# Battery Storage Economics for Demand Charge Management

Demand charges are levied on energy consumers in a variety of ways, including being based on the consumer's peak load when the system peak of the power supplier occurs (i.e., coincident peak), the consumer's peak load irrespective of when the system peak occurs (i.e., non-coincident peak), the consumer's peak load achieved on a rolling basis, or the consumer's peak load achieved in a preceding time period. Demand charges can also be seasonally differentiated. Often, individual consumers—whether it is a distribution cooperative that obtains its power from a wholesale supplier or an end-use customer—can reduce the demand charges levied on them by controlling their own peak load.

Distribution cooperatives can achieve peak load reduction either by curtailing their load or by installing self-generation or energy-storage devices (e.g., installing reciprocating engines or battery energy storage systems), to the extent that their wholesale power contracts permit such installations. The economics of installing load-serving equipment primarily depend on the load profile (e.g., frequency distribution and amplitude of the system's peaks) of the system and the applicable demand charges from their energy supply tariff.

This paper examines the economics of installing a battery energy storage system (BESS) as a way to reduce demand charges for a typical distribution cooperative that is subject to demand charges from its wholesale power supplier. The metric used to characterize the economics of installing a BESS is the payback period. It is calculated by estimating the periodic net savings achieved via peak load clipping and computing the time period required for those savings to recoup the initial investment made in the BESS. Since BESS capital costs vary by location and demand charges vary across utilities, a family of payback period curves were generated under various assumptions for capital costs and demand charges.

## Considerations and Options for Minimizing Demand Charges

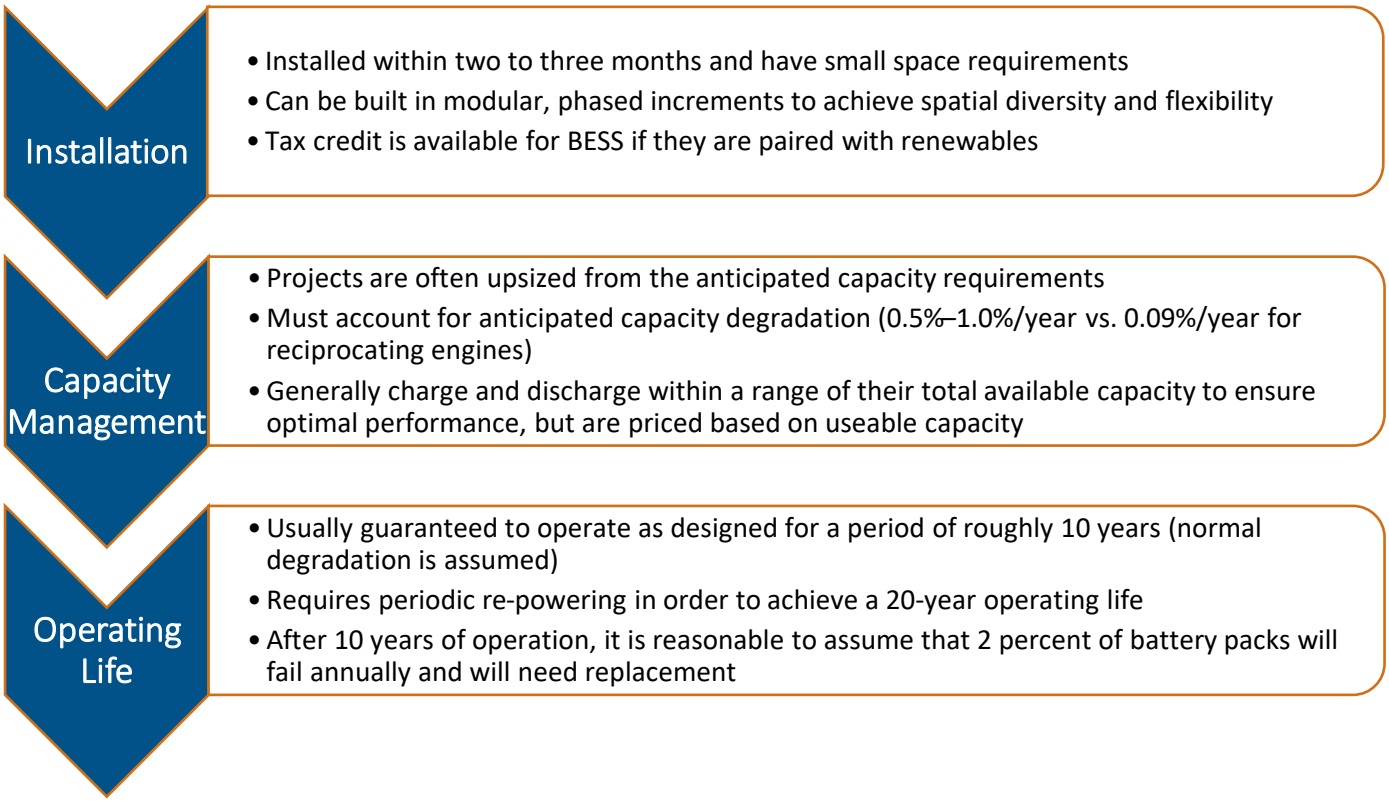
Both a small modular generation system such as a quick-starting gas- or diesel-fired reciprocating engine, as well as an appropriately sized BESS can help systems clip their peak load to the desired level. For reciprocating engines, generally natural gas-fired engines are preferred where fuel supply infrastructure (e.g., gas pipeline access) is readily available and in applications that involve annual use exceeding 600 to 700 hours. Diesel-fired engines are economically superior when low annual utilization is expected and where natural gas supply infrastructure is lacking.

While a reciprocating generation system requires fuel delivery and storage at the site and has the potential to violate site-specific environmental requirements (including noise attenuation), a BESS requires only a point of interconnection to the grid and presents few or none of the site-specific environmental constraints. Both reciprocating engines and BESSs can be installed in a relatively short time frame and can be deployed for peak load clipping in more or less the same manner.

## Battery Energy Storage Systems

Deployment of batteries for peak shaving applications has been gaining momentum over the last several years, coinciding with declining capital costs and advances in lithium-ion technology (e.g., increasing round-trip efficiency, power density and availability of more sophisticated energy management systems). The ease, including the short lead times needed for BESS installations, has been highlighted in a number of high-profile projects installed in the last couple of years, including at cooperative locations (e.g., Kauai Island Utility Cooperative, Connexus Energy, United Power and Middle Tennessee EMC, among others). An overview of BESS features is outlined in Figure 1.

**Figure 1: Features of Battery Energy Storage Systems**




System design is a key factor influencing the economics of a BESS. For example, BESS capital costs increase as the duration of discharge of the underlying battery increases. Assuming the same peak power output, a battery with a two-hour discharge duration will cost 30 percent to 40 percent less to install than a battery with a four-hour discharge duration. Utilities should, therefore, carefully evaluate the discharge duration they require to effectively clip their peak. The required discharge duration will be different from utility to utility and will depend on how accurately the utility can predict when its peak periods will occur, as well as the duration and frequency of its peak periods during a billing period.

Some utilities may be able to clip their peak with just a two-hour discharge duration while others may require a four-hour discharge duration. Utilities considering a BESS project should conduct a rigorous assessment of the projected system utilization based on simulations of historical and forecasted load curves to help determine the optimal system configuration to control their peak load while minimizing capital costs.

## Economic Analysis

Once the optimal power output and discharge duration of the BESS is determined, the economic analysis involves estimating the following factors:

- **Capital costs**, which are based on the power output and discharge duration of the BESS;
- **Charging costs**, which are based on the locational costs of energy, the roundtrip efficiency of the battery and the projected utilization of the battery;
- **Operating costs**, which are based on the size of the BESS; and
- **Realized benefits**, which are based on the capacity charges avoided, including transmission charges that are based on the utility's peak load.

These projections are extrapolated for the expected life of the BESS project, and the cumulative net savings are assessed against the initial capital costs to determine the payback period. The estimated savings from demand clipping are based on the reduction in peak load, which is equal to the power output capacity of the battery, and the demand and transmission charges that are levied on a monthly basis. For example, if a utility has a demand charge of $10.00/kW-month (or $10,000/MW-month), and effectively clips its peak load using a 4 MW BESS, then the utility would generate savings at a rate of $40,000/month, regardless of the discharge duration of the BESS. In real-world applications, the required battery duration to effectively reduce peak load will be dependent upon each utility's unique load profile.

Further, the analysis assumes that a utility will be able to clip its peak load with a BESS capacity factor of 7.5 percent, meaning it will discharge electricity for roughly 660 hours per year. For a four-hour and two-hour battery, that equates to roughly 165 and 330 charge and discharge cycles per year, respectively. This is a similar capacity factor to a typical gas-fired reciprocating engine being used for peak load clipping. Both the optimal capacity factor and battery duration will be unique to each utility and based on its specific load profile and the structure of its wholesale power tariff.

Figure 2 illustrates cash flow schedules for both a 4 MW/16 MWh (four-hour duration) BESS and a 4 MW/8 MWh (two-hour duration) BESS being utilized solely for peak clipping and demand charge management. The subsequent chart in

Figure 3 provides the estimated payback period curves for both four-hour and two-hour BESSs using the base case assumptions outlined in Appendix 1 and varying assumptions of capital costs and demand charges to show sensitivities. The analysis reveals that the capital costs, applicable demand charges and duration of the battery all play significant roles in shaping the economics of a BESS.

## Figure 2: Illustrative Cash Flows for a BESS Utilized for Peak Clipping

**Four-hour BESS — 4 MW/16 MWh – $400/kWh installed cost (base case)**

| | Year 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Initial Outlay | $6,400,000 | | | | | | | | | | |
| Avoided Demand Charges | | $528,000 | $533,174 | $538,400 | $543,676 | $549,004 | $554,384 | $559,817 | $565,303 | $570,843 | $576,437 |
| Avoided Transmission Charges | | $288,000 | $290,822 | $293,672 | $296,550 | $299,457 | $302,391 | $305,355 | $308,347 | $311,369 | $314,420 |
| Net Charging Cost | | ($10,388) | ($10,388) | ($10,388) | ($10,388) | ($10,388) | ($10,388) | ($10,388) | ($10,388) | ($10,388) | ($10,388) |
| O&M | | ($24,000) | ($24,480) | ($24,970) | ($25,469) | ($25,978) | ($26,498) | ($27,028) | ($27,568) | ($28,120) | ($28,682) |
| Net Savings | | $781,612 | $789,128 | $796,714 | $804,369 | $812,094 | $819,889 | $827,756 | $835,694 | $843,704 | $851,787 |
| Cumulative Savings | | $781,612 | $1,570,740 | $2,367,454 | $3,171,823 | $3,983,917 | $4,803,806 | $5,631,562 | $6,467,255 | $7,310,959 | $8,162,747 |

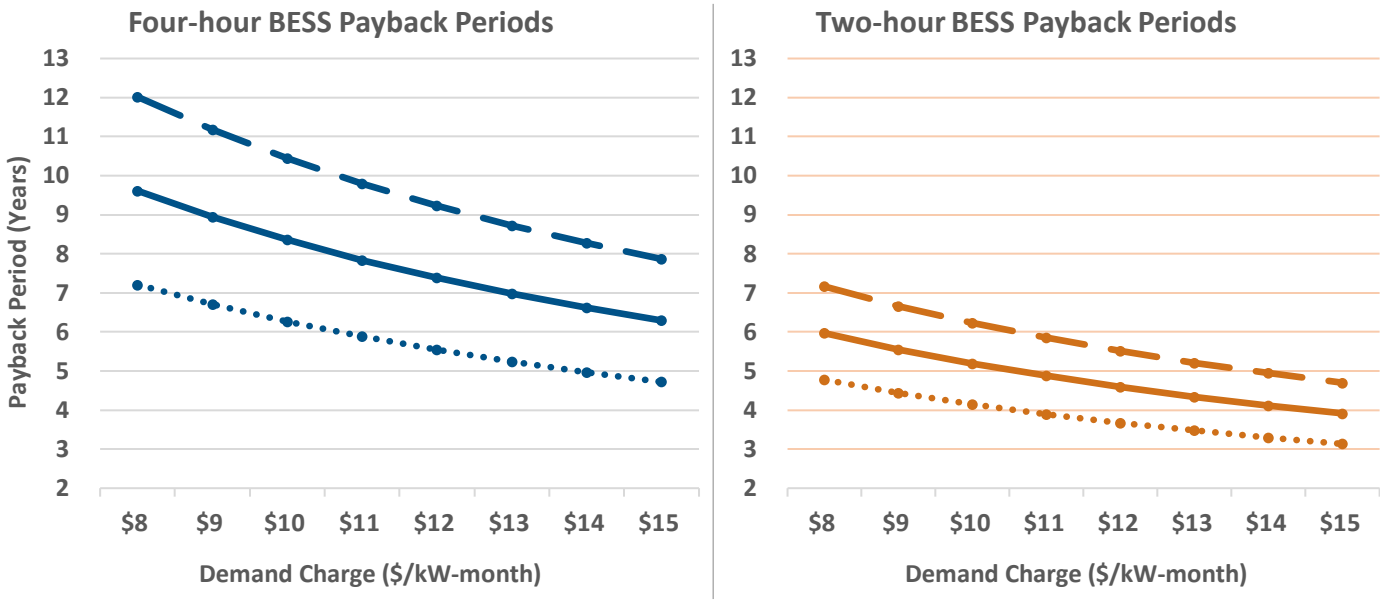
| **Payback Period (Years)** | **7.84** |
|---|---|

**Two-hour BESS — 4 MW/8 MWh – $500/kWh installed cost (base case)**

| | **Year 0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Initial Outlay | $4,000,000 | | | | | | | | | | |
| Avoided Demand Charges | | $528,000 | $533,174 | $538,400 | $543,676 | $549,004 | $554,384 | $559,817 | $565,303 | $570,843 | $576,437 |
| Avoided Transmission Charges | | $288,000 | $290,822 | $293,672 | $296,550 | $299,457 | $302,391 | $305,355 | $308,347 | $311,369 | $314,420 |
| Net Charging Cost | | ($10,388) | ($10,388) | ($10,388) | ($10,388) | ($10,388) | ($10,388) | ($10,388) | ($10,388) | ($10,388) | ($10,388) |
| O&M | | ($20,000) | ($20,400) | ($20,808) | ($21,224) | ($21,649) | ($22,082) | ($22,523) | ($22,974) | ($23,433) | ($23,902) |
| Net Savings | | $785,612 | $793,208 | $800,876 | $808,614 | $816,424 | $824,305 | $832,260 | $840,288 | $848,391 | $856,568 |
| Cumulative Savings | | $785,612 | $1,578,820 | $2,379,696 | $3,188,310 | $4,004,733 | $4,829,039 | $5,661,299 | $6,501,587 | $7,349,978 | $8,206,546 |

| **Payback Period (Years)** | **4.87** |
|---|---|

## Figure 3: Payback Periods for Four-Hour and Two-Hour BESSs




**LEGEND – BESS Installed Costs ($/kWh)**

| | Four-hour | Two-hour | Comments |
|---|---|---|---|
| High Cost | $500 | $600 | Upper end of prices available today |
| Base Case | $400 | $500 | Competitive prices available today |
| Low Cost | $300 | $400 | Lower end of prices available today |

Note that the BESS economic analysis in these figures does not include the following:

- Tax benefits for the BESS, which may be available when the system is paired with solar or other renewable energy generation, but could also restrict the utility's ability to clip peak load if the BESS is not charged while a peak load event is occurring.
- Value from energy arbitrage, which occurs when charging during a period of low energy prices (i.e., off-peak rates) and discharging when energy prices are higher (i.e., on-peak rates).
- Monetizing other grid applications and services that can be obtained from owning and operating a BESS (e.g., capacity/resource adequacy payments, distribution infrastructure deferral and demand response).

Owners of a BESS should consider utilizing the asset for various monetizable use cases to optimize economics. There is no set blueprint for determining the best way to utilize a BESS, and not all use cases make economic or operational sense to stack together. For example, a BESS being primarily used for peak clipping will not be suitable for load following. The former is an energy application where the duration of response is greater than the magnitude of response, while the latter is a power application where the magnitude of response is greater than the duration of response.

Longer duration batteries will generally have more flexibility to perform multiple functions as they require less charge and discharge cycles for the same amount of discharged energy. Note that monetizing additional value streams comes with increased charging costs and accelerated battery capacity degradation. Utilities primarily focused on peak clipping must account for battery degradation to ensure there is enough useable capacity throughout the life of the project to effectively reduce their peaks during the appropriate periods.

## Conclusions

This analysis shows that both four-hour and two-hour BESSs can provide economic value in a variety of peak load clipping applications with payback periods under 10 years—the normal manufacturer guaranteed performance life of a typical BESS—within the range of capital costs that are now prevalent in the industry. Further, if the same economic savings can be achieved with a two-hour BESS—typically costing around 30 percent to 40 percent less for the same peak power output capability—even lower payback periods can be realized. An environment of declining BESS costs, the potential to capture tax benefits (by pairing with renewable energy resources) and the opportunity to capture additional value streams from other grid applications all support giving serious consideration to installing a BESS to clip peak loads and realize overall savings. A careful analysis of load characteristics and applicable power supply tariffs, the potential for those tariffs to change over time and the structuring of the transaction are recommended when making BESS investment decisions.

## Appendix 1

**Key Assumptions for a Four-Hour BESS**

Applicable when the expected "peak" time can be predicted within a four-hour window.

| Assumption Metric | Unit | Value |
|---|---|---|
| Demand Charge | $/kW-month | $11.00 (variable for sensitivity analysis) |
| Energy Charge | $/kWh | $0.0224 |
| Transmission charge | $/kW-month | $6.00 |
| Demand & Transmission Charge Escalation | % | 2.00% |
| Battery Power Capacity | MW | 4 |
| Power Capacity Annual Degradation | % | 1.00% |
| Discharge Duration | hours | 4 |
| Initial Energy Capacity, Year 1 | MWh | 16.00 |
| Battery System Installed Cost | $/kWh | $400 (variable for sensitivity analysis) |
| Battery System Installed Cost | $ | $6,400,000 |
| Capacity Factor (for energy delivered) | % | 7.50% |
| Energy Delivered, Year 1 | MWh | 2,628 |
| Round Trip Efficiency | % | 85.00% |
| Energy to Charge the Battery, Year 1 | MWh | 3,092 |
| O&M | $/kW-year | $6.00 |
| Implied Cycle per year | # | 164 |

## Appendix 2

**Key Assumptions for a Two-Hour BESS**

Applicable when the expected "peak" time can be predicted within a two-hour window.

| Assumption Metric | Unit | Value |
|---|---|---|
| Demand Charge | $/kW-month | $11.00 (variable for sensitivity analysis) |
| Energy Charge | $/kWh | $0.0224 |
| Transmission charge | $/kW-month | $6.00 |
| Demand & Transmission Charge Escalation | % | 2.00% |
| Battery Power Capacity | MW | 4 |
| Power Capacity Annual Degradation | % | 1.00% |
| Discharge Duration | hours | 2 |
| Initial Energy Capacity, Year 1 | MWh | 8.00 |
| Battery System Installed Cost | $/kWh | $500 (variable for sensitivity analysis) |
| Battery System Installed Cost | $ | $4,000,000 |
| Capacity Factor (for energy delivered) | % | 7.50% |
| Energy Delivered, Year 1 | MWh | 2,628 |
| Round Trip Efficiency | % | 85.00% |
| Energy to Charge the Battery, Year 1 | MWh | 3,092 |
| O&M | $/kW-year | $5.00 |
| Implied Cycle per year | # | 329 |