LCOS Methodology

The LCOS determined from this analysis provides a $/kWh value that can be interpreted as the average $/kWh price that energy output from the storage system would need to be sold at over the economic life of the asset to break even on total costs.

Equation 1 below shows the LCOS calculation.

$$LCOS = \frac{((FCR \times CAPEX_{PV}) + O\&M_{Fixed})}{AH} + ECC \quad (1)$$

Where:

$LCOS$ = Levelized cost of storage ($/kWh)

FCR = Fixed Charge Rate (%)

$CAPEX_{PV}$ = Present value of capital expenditures ($/kW)

$O\&M_{Fixed}$ = Annual fixed O&M ($/kW-year)

AH = Annual hours discharged

ECC = Electricity charging cost ($/kWh-discharge) inclusive of costs due to losses [ECC = charging cost for purchased energy ($/kWh) divided by system RTE (%)].

LCOS Equation Sub-components

CAPEX

The present value of capital expenditures ($CAPEX_{PV}$) is used to determine the total investment in the storage system in present year dollars. While the bulk of the CAPEX cost is assumed to be incurred in year 0 for this report, various capital investments for augmentations and replacements will be incurred in future years. Equation (2) shows the present value equation for capital expenditures over the project life of the system. The year in which augmentation, major overhauls, and replacements for battery systems take place will be dependent on the cycle life, calendar life, DOD, and other factors for each system, as specified in the LCOS section of the report.

$$CAPEX_{PV} = \sum_{n=0}^{N} \frac{CF_n}{(1+d)^n} = CF_0 + \frac{CF_1}{(1+d)^1} + \frac{CF_2}{(1+d)^2} + \cdots + \frac{CF_N}{(1+d)^N} \quad (2)$$

Where:

$CAPEX_{PV}$= Present value of capital expenditures

CF_n = Cash flow in year n

N = Project Life

d = $WACC_{Real}$

Information on the major overhauls and replacement frequency and cost (CF_N) as well as the project life (N) for each storage technology can be found in Section 6. The $WACC_{Real}$ is calculated below.

Weighted Average Cost of Capital

The real $WACC_{real}$ is presented in Equation 3. This value represents the rate paid to financial assets as a weighted average after adjustment for inflation.

$$WACC_{Real} = \frac{(1+WACC_{Nominal})}{(1+inflation)} - 1 \quad (3)$$

$$WACC_{Nominal} = DF \times i_{nom} \times (1-\tau) + (1-DF) \times COE_{nom} \quad (3.1)$$

Where:

Table A4.1. WACC Equation Variable List and Definition

Variable	Name	Definition
$inflation$	Inflation rate (%)	Assumed rate of inflation. Assumed to be 2.8% in this report.
DF	Debt Fraction (%)	Percent of total capital expenditures financed with debt.
i_{nom}	Nominal interest rate (%)	Interest rate assumed on expenditures financed with debt.
τ	Tax rate (federal and state)	Federal and state combined tax rate (%).
COE_{nom}	Nominal cost of equity (%)	Rate of return paid on assets financed with equity.

Fixed Charge Rate

The fixed charge rate gives the percent of capital expenditures that must be recovered on an annual basis to cover annual revenue requirements. It is a function of the capital recovery factor (CRF) and the construction finance factor (CFF), defined below (Equation 4). The tax depreciation method is the modified accelerated cost recovery system (MACRS), half-year convention.

$$FCR = CRF \times \frac{(1-\tau \times PVD_{MACRS})}{(1-\tau)} \times CFF \quad (4)$$

Where:

CRF = Capital recovery factor (%)

τ = Tax rate (federal and state)

PVD_{MACRS} = Present Value of Depreciation (MACRS)

CFF = Construction finance factor (%)

Capital Recovery Factor

The CRF represents the constant annual payment necessary to amortize a loan over a specific lifetime. It is a function of the assumed economic life (*t*) and $WACC_{Real}$ (*d*). This equation (Equation 5) returns the CRF as a fraction of the original principle that must be paid annually.

$$CRF = \frac{d}{1-(1+d)^{-t}} \quad (5)$$

Where:

CRF = Capital Recovery Factor (%)

t = Economic life (years)

d = $WACC_{Real}$, see Equation (3)

The economic life (*t*) is the assumed number of years to pay off asset costs. This value is assumed to be 20 years for all technologies in this report for the base case.

Construction Finance Factor

The CFF represents the financing costs that are incurred during the construction period of the project and is shown in Equation 6.

$$CFF = \sum_{c=0}^{C}(AI_c \times CF_c \times LC) + \sum_{c=0}^{C}(AE_c \times CF_c \times EC) \quad (6)$$

Where:

CFF = Construction Finance Factor (%)

c = Year of construction period

C = Total construction period (years)

AI_c = Accumulated interest during construction in year c

CF_c = Capital fraction (%) in year c

LC = Percent of leverage

EC = Percent of equity

AE_c = Accumulated equity during construction

Where:

$$AI_c = 1 + ((1 + i_{nom})^{c+0.5} - 1) \quad (6.1)$$

$$AE_c = 1 + ((1 + COE_{nom})^{c+0.5} - 1) \quad (6.2)$$

i_{nom} = nominal interest rate

COE_{nom}= nominal cost of equity