AMERICAN WIND ENERGY ASSOCIATION

# Wind Power and Energy Storage

Some of the most common questions about wind power revolve around the role of energy storage in integrating wind power with the electric grid. The reality is that, while several small-scale energy storage demonstration projects have been conducted, the U.S. was able to add over 8,500 MW of wind power to the grid in 2008 without adding any commercial-scale energy storage. Similarly, European countries like Denmark, Spain, Ireland, and Germany have successfully integrated very large amounts of wind energy without having to install new energy storage resources. In the U.S., numerous peer-reviewed studies have concluded that wind energy can provide 20% or more of our electricity without any need for energy storage.

How is this possible? The secret lies in using the sources of flexibility that are already present on the electric grid. Every day, grid operators constantly accommodate variability in electricity demand and supply by increasing and decreasing the output of flexible generators – power plants like hydroelectric dams or natural gas plants that can rapidly change their level of generation. Thus, the water kept behind a dam or the natural gas held in a pipeline may be thought of as a form of energy storage, with operators using this energy when it is needed and "storing" it when it is not. Grid operators use these same flexible resources to accommodate any variability introduced by wind energy.

A tremendous amount of flexibility is already built into the power system. Demand for electricity can vary by a factor of three or more depending on the time of day and year, which nationwide translates into hundreds of gigawatts[1] of flexibility that are already built into the power system. Because these power plants and other sources of flexibility have already been built, it is almost always much cheaper to use this flexibility than to build new sources of flexibility like energy storage facilities. While continuing advances in energy storage technology can make it more economically competitive as a provider of grid flexibility, it is important to remember that resources like wind energy can already be cost-effectively and reliably integrated with the electric grid without energy storage.

**The Flexibility Supply Curve**
Figure 1 lists some of the grid resources that are available to provide flexibility, in order of increasing cost. “Markets” and “Flexible Generation” are the lowest cost options for providing flexibility, so they are the preferred resource for accommodating overall grid variability, including any incremental variability added by wind energy.

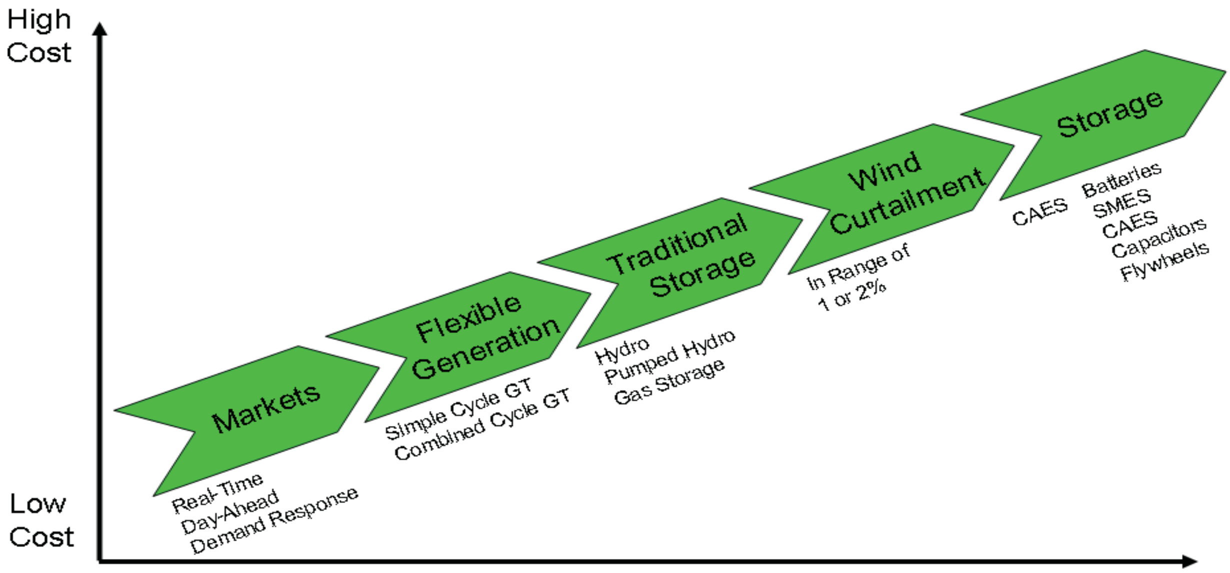


Figure 1: Flexibility Supply Curve[2]

Wind integration studies in the U.S. have consistently found that using these existing sources of system flexibility to accommodate the variability added by wind energy costs less than $0.005 per kilowatt-hour (kWh) of wind energy, or approximately 10% of the typical wholesale value of wind energy.[3] These peer-reviewed studies have also found that most regions have more than enough existing, low-cost flexible resources to accommodate wind energy providing 20% or more of a region's electricity. New energy storage systems would have to be economically competitive with these sources of flexibility.

As the penetration of wind energy continues to grow, at some point in the distant future the amount of flexibility currently available on the grid may be fully tapped. However, there are innovative ways to utilize currently untapped sources of flexibility on the existing power grid that are less costly than new storage plants. Demand response, in which large power consumers like factories briefly reduce their non-essential power consumption in exchange for lower electric rates, is already being used by several grid operators to provide a large amount of flexibility at very low cost. Improved grid operational procedures can make the scheduling and dispatch (or use) of power plants more flexible. The expansion of energy markets, as well as the creation of markets for flexibility itself, can create strong incentives for power plant owners to make their plants more flexible. The occasional curtailment (reduction) of wind output can also be a very cost-effective source of flexibility. Finally, new flexible generation, particularly natural gas-fired power plants, can be added to the grid at low cost to provide enhanced flexibility. Thus, there appears to be a vast quantity of flexible resources that can provide flexibility at lower cost than energy storage.

The high cost of energy storage is the chief reason why it is not more widely used today. As Figure 2 indicates, using energy storage to provide flexibility typically costs at least several cents per kWh for the capital costs alone (without factoring in operating costs, the value of energy lost in the conversion process, and other costs), although as the chart illustrates the capital cost varies significantly among different technologies and from project to project. In particular, the costs for building a new pumped hydroelectric storage plant (which pumps water into a higher elevation reservoir to be used later to produce electricity) are likely to be significantly higher today than the historical costs indicated in the chart, due to the increasingly limited availability of suitable plant sites as well as environmental restrictions on new construction.

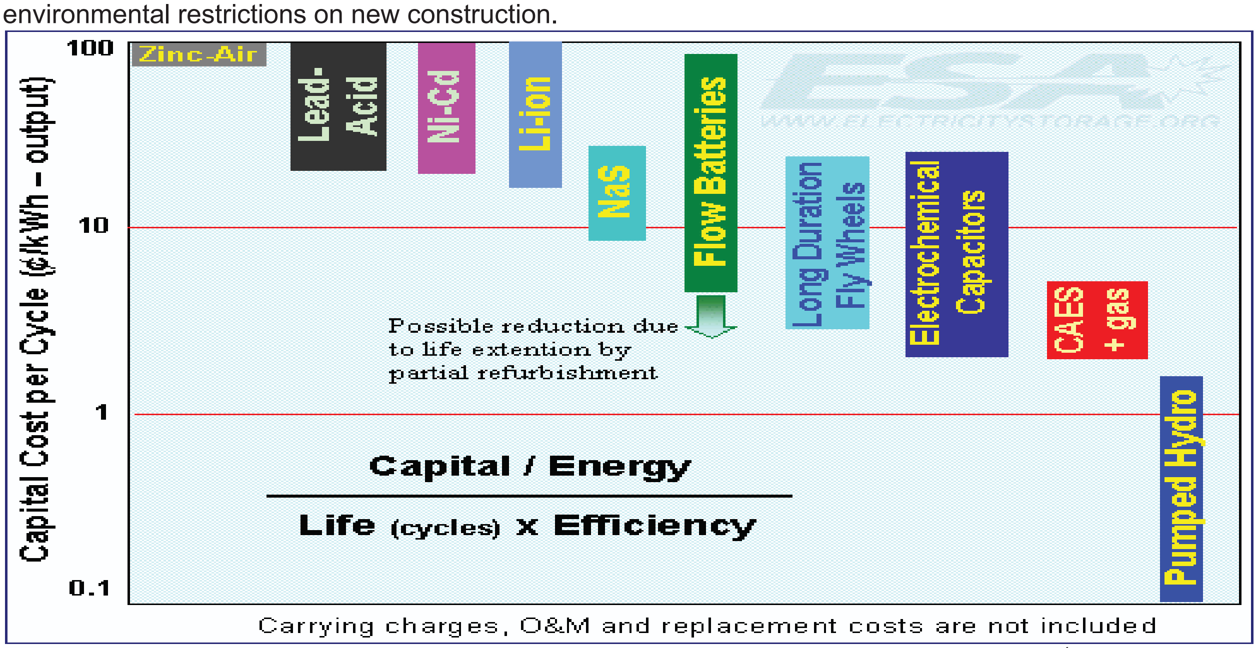


Figure 2: Capital Costs of Different Energy Storage Technologies[4]

As the chart indicates, pumped hydroelectric storage and compressed air energy storage (pumping air into underground caverns, to be used later to help drive a turbine generator) are among the lowest cost energy storage options at several cents per kWh. However, existing sources of flexibility, like hydroelectric and natural gas plants, are able to provide flexibility at a fraction of this cost. For example, the average market price in New York state for reserve generation to provide flexibility within 30 minutes is just over $0.001/kWh, or 1/10$^{th}$ of one cent per kWh.[5]

In addition, many types of energy storage are poorly suited to help accommodate the specific type of variability that wind energy adds to the electric grid. As another AWEA fact sheet entitled “20% Wind Energy by 2030: Wind, Backup Power, and Emissions” explains, wind energy output shows very little variability over the minute-to-minute timeframe, with significant changes in output only tending to occur over time periods of 30 minutes or more.[6] Fortunately, it is much cheaper to provide flexibility over these longer time periods; for example, 30-minute reserves cost 50 times less on average than second-to-second reserves in New York.[7] Some energy storage technologies, such as flywheels and advanced batteries, can be cost-effective for accommodating demand variability on the second-to-second time frame, but energy storage technologies cannot currently compete with conventional sources of flexibility for accommodating wind's longer-duration variability.

**The Myth of “Firming” Wind with Energy Storage**

Some people assume that wind output must be “firmed,” i.e. have its variability leveled out, to make it valuable to electric utilities or system operators. In reality, there is no need for individual power plants to provide constant power output; this is a good thing, as all power plants experience unexpected outages fairly frequently. As previously discussed, significant variability is already present on the electric grid due to changes in electricity demand and supply as consumers turn appliances on and off and power plants unexpectedly go out of service. Many changes in wind output actually cancel out opposite changes in electricity demand or supply. Therefore, attempting to “firm” wind can actually add to the total variability on the electric grid. Instead, it makes more sense for energy storage to be viewed as a system resource that can help even out the aggregate variability of all generators and all demand on the electric grid, and not used as a dedicated resource for a single generator or load.

In certain rare situations, it could make sense to couple energy storage with a wind plant, although no such projects have been deployed to date. If a constraint on the transmission grid prevents a wind plant or group of wind plants from selling their full output on a consistent basis, it could be economical to store electricity that would otherwise have been wasted. However, this type of application is a short-term fix; building out the transmission grid is typically the more optimal long-term solution to a transmission constraint.

**Storage: Helpful But Not Necessary For Integrating Wind**

While energy storage is not needed to integrate wind energy with the electric grid and is often not cost-effective, having certain types of energy storage on the grid can modestly reduce the cost of integrating wind. However, given the low cost of using existing flexibility to integrate wind energy, it is difficult for these storage technologies to compete economically.

The only form of energy storage that is currently operational on a large scale in the U.S. is pumped hydroelectric storage, with a little over 20 GW of installed capacity. Interestingly, much of this storage was built to accommodate the significant increase in nuclear generation that occurred during the 1960’s, 70’s, and 80’s. Just as it is difficult for wind plants to increase their output in response to grid demands, it is very difficult for nuclear plants and even coal plants to increase or decrease their output in response to commands from the grid operator. Changing the output of a nuclear or coal plant requires changing the amount of heat traveling through the plant’s steam system. The resulting temperature fluctuations can cause thermal stress to plant equipment, significantly increasing maintenance expenses and causing safety concerns.

Thus, all inflexible generators benefit when other sources of flexibility, including energy storage, can relieve them of having to accommodate changes in electricity supply and demand. In fact, a study in the Netherlands found that coal plant owners were the primary beneficiary of energy storage as it allowed coal power plants to run more at night, with this low-cost energy being stored and used to displace expensive natural gas generation during the day, interestingly causing a net increase in electric sector carbon dioxide emissions.[8]

Wind integration studies have made it possible to precisely determine the value that energy storage provides for integrating wind energy. By modeling a 10% wind penetration on the Colorado power grid with and without the presence of a 324-MW hydroelectric pumped storage plant, a wind integration study for the state of Colorado found that the pumped storage plant reduced wind integration costs by $.00134 per kWh of wind energy, which corresponds to annual savings of $2.5 million under the 10% wind scenario.[9] Given that a new pumped hydroelectric plant typically costs well over $1 million/MW of installed capacity, it would take over 100 years to pay back the initial cost of the plant based on the benefits for wind alone, without even taking into account financing or operating costs for the pumped hydro plant. Thus, energy storage has a high cost hurdle to overcome.

While energy storage technologies may currently have difficulty competing economically with conventional sources of flexibility – especially over the time frame most relevant for wind integration – continuing advances in energy storage technology can make energy storage more competitive as a provider of grid flexibility. For example, there is significant potential for the batteries of plug-in hybrid electric vehicles to be used as energy storage for the grid, because the expense of their batteries would largely be covered by the fuel savings they provide to the vehicle owner. While the potential of such technologies is exciting, it is important to remember that resources like wind energy can already be cost-effectively and reliably integrated with the electric grid without energy storage.

## References

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