Energy Storage in Deregulated Market Structures

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December 2009

Masters Project submitted in partial fulfillment of the requirements for the Master of Environmental Management degree in the Nicholas School of the Environment of Duke University
2010
Abstract

Wind energy is able to provide electricity with a minimal environmental footprint and is therefore anticipated to play a much larger role in future electricity generation. Although wind is able to provide electricity with limited environmental externalities, it produces the most electricity at night, when there is little demand, and produces the least electricity during the day, when demand is highest. One approach to address this countercyclical production is the implementation of energy storage. The ability to store electricity enables an operator to match electricity production to demand. The focus of this project is to understand the revenue generating capabilities of energy storage in deregulated market structures.

A model was developed to analyze the possible revenue generation of utility scale energy storage. The two main categories of energy storage, short-term and long-term applications, as well as two deregulated markets, ERCOT and CAISO, were evaluated. The objective of the analysis was to determine the energy storage application and market structure generated the most value. The model integrated the price of electricity and ancillary services with wind production data to determine the revenue generation of each application and each market.

The results indicate that annual revenue generation between the different energy storage applications and the different markets is very similar. Although the storage applications provided similar revenues, the rate of return for each application was very different. The short-term application offered much higher rates of returns due to significantly lower upfront capital costs. The short-term application rate of return consistently exceeded the hurdle rate while the long-term application did not. Therefore, short-term energy storage is the only recommended investment. Additionally, due to the operation parameters of the model set to maximize revenue, the production curve did not change to match demand.
Introduction

The United States has historically generated electricity primarily with coal, nuclear, and natural gas fired power plants (Schnapp, Electric Power Annual, 2009). These energy sources provide stable, predictable electricity needed to reliably meet electricity demand. However, coal and nuclear plants have unintended environmental consequences that have reduced their attractiveness as a future fuel source. Burning coal for electricity generation is the largest source of carbon dioxide emissions in the United States (Human-Related Sources and Sinks of Carbon Dioxide, 2009). Intensive emissions of carbon dioxide over the past century have made it the greenhouse gas most attributable to anthropogenic global climate change (IPCC, 2007). While nuclear power generation emits no carbon dioxide, it creates nuclear waste that lasts for thousands of years with no environmentally safe method of disposal (Nuclear Waste Disposal).

Due to the environmental externalities of nuclear and coal generation, the focus on developing and integrating renewable energy into the electricity generation portfolio has become increasingly important. Renewable energy such as wind and solar emit no carbon dioxide and produce no toxic waste. However, renewable energy lacks the reliability of coal, nuclear, and natural gas generation. Renewable energy sources generate electricity only when the resources are available. This intermittency of renewable energy creates problems matching electricity production with electricity demand (Korpass, Holen, & Hildrum, 2003). The typical demand curve is represented by an increase in demand during daytime hours and decreased demand at night (Tseng & Costello, 2004).

Some renewable energy, such as solar, matches the demand curve very well, producing electricity during peak demand. However, wind is typically countercyclical of the typical demand curve, providing electricity when demand is low (Hennessy & Kuntz, 2005). Wind is an
important renewable energy source, representing 14% of the renewable energy generated
electricity in the United States in 2008 (Electricity Net Generation From Renewable Energy by
Energy Use Sector and Energy Source, 2009). The countercyclical nature of wind can be seen in
Figure 1 below (price can serve as a proxy for demand: as demand increases, price increases; as
demand decreases, price decreases).

Figure 1

Although wind represents an important portion of renewable energy production, the
overall amount of renewable energy, not including hydroelectric power, is very small
representing only 2.5% of US electricity production (Schnapp, Electric Power Annual, 2009). At
these low penetration levels, the intermittency and off-peak production of renewable energy can
be absorbed by the electric grid (Korpass, Holen, & Hildrum, 2003). However, as renewable
energy reaches penetration levels of approximately 20-30% the ability for the grid to absorb this
intermittency is stretched and grid stability becomes a concern (McDowall, 2006).

One approach in addressing the renewable energy intermittency problem and
countercyclical production is the implementation of energy storage. Several energy storage
systems are currently under evaluation to determine their effectiveness integrating renewable
energy into the grid. These storage systems fall into two main categories. The first category is considered a short-term application. In this variation of the model, the storage unit can charge and discharge its entire capacity in a single time period (set as 15 minutes in the model based on the market structure) and therefore offers grid stabilization benefits and short-term energy arbitrage. Some examples of this type of storage solution include flywheels, ultra capacitors, and lithium ion batteries. The second category is considered a long-term application. This variation represents an energy storage unit that takes eight hours to charge and discharge its entire capacity, making it effective in day/night energy arbitrage. Therefore, it can maintain a higher amount of energy (MWh) than the power application but is unable to charge and discharge the energy as quickly. Examples of the long-term application are flow, sodium sulfur, lead acid, and advanced lead acid batteries.

While there are numerous energy storage options being evaluated as potential solutions, there are few utility scale units currently integrated into the grid (Noailles, 2009), (Kathpal, 2009), (Walawalkar, Apt, & Mancini, 2007). With the US grid meeting a peak load of 782,227 MW (Schnapp, Electric Power Annual, 2009) the penetration of energy storage into the grid is infinitesimally small.

A determining factor in energy storage penetration into the electricity grid is its economics. The objective of this report is to analyze the cost effectiveness of a utility scale energy storage unit, coupled with a wind farm in a deregulated market structure. The goal of the paper is to determine the economic viability of energy storage. Economic viability is determined by the investment’s net present value (NPV) and internal rate of return (IRR). If the investment proves to be economically viable, how good is the investment and what are the expected returns? If the investment does not provide adequate returns at the current capital expenditure (CAPEX),
at what CAPEX does it become commercial viable? This paper also compares two different
deregulated markets, California Independent System Operator (CAISO) and the Electric
Reliability Council of Texas (ERCOT), to determine which market energy storage generates the
most value. Both markets were also analyzed over time to capture the long-term value of storage
to understand the temporal trends.

The deregulated market structure provides the perfect incubator for analyzing and
developing energy storage. Deregulated markets have market prices that are publicly accessible
and can be easily analyzed to determine the true value of energy storage. This is in contrast to
regulated market structures where value from energy storage is through cost savings created by
shaving peak demand. The marginal cost of generation for individual utilities is typically
proprietary information and is therefore inaccessible.
Materials and Methods

A model was developed to analyze the possible revenue generation of a 1 MW utility scale energy storage unit in a deregulated market structure. The excel-based model is driven primarily by the price of energy and ancillary services\textsuperscript{1}, in combination with the amount of wind production. All pricing data used in the model was historical information obtained from the respective ISO websites (California ISO) (ERCOT). Historical data was used in the valuation model because the model relies on the unpredictable variance of real time prices. This price variability is unable to be captured in future pricing projections and therefore future price curves would not provide an accurate valuation.

The wind production data used in the model was obtained from the National Renewable Energy Laboratory’s (NREL’s) Western Wind and Solar Initiative. NREL provides wind speed data for hundreds of sites located in the western portion of the United States for the years 2004, 2005, and 2006. The 2006 wind speed data was used throughout all modeling periods of 2005, 2006, 2007 and 2008. While wind speed fluctuates from year to year, the overall trend of wind patterns remains relatively constant and therefore extrapolating a single year’s data forward into following periods is not expected to significantly impact the results herein. Each site is identified as a Class 1, 2, 3, 4, or 5 wind site. Class 1 wind sites have the lowest amount of wind availability and Class 5 sites have the highest. NREL combines the recorded wind speed data with the production curve for a Vestas V90 3MW wind turbine to determine expected electricity production output. The database then creates a simulated installation of ten V90 turbines and

\textsuperscript{1} Ancillary services are necessary to support the stability of the electric grid infrastructure. The services promote grid stability by providing additional electricity, or removing excess electricity from the grid to balance generation with load. Ancillary services in the CAISO and ERCOT markets are comprised of four separate services that each have their respective market places; Non-Spinning Reserve, Responsive Reserve, Regulation Up, and Regulation Down. All ancillary services require the providing entity to put electricity onto the grid, with the exception of Regulation Down, which requires electricity to be pulled off the grid (Kirby & Hurst).
reports the expected electricity production from the installation (Western Wind Dataset, 2009). Therefore, the wind farm the energy storage unit was coupled with in the model had a nameplate capacity of 30MW.

Before collecting price and wind production data, sites to be analyzed needed to be selected. Selection criteria for the sites was based on two factors, the regional location (ie which ISO) and the specific location within the selected ISO. The analysis is focused on the United States electricity grid, which has six ISO’s (Electric Power Markets: National Overview, 2009). Of the six ISO’s, CAISO and ERCOT have been on the forefront of developing and implementing the deregulated market structure. For this reason, the analysis focuses on the CAISO and ERCOT markets.

Within the CAISO and ERCOT markets there are hundreds of sites with wind speed readings included in the NREL database. To be as representative as possible to the true value of an energy storage installation, the exact site location was chosen based on the location of a currently operating wind farm within each ISO region. A map of all wind farms in the CAISO and ERCOT service territories was obtained from the Renewable Energy Collaboration website (Site Pre-Assessment) and overlaid with the NREL wind production database. The sites selected from each ISO were the highest available wind sites with a corresponding wind farm. Matching the NREL wind speed data with an operational wind farm provides a realistic analysis of energy storage.

The site data was collected, as previously described, and input into the model. The model accounts for the price for each service (energy and ancillary services) and the availability of the energy storage unit (fully charged, fully discharged, partially charged) and then decides which option maximizes the hourly revenue generation. This determination is performed every hour of
every day for an entire year. The temporal approach taken in this analysis limits the amount of back-casting bias that is inherent when utilizing historical data. The annual revenue generation was then inserted into a Discounted Cash Flow (DCF) model with a fifteen year planning horizon to determine the project’s net present value (NPV) and internal rate of return (IRR). A fifteen year planning horizon was used because this is the expected lifetime of most energy storage systems; however, this lifetime is affected by various conditions such as usage, depth of charge/discharge, and environmental conditions (Kaiser, 2007). These conditions were assumed to be zero and therefore the life of the system was maintained at 15 years. The model allows flexibility in the technological capabilities to represent various energy storage solutions and capabilities. This capability also enables the model to undergo sensitivity and scenario analysis. The model incorporates a number of important aspects of energy storage such as the size, efficiency, charging and discharging time, power capability, and capital costs that can all be changed to evaluate various scenarios.

Understanding the actual operation of the model is a key part of the study. For this reason, an explanation of the model is provided below. Figure 2 provides a graphical explanation and is provided at the end of the verbal description.

1) The market price of each service (market price of energy and ancillary services), the amount of wind production, and the availability of the storage unit are the original drivers of all later decisions.

2) The “Best Revenue Available” is selected.
   - This “Best Revenue Available” is selected based on two criteria.
The availability in the storage unit. For example, if it is fully charged, then the only response it can take is to discharge. Therefore, this is dependent on the “Amount in the Storage Unit” from the previous period.

The best price, given the availability determined above. For instance, if the storage unit was fully charged, then the model will select the best price for a discharging service.

3) Each service is given a code to signal if it is active or inactive, depending on the price given in the Best Revenue.

4) The amount the storage unit charges from production is dependent on the amount that is in storage from the previous period and if the storage unit is being charged from the grid.
   - There must be available capacity (hence the dependence on the amount in storage in the previous period) and none going to the unit from the grid. This is the case because there is revenue generation coming from electricity pulled from the grid while there is no revenue generation when charging from production.

5) The amount in storage during each period is the sum of the amount of electricity going to storage from production, the grid, and the amount in the storage unit from the previous period minus the amount that is being discharged from the storage unit and being put on the grid.

6) The amount of electricity going to the grid depends on the amount of electricity produced in each period, the price, the amount of electricity from production going to storage, and the amount of electricity being discharged from the storage unit.
• The price is a factor because if the price is negative\(^2\) the wind farm shuts down and does not send any electricity to the grid, as a negative price would be received for this electricity and thereby decreasing revenues.

7) Each revenue stream is simply the amount of each service used multiplied by the price of the respective service.

See Figure 2 below for a graphical depiction of the model’s operation.

Figure 2

\(^2\) Energy prices have the ability to become negative in both the CAISO and ERCOT markets. As previously discussed, wind generates the most electricity at night, when demand is the lowest. When there is high production from wind installations and low demand, there becomes an oversupply of electricity, causing the price of energy to drop. The reason the price drops below zero is due to the effects of the Production Tax Credits for renewable energy. Renewable energy sources (such as wind) receive a tax credit of approximately $35/MWh generated. Therefore, wind operators are willing to continue to produce electricity as long as the price of electricity is above negative $35.
There are short-term and long-term applications of the basic model that represent different functionalities of the energy storage unit itself. The different energy storage applications, as well as the different market locations were evaluated to determine the best investment option.
Results

The initial motivation behind implementing energy storage technologies was to align the wind production curve with the electricity demand curve. Analyzing the results of the model indicates the shape of the daily production curve was not changed with the installation of energy storage. Although the shape of the production curve did not change, the curve was shifted upwards (see Figure 3 because the energy storage unit is pulling electricity from the grid when it is beneficial to do so (negative pricing and regulation down).

The energy storage unit can be operated so the production curve matches the demand curve, as was described in the Introduction above; however, this style of operation does not maximize revenue. Below is an example of the revenue generated by leveling the production curve, compared with an example aimed at maximizing revenue.

The market clearing price of electricity is $10/MWh at night and $50/MWh during the day. Using energy storage, the wind farm can store the $10/MWh energy at night and not put it onto the grid until the next day and get $50/MWh. By storing the energy at night and discharging it during the day the net revenue generated is $40/MWh ($50 from the market minus the $10 in...
lost revenue by storing it instead of putting it on the grid). However, by participating in the ancillary service markets, such as regulation down, the wind farm can continue to dispatch the nighttime production onto the grid for $10/MWh, charge the storage unit from regulation down for market price – let’s say $20/MWh, and then discharge the storage unit during day at the market price of $50/MWh. Operating the storage in this fashion allows the wind farm to generate a net revenue of $10MWh from the nighttime production going to the grid, plus $20/MWh by pulling electricity from the grid for regulation down, plus $50/MWh by discharging to the grid during the day for a total of $80/MWh. Clearly, managing the energy storage unit in this way provides the most revenue creation; however, it does nothing to level the production curve to better match demand.

This result raises an interesting question as to the importance of ancillary services in generating revenue. If ancillary services play a small role in revenue generation, then it would be possible to alter the operation of the storage unit to flatten the production curve without significantly changing the financial valuation. Figure 4 shows the source of revenue generation in both ISO markets as revenue generated from energy markets and ancillary services. Ancillary services provide an average of 34.5% and 45.3% of the storage value in the ERCOT and CAISO markets, respectively. Therefore, if the storage unit did not participate in the ancillary services market, then the revenue generated would decrease significantly.
Another result of the model is the revenue generated by each type of energy storage application (short-term and long-term). Revenue generation in ERCOT for the short-term and long-term applications is very similar (see Figure 5). The two applications have similar value because prices are not volatile from one 15 minute interval to the next. If prices changed dramatically from period to period, then it would be beneficial for the short-term scenario because it could take full advantage of the price spikes by discharging its entire capacity within the single period. Meanwhile, slower changing market prices allow for the long-term application to capture similar value as the short-term.

Figure 5
Utilizing the annual revenues, the storage systems can be evaluated in a DCF financial model to determine if the annual revenues are sufficient to overcome the upfront capital expenditure of the storage unit. While the revenue generating capability between the long-term and short-term applications is similar, the costs of the different applications are dissimilar. The cost of the long-term application ranges from 1.8 to 3.5 times higher than that of the short-term application. Specifically, this analysis utilized the most cost effective systems within each application group, which are sodium sulfur batteries for the long-term application and flywheels for the short-term application. The costs for the short-term storage system (ie flywheel) range from $550/kW to $750/kW, while the long-term application (ie sodium sulfur) range from $1,150/kW to $2,250/kW (Walawalkar, Apt, & Mancini, 2007). With decreased costs and similar revenue generation, the short-term application creates a much higher return on investment than the long-term application (Figure 6). In the figure, the red line indicates a return of 10%, which is equivalent to the weighted average cost of capital (WACC) used in the DCF valuation (Walawalkar, Apt, & Mancini, 2007). A return above the red line is a project with a positive NPV, while any returns below the line indicate a negative NPV.

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3 Positive Net Present Value (NPV) projects are projects that create value for the investor, while negative NPV projects destroy value.
Figure 6
Base Case

*Base Case Assumptions:
- CAPEX = Short-term: $650/kW; Long-term: $1,700/kW
- Fixed O&M = Short-term: $25,000/year; Long-term: $52,500/year
- 15 year planning horizon, equipment life, and depreciation schedule
- WACC = 10%
- Unlevered transaction

(Walawalkar, Apt, & Mancini, 2007)
Discussion

In theory, energy storage can reduce the daily intermittency of wind production and thus enable a larger percentage of the generation portfolio to originate from wind. Nighttime electricity production can be stored by the energy storage unit and then discharged onto the grid during times of high demand. This not only levels the daily production curve, but also provides a financial benefit by capturing the difference between the low price of energy at night and the high price of energy during the day.

The results of this analysis indicate that energy storage operated to maximize revenues under current market conditions do not actually flatten the production curve. The results also show that operating the storage unit differently (ie not participating in the ancillary services market) significantly reduces the revenue generating capability. As the market evolves and energy storage technology matures, the value proposition of energy storage is likely to change. With further maturation, investment, and installation of storage technology, it is likely that the value of ancillary services will decrease. The ancillary services market currently has a high value; however, with increased implementation of energy storage, the market can become saturated and lose much of its value (Kempton & Tomic, 2005). A saturation of the ancillary services market shifts the value maximizing equation to incorporate more value from energy markets and thereby flattening the production curve.

Analyzing future uncertainty raises the question of what model inputs are most important to the valuation. It is important to understand the key inputs to ensure those inputs are accurately represented. Figure 7 depicts a tornado diagram, which represents the variance in the NPV output depending on a change in each of the input variables.
Figure 7
Short-term

<table>
<thead>
<tr>
<th>Variable</th>
<th>Short-term Value</th>
<th>Long-term Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAPEX for Battery</td>
<td>$2,250</td>
<td>$1,125</td>
</tr>
<tr>
<td>WACC</td>
<td>12.00%</td>
<td>8.00%</td>
</tr>
<tr>
<td>Fixed O&amp;M</td>
<td>$90,000</td>
<td>$15,000</td>
</tr>
<tr>
<td>Charge Discharge Efficiency</td>
<td>60%</td>
<td>85%</td>
</tr>
<tr>
<td>Charge/Discharge Time</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Terminal value</td>
<td>(300,000)</td>
<td>0</td>
</tr>
</tbody>
</table>

Note: This tornado diagram is for the ERCOT market; however, the CAISO diagram is very similar and therefore this chart is representative of both markets.

It is important to note that impact on NPV is a function of both the importance of the variable within the model as well as the range of the given variable. Therefore, the tighter the range of the variable, the less impact it will have in the tornado diagram. The WACC of the project is an internal function of the level of risk and credit rating of the investing entity and as a result is essentially a static input. Consequently, CAPEX is the most important dynamic variable to the model in both the long-term and short-term applications. Figure 8 below shows how
important CAPEX is to the rate of return through a scenario analysis. Given various price ranges (ranging from a Low Case to a High Case) the rate of return changes significantly.

**Figure 8**

**Low Case**

**Base Case**

**High Case**
Making an investment decision based on these results depends on several factors. First, it is reliant on the ultimate goal of the investment. If the goal of the investment is to add monetary value to the investing company, then it is important to invest in a project with a positive NPV. However, energy storage is a nascent technology and therefore storage projects may be regarded as R&D investments. In this case, the required rate of return can be significantly lower, as many R&D projects are not undertaken to generate a positive return on that specific project. Rather, R&D projects further the development of technology and enable the company to gain experience for future projects. Second, it is contingent on the risk tolerance of the investing party. A risk averse investor should wait until the storage unit can be obtained in the low cost case. This provides the highest assurance that the project will be a positive NPV project. However, if the investor has a higher risk tolerance, positive NPV’s could be gained if the CAPEX were at the Base cost case or High cost case. At these costs the investor has the potential for a positive NPV but also exposes himself to downside risk.

Recall that the long-term application generated similar or higher revenue than the short-term application. With the CAPEX being the most important driver of NPV, the decreased cost
of the short-term application is the reason it is a much better investment (in terms of returns) than the long-term application. The price of long-term applications has remained much higher than short-term applications, and while technology improvements have caused capital costs to fall, significant manufacturing economies of scale have not yet been realized (Walawalkar, Apt, & Mancini, 2007).

The upfront capital cost is not the only uncertainty and risk associated with energy storage. There are multiple risks that must be weighed before making an investment. One risk is the technology risk associated with development, installation, and operation of an energy storage unit at the proposed scale. Energy storage is still a developing industry and, as such, has little experience in delivering at the scale envisioned in this project. To overcome this risk, investors should seek out and identify vendors with experience in large-scale projects and resources to meet project needs. This risk can also be surmounted by diversifying the energy storage unit into both of the available applications – long-term and short-term. Although the total size of the unit will remain at the specified 1 MW, the unit can be separated into a mix of long-term and short-term units. The results clearly indicate that the short-term application provides the highest financial value (mainly due to the much lower upfront cost); however, at this stage in development the true returns on an investment remain uncertain. By diversifying the investment into the separate applications, both technology and vendor specific risk is reduced and the investor can gain experience with multiple storage applications. This experience, especially for large investors such as utilities, will provide essential operational knowledge moving into the future. The diversified storage approach should also lessen the manufacturing burden on each vendor and provide flexibility in the project.
There is also market risk associated with investment in energy storage. This market risk includes the previously discussed ancillary services market, which has the potential to become saturated and lose value, but also includes structural changes to the market and transmission system. The ERCOT market is based on a zonal market structure with only four different energy prices within the entire service territory. This structure is undergoing a transition to a nodal structure where there will be hundreds of market prices received throughout the service territory (see Figure 9) (ERCOT). The change in structure creates tremendous uncertainty in the value of energy storage.

**Figure 9**

Current zonal structure | Future nodal structure

In addition to the changing market structure, ERCOT is also undergoing a major build-out of the transmission system. Texas has the most installed wind capacity in the United States, with most of the development in the windswept western region of the state (Site Pre-Assessment). The wind farm development has constrained the transmission grid that transports electricity generated in the western part of the state to the load centers of Houston and Dallas in the eastern part of the state. To accommodate the large amount of needed transmission, ERCOT
is currently developing five major transmission lines, known as the Competitive Renewable Energy Zone (CREZ) transmission lines. Both the market change and CREZ build-out are expected to be completed by 2015, well within the 15 year planning horizon of the proposed project (ERCOT).

External risk can also cause large value swings within individual markets. The value of energy storage in the ERCOT market was much higher in 2005 than any other year evaluated. The ERCOT market was significantly affected by the landfall of Hurricane Katrina. Natural gas fired power plants are major providers of electricity in Texas, representing 49\% of electricity generation in 2006 (Texas Electricity Generation, by Fuel Source). The hurricane created huge disruptions in the natural gas supply and thus caused the price of gas to skyrocket (Natural Gas Navigator, 2009). This increase in natural gas price resulted in the price of electricity to increase, widening the gap between the daytime and nighttime market prices. The average price of electricity in 2005 was approximately 20\% higher than 2006, 2007, and 2008 (ERCOT). While this particular disruption caused the value of energy storage to increase, it is possible for disruptions to occur that result in a decrease in value.
Conclusion

This paper has evaluated the installation of a single, 1MW energy storage unit in a deregulated market structure. The goal was to determine which energy storage application, long-term or short-term, and which market structure, ERCOT or CAISO, added the most value. The results of the analysis indicate that the short-term application provides the highest value in both the ERCOT and CAISO markets. Both applications generated similar revenue streams; however, the short-term application had a much lower upfront capital cost. Although the short-term storage application provides higher returns, hybrid solutions that combine both long-term and short-term applications can be implemented to diversify the vendor and technology specific risk.

Results also show that returns are more variable in the ERCOT market, with similar but more consistent returns in the CAISO market. The CAISO market also provides a more stable market structure moving into the future. The ERCOT market changes make it difficult to identify the true value of energy storage.

The investment decision hinges on the goals of the project, initial CAPEX of the energy storage unit, and the risk profile of the investor. The initial CAPEX is the most important variable that impacts the project NPV in both long-term and short-term applications. If the goal of energy storage is to earn a positive return, the short-term application of energy storage can be invested in under all cost scenarios. Meanwhile, the long-term application should only be invested when CAPEX is in the low cost case. However, an investment may be made, depending on the risk tolerance of the investor, in the base cost case. The long-term application should not be invested in under the high cost case due to the unlikely probability of generating a positive return. However, if this is considered an R&D project, the investment may still make sense at
any of the listed price points depending on the level of expected knowledge gained from the project.

Pulling back from the financial analysis, it is also important to note the implications energy storage has on the ability to integrate wind energy into the grid. This analysis indicates operating the storage unit to maximize profits does nothing to level the wind production curve. Changing the operation parameters to level production severely reduces the financial benefits of storage. Therefore, for energy storage to act as an integration enabler there must be a change in either revenue generation or storage unit costs.
Literature Cited


