry, excess generation and transmission facilities, which are necessary to meet peak demand, remain underused for much of the year. On average, power facilities are used only 55% of the time; and transmission systems are only marginally better at 60%. By establishing a number of caches of energy along the value chain, storage can balance supply with demand on short timelines. This allows for a more efficient use of the existing resources in the market, lowering prices and improving the quality of the service.

In effect, storage functions as a "shock absorber" for the nation's electric infrastructure, enhancing its efficiency, reliability and security. By maintaining even a relatively modest amount of reserves, storage facilities—big and small—will have a positive impact on the market.
Benefits of Energy Storage
Along the Electricity Value Chain

Challenges

Volatility  Low Utilization  Congestion  Security  “Dirty” Power

Fuel  Generation  Transmission  Distribution  Services

Energy Storage

Benefits

Without Storage
Without a means to store electricity, a number of conditions will remain endemic to the industry. Three are of particular concern:

- **Raised Volatility**: Higher and more unpredictable prices which lead to reduced investment by manufacturing and service industries in that region.
- **Reduced Reliability**: Lower assurance that high quality power will be continually available raises the cost of doing business due to the risk of damaged equipment.
- **Threatened Security**: Problems in one part of the power grid spread everywhere within seconds. Fewer backups mean a greater chance of system disruption from an unforeseen failure and open the whole system up to a much higher probability of greater damage from sabotage.

Other problems that stem from a lack of resilience in the system include constrained transmission capacity, unrealized existing asset capability, inhibited growth of renewable technologies, and a destabilized carrying capacity of the nation’s power grid.
How Storage Helps

By utilizing energy storage technologies, each of these challenges facing the industry can be greatly diminished—leading to a more efficient market that costs less to operate and that is more responsive to market changes and reliable in the event of a disruption. The implementation of energy storage facilities increase the system-wide ability to:

**Dampen Volatility:** By providing power during shortages and absorbing power during times of excess, price and physical availability swings will diminish.

**Create Efficient Markets:** Storage will increase the utilization of existing assets, prompting private industry to invest and increase the availability and quality of power.

**Improved Safeguards:** Readily available energy stored throughout the system will prevent disruptive events from spreading and affecting the entire grid.

Load Profile of a Large-Scale Energy Storage Facility

Large-scale storage systems will provide the ability to use low-cost power during peak demand periods of the day—reducing the need for high-cost peaking plants to cycle on and off and lowering the volatility of the wholesale market. By removing the bottlenecks within the transmission system, these facilities will also reduce power transmission losses and improve the quality and reliability of delivered power.
Reducing Electricity Demand Lowers Peak Prices

Smaller-scale energy storage systems also have a tremendous role to play in the upcoming deregulated electric power market. By one Department of Energy (DOE) estimate, $150 billion dollars of work is lost or wasted due to poor power quality and reliability at customer’s sites. Although peak shaving is a significant virtue of consumer-located energy storage facilities, the real benefit will be in preventing damage or losses to ongoing business activity and saving far more revenue than the plant or office’s electric bill by reducing downtime and increasing productivity.

The Gas Storage Industry

We have to look no further than the natural gas industry to see a successful use of storage in an energy market. Gas storage adds needed flexibility in the market, and federal energy policy played a pivotal role in transforming the storage market to the one we know today. Similar attention to the electric power industry’s use of storage could spawn a comparable renaissance in this industry’s ability to foster flexibility, reliability, and security.

Prior to deregulation, the expansion of the gas storage market was used primarily to hold down the cost of infrastructure expansion. Gas was shipped to the demand regions during the summer and stored in underground reservoirs for use during the winter months. As part of the deregulation of this industry, gas storage was separated from the “bundle” of services rolled into the transmission cost of gas and end-users were forced...
to choose how or whether they would use the service. The results are impressive. Far more flexible storage facilities have dominated new facility development since deregulation, leading to a number of products and services within the market that make it more efficient.

Indeed, gas storage has grown to become a critical “dimension” in making gas markets efficient. Without it, trading, reliability, and tailored services would all be far more expensive—and in the worst case not available at all. As the electricity market restructures, it will also need to rely upon a growing capacity to store energy to improve its efficiency, and dampen volatility.

Storage’s Changing Impact on the Gas Industry

Energy Storage Can Help Now—And in the Future
Even as the country addresses the problems of the current market, more challenges await as demand for power continues to grow unabated. Each year, demand for power increases about 2%—more in good years, less in slow ones. To meet this, we add a little more than 3% to capacity each year (peak demand grows faster than the average demand). Unfortunately, transmission capability has not expanded to meet the growing need, causing an increasingly intractable constraint problem. As demand continues to expand, storage facilities, which are designed to excel in a dynamic environment, can play a crucial, multi-functional role in alleviating this constraint. Storage facilities that store power for arbitrage can also maintain the stability of the system and provide protection for the network in case of a disruption.

All industries need a storage component to operate properly. As we have seen with the gas industry, energy markets also need storage to emerge successfully from deregulation. Without it, the market will not function as efficiently, and price spikes and
shortages will become chronic problems. Many of the market-based services (like tailored end-use products) that make the gas industry as flexible as it is today only became available through leveraging storage capacity.

Energy storage could have an even larger impact on the power market. This industry is three times the size of the gas industry and operates on a much faster and dynamic basis—what happens in the gas market on a seasonal or monthly basis happens daily in the electricity business. Since storage was added to manage the gas system, the industry has installed fewer miles of pipe to handle the increased load and the capacity factor on the existing system has risen. Storage can do the same for the electricity market by reducing the amount of new generating and transmission capacity that would otherwise need to be built. Storage will also increase the utilization of the existing generating assets and transmission system, lowering costs. Right now, it operates with very little dynamic storage; without adding any, the chronic supply, delivery, and pricing problems will continue.

The current power market suffers from uncertainty. The regulatory framework is incomplete, obvious market leaders have fallen by the wayside, and the winning business models are still not defined. Energy storage facilities do not promise to fix all of the industry’s woes; what they can do is to remove some of the uncertainty by providing a scheduled resource. In this way, they can help consumers avoid the worst of the new market (high prices) while increasing reliability, security, and by giving both consumers and investors new choices and opportunities—precisely what the Government wanted from deregulation.

**Energy Storage Applications**

Electricity and Stability. It's what the electric power transmission system needs and it's what energy storage facilities provide. Energy comes in the form of megawatt-hours (MWh) of electrical power that is transported across the network to light our homes, run our computers, and power our factories. Stability is needed in a form of energy called reactive power and is needed for the stability and proper working of the grid; they must be managed together to provide reliable service.

The U.S. transmission system is really one big, real-time balancing act. As electrical power flows from the power plants to the customers, conditions on the grid are always changing as loads turn on and off, disruptions occur (such as a downed power-line), and wholesale power moves across the network. Currently, to counter-balance these changes, utilities ramp power plants up or down second by second in order to follow the load. As the congestion on the transmission system increases, utilities are spending significant sums for stabilizing equipment. On top of this, utilities have been upgrading their networks to promote "net-metering," the capability of selling power back to the grid. Although this will benefit customers, the stability of the grid will suffer. Energy storage facilities could be an answer to many of these issues. Some technologies are designed to provide long-duration discharges of energy, while others focus their discharge capability on a shorter timeframe and higher power delivery. By providing energy
resources on demand, these assets can help to increase the utilization of existing generation and transmission facilities, improving their efficiency. Storage facilities can also provide for a means to inject bulk energy to curtail peak demands on the power facilities, and reactive power to maintain a stable and working grid. Some of the more important roles energy storage could play include:

**Generation**

**Commodity Storage:** Storing bulk energy generated at night for use during peak demand periods during the day. This allows for arbitraging the production price of the two periods and a more uniform load factor for the generation, transmission, and distribution systems.

**Contingency Service:** Contingency reserve is power capacity capable of providing power to serve customer demand should a power facility fall off-line. Spinning reserves are ready instantaneously, with non-spinning and long-term reserves ready in 10 minutes or longer.

**Area Control:** Prevent unplanned transfer of power between one utility and another.

**Frequency Regulation:** Maintain a state of frequency equilibrium for the system’s 60Hz (cycles per second) during regular and irregular grid conditions. Large and rapid changes in the electrical load of a system can damage the generator and customers’ electrical equipment.

**Black-Start:** Units with the capability to start-up on their own in order to energize the transmission system and assist other facilities to start-up and synchronize to the grid.

**Transmission and Distribution**

**System Stability:** The ability to maintain all system components on a transmission line in synchronous operation with each other to prevent a system collapse.

**Voltage Regulation:** Maintain a stable voltage between each end of all power lines.

**Asset Deferral:** Defer the need for additional transmission facilities by supplementing and existing transmission facilities—saving capital that otherwise goes underutilized for years.

**Energy Service**

**Energy Management:** Allows customers to peak shave by shifting energy demand from one time of the day to another. This is primarily used to reduce their time-of-use (demand) charges.


**Power Quality:** Provides electrical service to the customer without any secondary oscillations or disruptions to the electricity "waveform" such as swells/sags, spikes, or harmonics.

**Power Reliability:** Provides bridging power (UPS) for consumers to 'ride-through' a power disruption. Coupled with energy management storage, this allows remote power operation.

**Multifunctional Capabilities**

Practically all energy storage facilities are expected to perform a number of support functions—that is after all one of their greatest strengths. Besides energy and power, the duration of the discharge and the depth of discharge required for each segment of the value chain help determine which technology's capability envelope fits with the required capabilities. These multiple role requirements coincide with the area of the grid that they will support:

**Generation:** Energy storage facilities supplementing generation facilities are the largest of the energy storage technologies, with their primary focus being to provide energy to the grid in long duration discharges on a daily or hourly schedule. This role allows for increasing the value of the off-peak generating capability and increasing the utilization of these assets.

Storage facilities can also provide contingency reserves for periods when the grid has a sudden shortfall of energy. If that shortfall is massive and causes a complete failure of the grid, storage facilities can assist in the re-energizing of the grid with its black-start capability. These facilities also provide wide-area support and regulation to the power grid.

**Transmission and Distribution:** Energy storage facilities designed to support transmission and distribution networks maintain the stability and reliability of the grid. These facilities are more concerned with the ability to quickly inject stabilizing power—not long-term energy—into the grid with a short discharge, but a faster reaction time.

Although the advent of Regional Transmission Organizations (RTO) formation is allowing more widespread movement of power, it does not change basic physics; the grid is only designed to deliver so much power, no matter how many wholesale delivery contracts that are sold. Transmission facilities take a long time to be permitted and built. They are always expensive, and in some cases may not get built at all. With RTO's or without, storage facilities can play an integral part in enhancing the quality of the national transmission and distribution system.

**Energy Service:** Although the desire to reduce the cost of power is very important to large consumers, the desire to prevent disruptions in their energy service from
affecting their manufacturing processes is even larger. Therefore, energy storage systems in this market are primarily designed to improve the use of power at a customer’s site rather than generate income. These facilities do not necessarily have the discharge endurance of some of the larger systems, but rather focus on the response time and power deliverability.

Energy storage facilities can be used in three primary roles in the retail energy sector: reducing energy costs through peak shaving, improving the quality of power, and providing increased reliability of service. The size of the facility is wholly dependent upon the customer’s demand. Generally, it is designed for repeated, small discharges for power conditioning service with the ability to provide limited bridging power to essential equipment during an outage.

**Renewable Energy**

One of the greatest challenges facing our nation is how to harness and deliver our immense renewable energy resources. Developing these resources will not only improve the environment but also increase our energy security and improve the competitiveness of our country’s renewable energy producers by providing a growing market for their products.

However, renewable energy resources have two problems. First, many of the potential power generation sites are located far from load centers. Although wind energy generation facilities can be constructed in less than one year, new transmission facilities must be constructed to bring this new power source to market. Since it can take upwards of 7 years to build these transmission assets, long, lag-time periods can emerge where wind generation is "constrained-off" the system. For many sites this may preclude them from delivering power to existing customers, but it opens the door to powering off-grid markets—an important and growing market. One of the largest proponents and users of these systems is the Department of Defense for its integration of solar and battery storage systems for use in solar power for remote communication installations.

The second problem is that most of the power that is generated that is accessible to the grids is generated when there is low demand for it. By storing the power from renewable sources from off-peak and releasing it during on-peak, energy storage can transform this low value, unscheduled power into schedulable, high-value products (see exhibit). Beyond energy sales, with the assured capability of dispatching power into the market, a renewable energy source could also sell capacity into the market through contingency services.

This capability will make the development of renewable resources far more cost-effective—by increasing the value of renewables it may reduce the level of subsidy down to where it is equal to the environmental value of the renewable, at which point it is no longer a subsidy but an environmental credit.
Renewable Energy Sales into Peak Market Prices
With Energy Storage

Public Policy
The current regulatory environment is changing to harness the capabilities of the new economic realities and technical developments in the industry. As the government encourages and facilitates this new market design, the storage community is simply looking for an equal playing field to compete for opportunities to sell low-cost power and provide ancillary services. As was seen in the gas storage industry, when the Federal government took steps to promote the further use of storage, the entire market benefited from its existence in a competitive and fluid environment.

Federal and State governments are currently working to modernize existing regulations by establishing a standardized transmission service and market design for electric power market. Existing market participants have sometimes curbed development of competitors by providing unequal access to the market for these new entrants verses the incumbent's own subsidiary. The Energy Storage Council's goal is to have the market evolve into one where free competition for services sets the basis for relative strength in the market—not a corporate bloodline.
National Energy Policy

By reviewing the Administration’s new National Energy Policy, we can see how energy storage facilities will help meet its goals. The new policy has three guiding principles: 1) the policy is a long-term, comprehensive strategy, 2) the policy will advance new, environmentally friendly technologies to increase energy supplies and encourage cleaner, more efficient energy use, and 3) the policy seeks to raise the living standards of the American people, recognizing that to do so our country must fully integrate its energy, environmental, and economic policies. The Administration has urged action on five specific goals:

1. Modernize conservation.
2. Modernize the energy infrastructure.
3. Increase energy supply.
4. Accelerate the protection of the environment.
5. Increase our nation’s energy security.

Energy Storage technologies and facilities can be instrumental in meeting each of these stated goals:

**Modernize Conservation:** Energy storage will help modernize conservation practices by optimizing the economic and environmental profiles of fossil and nuclear assets through reducing dispatch and cycling costs and/or providing new electricity products to the market.

**Modernize Infrastructure:** Energy storage will help modernize the nation’s electric power infrastructure by enhancing its efficiency, reliability and security. By operating assets in a more systematic and enhanced role, private sector firms will invest to upgrade the system.

**Increase Energy Supply:** Energy storage will increase the productivity of domestic resources in two ways. First, by increasing the efficiency of existing power plants, our existing re-sources will go farther. Secondly, storage will promote renewable energy use thereby adding domestic resources to the fuel source.

**Protect the Environment:** Storage facilities will help reduce the environmental impact of existing power facilities and more quickly and efficiently integrate renewable ones into the system. By operating existing facilities in a more efficient manner, they will produce less waste and reduce dispatch and cycling costs.

**Security:** Energy storage facilities enhance the reliability of the grid. Reservoirs of energy stored at dispersed sites are less vulnerable to disruption, and can be called up at a moments notice to: 1) reduce volatility, 2) enhance the reserve margin, and 3) provide the necessary ancillary services critical to the proper workings of the transmission and distribution system.
Energy Storage Technologies

A number of technologies exist that are commercially viable now. These include:

**Pumped-Hydro Storage:** Pumped-hydro storage (PHS) is the oldest and largest of all of the commercially available energy storage technologies. Facilities exist in size up to 1,000 MW. Conventional pumped hydro facilities consist of two large reservoirs; one located at a low level and the other is situated at a higher elevation. During off-peak hours, water is pumped from the lower to the upper reservoir, where it is stored. To generate electricity, the water is then released back down to the lower reservoir, passing through hydraulic turbines and generating electrical power. Pumped-hydro storage facilities generally operate on a daily schedule, with many facilities operating as a conventional power facility for irrigation or other public uses. Due to high construction costs, long construction times, and the requirement of large amounts of land, only a few additional facilities are probable.

**Compressed Air Energy Storage (CAES):** Compressed air energy storage (CAES) systems use off-peak power to pressurize air into an underground reservoir (salt cavern, abandoned hard rock mine, or aquifer) which is then released during peak daytime hours to power a turbine/generator for power production. The idea behind this technology is to substitute the low-cost power from an off-peak baseload facility for the more expensive gas turbine-produced power to compress the air for combustion. In a gas turbine, roughly two thirds of the energy produced is used to pressurize the air. Since CAES facilities have no need for air compressors tied to the turbines, they can produce two to three times as much power as conventional gas turbines for the same amount of fuel. Compressed air energy storage is the only other commercially available technology (besides pumped-hydro) able to provide the very-large system energy storage deliverability (above 100MW in single unit sizes) to use for commodity storage or other large-scale setting. Two plants currently exist, with several more under development. The first operating unit is a 290 MW unit built in Huntorf, Germany in 1978. The second plant is a 110 MW unit built in McIntosh, Alabama in 1991. Both facilities utilize salt caverns for their underground air reservoir. The third will be a 2,700 MW facility (when fully built out, the initial unit is 270 MW) in Norton, OH that will use an abandoned limestone mine as the reservoir.

**Regenerative Fuel Cells:** Regenerative fuel cells—also known as redox flow-cell batteries—are capable of storing and releasing energy through a reversible electrochemical reaction between two salt solutions (electrolytes). Different designs exist around zinc bromide (ZnBr), and sodium bromide (NaBr) as the electrolytes. Charging of the facility occurs when electrical energy from the grid is converted into potential chemical energy. Release of the potential energy occurs within an electrochemical cell with a separate compartment for each electrolyte—physically separated by an ion-exchange membrane. The technology is a closed loop cycle, so there is no discharge of the regenerative electrolyte solutions from the facility. The scale of the facility is based primarily on the size of the electrolytic tanks, giving promise for this technology to join CAES and pumped hydro as large-scale energy storage options. One facility (15 MW, 120MWh) is under construction in the UK, with another (12 MW, 120 MWh) set for operation by the Tennessee Valley Authority (TVA) in 2003.
**Batteries:** A number of battery technologies exist for use as utility-scale energy storage facilities. Primarily, these installations have been lead-acid, but other battery technologies like sodium sulfur (NaS) and Lithium ion are quickly becoming commercially available. All batteries are electrochemical cells. They are composed of two electrodes separated by an electrolyte. During discharge, ions from the anode (first electrode) are released into the solution and deposit oxides on the cathode (second electrode). Reversing the electrical charge through the system recharges the battery. When the cell is being recharged, the chemical reactions are reversed, restoring the battery to its original condition. A number of installations exist including a 40 MWh (10MW) facility in Chino, CA and a 20 MW in Puerto Rico. These facilities can provide a number of applications covering the industry in the generation, transmission and energy service sectors.

**Superconducting Magnetic Energy Storage (SMES):** Superconducting Magnetic Energy Storage (SMES), an emerging technology, systems store energy in the magnetic field created by the flow of direct current in a coil of cryogenically cooled, superconducting material. A SMES system includes a superconducting coil, a power conditioning system, a cryogenic refrigerator, and a cryostat/vacuum vessel to keep the coil at the low temperature required to maintain the coil in a superconducting state. SMES are highly efficient at storing electricity (greater than 95%), and provide both real and reactive power. Power is available almost instantaneously, and very high power output is provided for a brief period of time. Due to their construction, they have a high operating cost and are therefore best suited to provide constant, deep discharges and constant activity. These facilities currently range in size up to 3 MW units, and are generally used to provide grid stability in a distribution system and power quality at manufacturing facilities requiring ultra-clean power such a chip fabrication facility.

**Flywheels:** A flywheel energy storage system stores energy through accelerating a rotor up to a very high rate of speed and maintaining the energy in the system as inertial energy. Advanced composite materials are used for the rotor to lower its weight while allowing for the extremely high speeds. Energy is stored in the rotor in the amount proportional to its momentum and the square of the angular momentum. The flywheel releases the energy by reversing the process and using the motor as a generator. As the flywheel releases its stored energy, the flywheel's rotor slows until it is discharged. Although current flywheel technology is most developed in the auto and aerospace industry, flywheels are increasingly being targeted for power delivery capabilities in the 500 kW range. These systems are compact and have lower maintenance costs and requirements than battery systems. The main focus for development of this technology has been the power quality and reliability market.

**Thermal:** Not generally thought of as one of the new, high-tech energy storage technologies, thermal energy storage systems already exist in widely used applications. Thermal systems can either be ice-based for peak shaving commercial and industrial cooling loads or molten-salt based for steam production. The ice systems create ice during off-peak hours, which is used during the day to supplement the cooling load for large commercial buildings, allowing for smaller chillers and substantially lower air conditioning operating costs—particularly peak demand charges. Molten salt thermal
systems are still in the development phase, but hold out promise to extend the ability of solar and other renewable energy resources to continue operating past the peak period of the sun’s daylight hours.

Hydrogen: Hydrogen energy storage is still in the developmental stages as well, but will be an integral component of any post-fossil energy market. The hydrogen can be stored in a gas, liquid, metal hydride, or carbon-based form, which is then released through a chemical reaction to power a fuel cell. Most storage systems can be used for both stationary and vehicle applications. For long-term stationary storage, chemical hydrides are the preferred method. However, there are no current commercial chemical applications for carbon-based hydrogen storage systems due to cost considerations.

Impact on Key Stakeholders

Energy storage promises to be a truly enabling technology that will positively impact the entire value chain. Most parties will gain, the only losers being those that have profited off of an unfair advantage by serving restricted customers locked into a dysfunctional market. As consumer become free to better their own position, the entire market will benefit and the gains promised from free competition will occur as the industry’s transformation unfolds.

Estimates range from $25 billion to $400 billion for what poor power quality costs the United States economy. By improving the stability, reliability and quality of power, the DOE estimated in 1993 that energy storage facilities could have a $57.2 billion positive impact from the widespread use of “high-density storage devices to…. store power during off-peak periods and deliver it when loads exceed generating capacity.” The Energy Storage Council has updated this forecast and found that figure to have grown to $148.8 billion over the next fifteen years. As energy storage facilities and systems are developed, five groups within the market will receive the greatest impact from the expansion of energy storage into the market:

Fuel Providers: The storage of electricity brings to the fuel providers the ability to bridge the power generation segment and its volatile spark spread. Since fuel costs represent 60%-80% of the costs at fossil facilities, the capability to lock in another set price for generation will give these players the ability to provide better risk management services to their clients.

Generators: Owners of coal-fired baseload power plants will have the opportunity to operate on a more uniform basis throughout the day. By generating and storing power at night, the facility will generate more revenue with very little additional fuel costs while their operating and environmental costs decrease through higher productivity and utilization.

Transmission and Distribution: By optimizing the operation of the transmission and distribution network, additional facilities can be deferred. This is one of the major benefits that storage facilities can provide, since each mile of a new transmission line can easily cost $1 million. Greater transmission stability will be
provided to RTOs since storage facilities possess faster reaction times than generating facilities (the entities currently providing most of the network stability) for ancillary services.

**Energy Services:** By storing power on-site, commercial and industrial consumers will not only significantly lower their energy costs, but also ensure a higher level of power quality and reliability. Poor power quality and reliability causes losses for all types of businesses; a five-minute power loss at a computer chip manufacturer can cost millions of dollars in lost work. This aspect of storage has major efficiency and productivity implications for US manufacturers.

**Renewable Energy Sources:** Not only does energy storage transform low value, unscheduled power into high-value product that can be scheduled into the market during peak demand, but storage also makes off-grid electrical systems that much more capable by allowing for a wider variety of generation sources.

As you can see, the strength of an energy storage facility is not in replacing an existing component of the electricity value chain; rather, it allows the existing ones to do their job better and cheaper. Without storage facilities situated along the value chain, additional and unnecessary expenditures will need to be made that will drive up the cost of power while giving us a lower-level of quality and reliability.

**Market Opportunities**

As the electric power industry evolves, different business models have developed to take advantage of the changing economic and technical marketplace realities. This same transformation will take place within the energy storage market. Since their applications cover the spectrum of the market, no single “business model” will suffice; however, four areas do hold out promise for a multifunctional energy storage facility to operate: baseload arbitrage, transmission support, energy services, and renewable energy storage. The first two exist in the wholesale side of the market, the second in the retail segment, and the fourth can exist in both the wholesale and retail market, depending upon the size of the renewable resource being developed.

Since storage facilities are capable of operating in a multifunctional role, new facilities are expected to perform more than one of these roles depending upon whether it is in the wholesale or retain end of the market. With the rise of this new technology, the question begs asking, could a “Storage Utility” emerge? Could one company focus solely on this one technology and create a viable business? When gas turbines entered the market, independent power producers sprang up, growing into today’s merchant power producers. However, storage facilities work best augmenting—not replacing—existing assets. Therefore, although a “storage utility” could emerge, a competing scenario is that existing energy market participants will incorporate storage technologies into their market strategies to enhance and extend the capabilities of their existing assets, be they generation or transmission.
**Baseload Arbitrage:** Arbitraging baseload nuclear and coal-fired generation between off-peak and on-peak hours represents the largest possible revenue-generating market opportunity for large-scale storage facilities. The amount of revenue generated will rest on a number of factors, but primarily the difference between day and night prices will be the determining factor. If the storage facility is owned by the same entity that owns the coal facility that will supply the power, the same firm will reap the additional benefits from a better performing baseload facility.

**Transmission Support:** Recent movement by FERC has brought to light what many have been saying for a long time; transmission issues are starting to take center stage in the deregulation of the industry. For some regions with chronic transmission constraints, additional power facilities simply add to the problem. Owners of transmission assets will be interested in the ability to defer facilities and improve utilization. RTO operators will be interested in storage facilities to provide ancillary services to maintain the grid’s stability to support a growing power trading market and relieve congestion.

**Energy Services:** At the customer site, prevention of poor power quality and reliability has driven many manufacturing and commercial facilities to install protective gear to either minimize or reduce the impact of outages on the business activity of the facility. Manufacturers of batteries, flywheels, SMES, and thermal systems have targeted this market for decades. Many firms that supply enterprise energy management systems are starting to incorporate storage facilities into their rollouts.

**Renewables Energy Storage:** One of the most exciting market opportunities lies in making renewable energy more competitive in the market. Storing the energy and discharging it under a contract basis can make the electricity far more valuable. Beyond energy sales, with the assured capability of dispatching power into the market, renewable energy source could also sell capacity into the market through contingency services.

**Going Forward**
A number of challenges now face the electric power industry: volatile wholesale market, increasing transmission constraints, and uncertainty on the part of customers as to what this has all meant. For the future, three issues will play a role in the development of energy storage:

**Government Role**
Prior to deregulation in the electric power industry, utilities had no incentive to create storage facilities. Although storage facilities replace the need for more expensive power plants, the later could be more easily rolled into the rate-base. Deregulation has changed that. In the competitive market, companies will make money based on their competitive position in the market instead of on a cost-of-service plus regime basis.
Large-scale storage facilities hold out great promise to improve the reliability of the grid, but one plant does not make an industry. To allow private sector participants to recoup their investments and make a return commensurate with their market risk, storage technologies must be given an equal footing in forthcoming regulations.

By including energy storage facilities in government planning and policy alternatives, the government will provide additional choices for consumers. Lowering consumer prices through avoiding high-cost spot power prices is one of the main tenants of Federal and State Government’s focus. Energy storage facilities are the single most effective tool in addressing these issues and in providing the most benefit when prices are volatile.

**Market Role**

Energy storage technologies provide a wide spectrum of capabilities that promise a similarly wide range of beneficial applications. Since their purpose is to act as a ‘shock absorber’ to the system, their incremental and beneficial impacts will accumulate as they are incorporated into the system. These capabilities can be grouped into three market roles:

- **Energy Management:** Arbitraging the commodity value of energy between low-cost off-peak power and high-cost peaking power—making it much more valuable to the market. Applications include: load leveling, transmission asset deferral, and peak shaving.

- **Bridging Power:** Provides bridging power to assure a continuity of service for seconds to minutes when switching from one source of generation to another. Applications include contingency reserve and uninterruptible power supplies (UPS).

- **Power Quality & Reliability:** Maintains the grid’s stability and protects sensitive manufacturing and computer equipment from unpredictable changes measured in milliseconds in the voltage and frequency of the power. Applications include systems stability, voltage regulation, and power quality and reliability.

**Market Benefits**

Storage facilities are not the only answer to the current high prices, low utilization, and poor power quality plaguing the industry—they’re just one of the cheapest and most efficient ones. Instead of attempting to provide all of the benefits to the market, a storage facility’s greatest strength is to improve the economic efficiency of the existing system, not replace it.

By optimizing the existing assets in the market, these facilities (power plants, transmission lines, etc.) will make more money, and hence be worth more. This greater value will entice more private industry investment into the market, prompting greater competition and lower prices—which is, after all, the ultimate goal of deregulation and competition.
The Energy Storage Council Charter

The Energy Storage Council (ESC) was formed to support the energy storage community in its effort to accelerate the introduction of energy storage systems and technologies into the marketplace. In order to accomplish this, a principal Council objective is to raise awareness of the ‘role of energy storage’ among, the public, policymakers and private business. To accomplish this objective, the ESC will:

- Represent the energy storage industry before public, governmental and quasi-governmental bodies.
- Enhance member company knowledge and understanding of legislative, regulatory, judicial, economic and technical developments relating to the energy storage industry.
- Increase public knowledge and understanding of energy storage and the industry through educational and informational programs.
- Encourage the use of energy storage in specific markets through promotional and/or market development programs.
- Collect and publish industry, economic and other statistical data.
- Develop industry public policy positions and recommend industry standards.

Policy Public Focus

The ESC is defining how energy storage can modernize the nation's energy infrastructure to enhance its efficiency, reliability and security, and work with government officials to:

- Determine how we can best specify and deploy the proper energy storage option for today’s power industry storage to improve the business case for renewable, fossil and nuclear power on the grid and in distributed generation systems.
- Demonstrate how the judicious use of energy storage systems can improve the functionality of new and existing power generation, transmission and distribution systems under new business models that take into account dynamic cost profiles at power stations and dynamic electricity pricing in the market.

Organization and Affiliations

The Council’s founding members are Alstom Power, Decker Energy International, Haddington Ventures, MAN Turbo, and Ridge Energy Storage. A governing Board of Directors oversees ESC’s business affairs, policy development and communications. Business enterprises that manufacture develop or use energy storage systems are eligible for ESC membership. This includes, but is not limited to natural gas storage firms; electric utilities focused on energy storage; and renewable energy system suppliers.

The Council will work closely with allied policy and technical organizations, such as the Electricity Storage Association, Edison Electric Institute, American Wind Energy Association, American Gas Association, Fuel Cell Association, Gas Turbine Association, National Hydropower Association, and Electric Power Research Institute.
The Energy Storage Council was originally conceived and founded by Jason Makansi, President of Pearl Street, Inc. Pearl Street is a technology deployment services firm that helps clients make strategic decisions, evaluate engineering parameters and feasibility, and develop and execute effective marketing programs in order to correctly position technologies in the marketplace. Pearl Street's client base spans the electricity value chain and includes large and small firms, venture capitalists, and governments.

**Business Sectors**
- Energy Technology Ventures
- Power Generation Best Practices
- Energy Storage
- Sustainability and Industrial Ecology
- Information Technology and E-Commerce
- Consumer and Investment Strategies.

**Client Services**
- Technology evaluation
- Competitive positioning
- Tactical communications
- Engineering due diligence
- Alliance creation and partner building
- Business development programs

**Technology Expertise**
- Fuel cells
- Energy storage systems
- Distributed power systems
- Advanced power plant sensors
- Information technology and web-enabled software
- Clean coal technologies
- Advanced coal combustion
- Multi-pollutant emissions control systems
- Next-generation nuclear power systems
- Wind turbines
- Dynamic power plant asset management

For more information, visit www.pearlstreetinc.com.