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A Manual for the Economic Evaluation of Energy Efficiency and Renewable Energy Technologies

Walter Short, Daniel J. Packey, and
Thomas Holt

National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, Colorado 80401-3393
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Investment decisions using revenue requirements are made by comparing the present value RR of alternatives that accomplish the same desired result. The alternative with the lowest RR is considered to be more economical.

Table 4-9. Before-Tax TLCC Evaluation

Year	Investment	Discounted Investment	Depreciation	Discounted Depreciation	O&M Costs	Discounted O&M Costs
0	$ 10,000	$ 10,000			$ 0	$ 0
1	0	0	$ 4,000	$ 3,571	1,339	1,196
2	0	0	2,400	1,913	1,379	1,100
3	0	0	1,440	1,025	1,421	1,011
4	0	0	1,080	686	1,463	930
5	0	0	1,080	613	1,507	855
NPV		$ 10,000		$ 7,809		$ 5,091
RR = TLCC = 10,000 - (0.34 x 7,809) + (5,091 x 0.66) = $10,705 / 0.66 = $16,220						

Revenue requirements are an example of a present value that can be annualized (discussed in the Annualized Value subsection). The annualized revenue requirement can be obtained as follows:

$$L(RR) = PV(RR) \times UCRF = PV(RR) \times \frac{d(1 + d)^N}{(1 + d)^N - 1} \tag{4-5}$$

Where d is either the real or nominal discount rate, depending on whether a real or nominal annualized required revenue is sought.

Returning to the example with RR = $16,220, the nominal annualized required revenue, assuming the same 12% discount rate, is $4,500. These are the current dollar revenues that must be collected in each of the 5 years of the life of the investment to cover all costs, including taxes.

Levelized Cost of Energy

Introduction

The levelized cost of energy (LCOE) allows alternative technologies to be compared when different scales of operation, different investment and operating time periods, or both exist. For example, the LCOE could be used to compare the cost of energy generated by a renewable resource with that of a standard fossil-fueled generating unit.

Discussion

The LCOE is that cost that, if assigned to every unit of energy produced (or saved) by the system over the analysis period, will equal the TLCC when discounted back to the base year. LCOE is recommended for use when ranking alternatives given a limited budget simply because the measure will provide a proper ordering of the alternatives, which may then be selected until the budget is expended. LCOE is not recommended when selecting among mutually exclusive alternatives because differing investment sizes are not considered (i.e., an investor will choose to invest more in an alternative with more favorable returns). This shortcoming may be corrected by applying LCOE to the incremental costs of the alternatives. The LCOE can be calculated using the following formula:

$$\sum_{n=1}^{N} \frac{Q_n \times LCOE}{(1 + d)^n} = TLCC, \text{ or} \qquad (4\text{-}6)$$

$$LCOE^{22} = TLCC \div \{\sum_{n=1}^{N} [Q_n \div (1 + d)^n]\}$$

Where:

LCOE = levelized cost of energy
TLCC = total life-cycle cost
Q_n = energy output or saved in year n
d = discount rate
N = analysis period.

Thus, the treatment of taxes in the TLCC calculation will carry over to the LCOE. For example, the LCOE can be calculated for the same example as was provided in the Total Life-Cycle Cost subsection for the private investor seeking his or her after-tax cost. In addition to the assumptions made in the TLCC example, assume the investment produces 1000 units of energy in the first year of operation, 950 in the second, 925 in the third, and 900 in the fourth and fifth. Recall from the previous example that the TLCC was calculated, after tax deductions, as $10,705. The remaining task is to calculate the discounted value of the annual energy output or energy saved; i.e., $\Sigma^{N}_{n=1}[Q_n \div (1 + d)^n]$. Applying this formula to the example using a nominal discount rate of 12%, the discounted value of energy output is 3391 units. Thus, LCOE = $10,705 / 3,391 = $3.16 in current dollars.

Once the TLCC is calculated, the LCOE can be figured in either current or constant dollars, regardless of the discount rates used to derive the TLCC. The form of the LCOE will be determined by the form of the discount rate used in the denominator of the equation $\Sigma^{N}_{n=1}[Q_n \div (1 + d)^n]$. In the previous example, a nominal discount rate was used in the denominator; thus, the resulting LCOE values are current values. For the same example, the LCOE based on a 8.74% real discount rate is $2.91 in constant dollars.

It is important to note that if the system output (Q) or savings remains constant over time, the equation for LCOE can be reduced as follows:

$$LCOE = (TLCC/Q)\ (UCRF) \qquad (4\text{-}7)$$

Where:

TLCC = total life-cycle cost
Q = annual energy output or saved
UCRF = the uniform capital recovery factor, which is equal to $\frac{d(1 + d)^N}{(1 + d)^N - 1}$.

[22]Even though it may appear in this formula that quantities are being discounted, this is actually a direct result of the algebra carried through from the previous formula in which revenues were discounted.

Using the data from the previous example but this time assuming an annual output of 1000 units per year and a nominal discount rate of 12%, the LCOE is equal to (TLCC/Q) (UCRF). The UCRF for this example is

$$[0.12(1 + 0.12)^5] / [(1 + 0.12)^5 - 1] = 0.277 . \qquad (4\text{-}8)$$

Thus, the LCOE is equal to $10,705 / 1,000 x 0.277 = $2.97.

Although $2.97 is the levelized after-tax cost, the before-tax revenues required to cover all costs is

$$\$16{,}220 / 1{,}000 \times 0.277 = \$4.50 \text{ [also } \$2.97 / (1 - 0.34) = \$4.50] . \qquad (4\text{-}9)$$

This means that if the energy units are sold for $4.50 per unit in current dollars over the next 5 years and the company sells 1000 energy units per year of operation, the investor will be able to pay the applicable income tax, earn 12% after taxes, and recoup the initial investment and annual O&M costs.

Suppose that a constant dollar LCOE was required for this example. The only difference required is to calculate the UCRF using a real discount rate, which in this case is 8.74% (carrying forward the previous assumption of a 12% nominal discount rate with 3% inflation). The UCRF then becomes

$$[0.0874(1 + 0.0874)^5] / [(1 + 0.0874)^5 - 1] = 0.255 . \qquad (4\text{-}10)$$

Thus, the LCOE is equal to $16,220 / 1,000 x 0.255 = $4.14.

This constant dollar example illustrates a shortcut LCOE calculation. The shortcut methodology for estimating the before-tax-revenues-required LCOE requires the assumptions that the project not only have constant output, but also constant O&M and no financing. If these assumptions can be made, the shortcut can be used with the application of the following formula:

$$LCOE = \frac{I \times FCR}{Q} + \frac{O\&M}{Q} \qquad (4\text{-}11)$$

Where:

LCOE	=	levelized cost of energy
I	=	initial investment
FCR	=	fixed charge rate, in this case the before-tax revenues required FCR (see Section 2, Fixed Charge Rate subsection)
Q	=	annual output
O&M	=	annual O&M and fuel costs for the plant.

Continuing with the before-tax-revenues-required example with constant output and an FCR of 0.284, which can be calculated from the formula provided in the Fixed Charge Rate subsection in Section 2, the quick estimate of before-tax-revenues-required LCOE can be calculated as:

$$LCOE = (10{,}000 \times 0.284) / 1{,}000 + (1{,}300 / 1{,}000) = \$4.14 , \qquad (4\text{-}12)$$

which is the same as the LCOE calculated from the TLCC.

If the investment is an energy efficiency investment, LCOE only makes sense in the context of the energy saved. Although TLCCs can be calculated for each energy-consuming system, LCOE should not be calculated for an individual energy-consuming system,[22] but rather for the incremental cost and savings attributable to the energy-efficient system. This can be accomplished by levelizing the difference in the nonfuel (electricity) life-cycle costs of the two systems.

For example, consider the energy efficiency example provided in the Total Life-Cycle Cost subsection of Section 4:

- Alternative A: a 75-watt incandescent light bulb operating 6 hours per night for a total energy requirement of 164.25 kWh per year, an unchanging 6 cents per kWh price of electricity, bulb replacement once a year at a cost of $1 per bulb. The nonfuel costs of this system are $4.03 $(1 + 1/1.12 + 1/[1.12]^2 + 1/[1.12]^3 + 1/[1.12]^4)$, or the discounted cost of purchasing a new bulb at the beginning of each year.

- Alternative B: a 40-watt fluorescent bulb that lasts for the entire 5 years operating under similar conditions for a total energy requirement of 87.6 kWh per year, a $15 initial investment, and a constant price of electricity of 6 cents per kWh. The nonfuel cost of this option is just the $15 cost of the fluorescent bulb at the beginning of the analysis period.

With a UCRF of 0.277, the "nominal levelized cost of energy saved" for this example is $([15-4.03]/76.65) \times 0.277 = 0.04$ $/kWh. This 4 cents per kWh can then be compared[23] to the nominal levelized cost of electricity, or 6 cents[24] per kWh in this example, to determine whether the energy efficiency investment is economical. In this example, the cost per unit required to save energy ($0.04/kWh) is cheaper than it is to purchase the energy ($0.06/kWh), and thus the more efficient bulb should be purchased. Alternatively, were the cost of electricity to drop below 4 cents per kWh, the most cost-effective investment would change to alternative A.

To gain a better understanding of the concept of nominal and real LCOE, examine Figure 4-1. It depicts the cost over the life of an investment and the resulting LCOE in both nominal and real terms. The cash flow lines show how nominal and real costs are equal in the base year, whereas in the future, real costs (i.e., inflation-adjusted) are lower than nominal costs. Likewise, the LCOE is lower in real terms than in nominal. The choice of real or nominal LCOE depends on the purpose of the analysis. Most short-term studies are shown in current dollars, whereas long-term studies are frequently computed in real dollars to adjust for many years of inflation. A current-dollar analysis will more closely resemble future cash flows (especially when the investment is largely financed), and a constant-dollar analysis paints a clearer picture of actual cost trends. Regardless of the method chosen, the most economical option will not change as long as all options are evaluated using the same method.

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[22]There is no reasonable value to use for "Q," the annual output in the LCOE equation. To use the energy consumed by the system would be to penalize (increase the LCOE) for less energy consumption.

[23]Care should be taken to ensure that taxes are treated equally for each investment. For this light bulb case, taxes are assumed *not* to be relevant because the investor is a homeowner. If the investor were a profit-making firm, the full cost of electricity (6 cents in the example) should be compared with the before-tax LCOE; or, alternatively, the after-tax cost of electricity to the firm ($0.06[1 - T]) should be compared with the LCOE after-tax deductions.

[24]Since, in this example, the cost of electricity as expressed in nominal dollars does not change, it is the same as the nominal levelized cost of electricity.

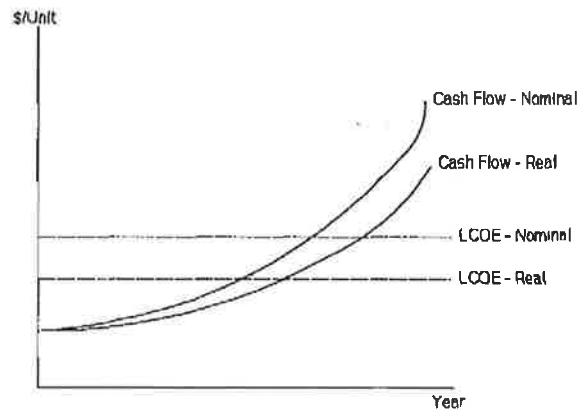


Figure 4-1. Levelized cost of energy cash flows

Annualized Value

Introduction

The annualizing process transforms a string of cash flows (F_n) into equivalent annual streams. Cash flows are discounted to their net present value and then annualized by multiplying the present value of the cash flow by the uniform capital recovery factor (UCRF); i.e., $[d(1 + d)^n] \div [(1 + d)^n - 1]$. This is similar to the annualization of required revenues mentioned at the end of the Revenue Requirements subsection and can be done with a single equation that combines the NPV and capital recovery factor calculations.

$$NPV = \Sigma^N_{n=1} F_n / (1 + d)^n$$

$$AV = UCRF \times NPV = UCRF \times \Sigma^N_{n=1} F_n / (1 + d)^n \qquad (4\text{-}13)$$

Where:

NPV = net present value
AV = annualized value
F_n = cash flow in period n
UCRF = uniform capital recovery factor
d = discount rate.

Discussion

This formula can be simplified if the cash flow F_n is escalating at a constant rate ΔP.

$$NPV = \Sigma^N_{n=1} [F_0(1 + \Delta P)^n] / (1 + d)^n \qquad (4\text{-}14)$$

$$= F_0 \Sigma^N_{n=1} k^n$$

$$= F_0[k(1 - k^n) / (1 - k)]$$

Levelized Cost of Energy (LCOE)

The LCOE is the total cost of installing and operating a project expressed in dollars per kilowatt-hour of electricity generated by the system over its life. It accounts for:

- Installation costs
- Financing costs
- Taxes
- Operation and maintenance costs
- Salvage value
- Incentives
- Revenue requirements (for utility financing options only)
- Quantity of electricity the system generates over its life

The LCOE in SAM depends on the following assumptions:

- The quantity of electricity generated by the system for each year in the analysis period, shown as Energy in the cash flow table. The performance model calculates the annual energy for Year one based on the hourly simulations. SAM adjusts this value by the factors that you specify on the Performance Adjustment page.
- Installation and operating costs on the System Costs page
- Financial assumptions on the Financing page
- Incentives on the Incentives page
- Depreciation assumptions on the Depreciation page

To use the LCOE for evaluating project options, it must be comparable to cost per energy values for alternative options:

- For residential or commercial projects, SAM assumes that the renewable energy system meets all or part of a building's electric load, so the LCOE is comparable to a $/kWh retail electricity rate representing cost of the alternative option to meet all the building's load by purchasing electricity from the grid at retail rates. To be economically viable, the project's LCOE must be equal to or less than the average retail electric rate.
- For utility (and commercial PPA) projects, SAM assumes that the project sells all of the electricity generated by the system at a price negotiated through a power purchase agreement (PPA). For these projects the LCOE is comparable to the power price. A financially viable project must have an LCOE that is equal to or greater than the available PPA price to cover project costs and meet internal rate of return requirements.

Real and Nominal LCOE

For all financing options, SAM calculates both a real and nominal LCOE value. The real LCOE is a constant dollar, inflation-adjusted value. The nominal LCOE is a current dollar value.

The choice of real or nominal LCOE depends on the analysis. Real (constant) dollars may be appropriate for long-term analyses to account for many years of inflation over the project life, while nominal (current) dollars may be more appropriate for short-term analyses.

Some industries prefer to use one form over the other. For example, when discussing LCOE for parabolic trough projects, analysts have tended to use the nominal LCOE (see Current and Future Costs for Parabolic Trough and Power Tower Systems in the US Market), while the U.S. Department of Energy has used the real LCOE in its comparative analysis of photovoltaic project costs (Solar Energy Technologies Program Multi-Year Program Plan 2007-2011).

Be sure to use the same form of the LCOE when comparing costs for different alternatives: Never compare a real LCOE of one alternative with a nominal LCOE of another.

LCOE Without Incentives

SAM displays a value labeled "LCOE (real-w/o incentives)" on some graphs. This value of the LCOE is calculated in the same way as the other forms of the LCOE described below, but excludes any tax credits or cash incentives that you specify on the Incentives page.

If you remove all incentives from your analysis, then the LCOE values with and without incentives are identical.

Additional Resources

You can explore the LCOE methodology for the residential, commercial, commercial PPA, and utility IPP financing options by downloading the spreadsheets from the SAM website at https://sam.nrel.gov/financial, or from SAM's Help menu. Each of the five spreadsheets duplicates SAM's cash flow equations using Excel formulas.

For more information about the levelized cost of energy and other economic metrics for renewable energy projects, see *Manual for the Economic Evaluation of Energy Efficiency and Renewable Energy Technologies*. (Short 1995) http://www.nrel.gov/docs/legosti/old/5173.pdf.

LCOE Definition

This description of the LCOE uses the vocabulary and equations described in the *Manual for the Economic Evaluation of Energy Efficiency and Renewable Energy Technologies*. (Short 1995) http://www.nrel.gov/docs/legosti/old/5173.pdf.

By definition, a project's equivalent annual cost C_n is the product of the LCOE and the quantity of electricity generated by the system in that year, Q_n:

$$C_n = Q_n \times LCOE$$

Project costs C_n include installation, operation and maintenance, financial costs and fees, and taxes, and also account for incentives and salvage value. SAM's performance model calculates the annual energy Q_n for $n = 1$. For $n > 1$, Q_n decreases from year to year if the **Year-to-year decline in output** value on the Performance Adjustment page is greater than zero.

That equation must be valid for all years in the project's life, so to calculate the LCOE, we must first calculate the total lifecycle cost, $TLCC$, which is the present value of project costs over its life N discounted at rate d:

$$TLCC = \sum_{n=0}^{N} \frac{C_n}{(1+d)^n}$$

The following equation shows the relationship between the LCOE and TLCC:

$$\sum_{n=1}^{N} \frac{Q_n \times LCOE}{(1+d)^n} = TLCC$$

Combining the two equations above gives:

$$\sum_{n=1}^{N} \frac{Q_n \times LCOE}{(1+d)^n} = \sum_{n=0}^{N} \frac{C_n}{(1+d)^n}$$

Notes.

The analysis period on the Financing page is equivalent to the project lifetime N.

The annual cost C_n includes the effect of inflation, so the nominal discount rate is the correct form to use on the right side of the equation.

The correct form of the discount rate on the left side of the equation depends on whether the LCOE is a real or nominal value.

The summation in the left hand term begins at $n = 1$, which is the first year that the system produces energy. The right hand summation begins at $n = 0$ to include investment costs in the calculation.

Solving for LCOE gives:

$$LCOE = \frac{\sum_{n=0}^{N} \frac{C_n}{(1+d)^n}}{\sum_{n=1}^{N} \frac{Q_n}{(1+d)^n}}$$

> **Note.** This equation makes it appear that the energy term in the denominator is discounted. That is a result of the algebraic solution of the equation, not an indication of the physical performance of the system.

LCOE for Residential and Commercial Financing

For a project using either the residential or commercial (except Commercial PPA) financing option, the LCOE is the cost of financing, installing, and operating a system per unit of electricity it generates over the analysis period, accounting for incentives and salvage value. (This differs from the LCOE for commercial PPA and utility financing options, which includes a margin for profits defined by the internal rate of return (IRR) that is not available for residential or commercial projects.)

> **Note.** For the Residential and Commercial financing options, the retail electricity prices from the Utility Rate page do not affect the LCOE. The LCOE is a measure of the cost of installing and operating the system, not of the value of electricity purchases avoided by the system. The project NPV is a measure of both the project costs and energy value.

For residential and commercial projects, you can compare a project's LCOE to the electricity rate that the residence or commercial entity would pay to an electric service provider if the project were not installed.

For the real LCOE, the real discount rate appears in the denominator's total energy output term:

$$\text{Real LCOE} = \frac{-C_0 - \frac{\sum_{n=1}^{N} C_{AfterTax,n}}{(1-d_{nominal})^n}}{\frac{\sum_{n=1}^{N} Q_n}{(1-d_{real})^n}}$$

Similarly, for the nominal LCOE, the nominal discount rate appears in the denominator's total energy output term:

$$\text{Nominal LCOE} = \frac{-C_0 - \frac{\sum_{n=1}^{N} C_{AfterTax,n}}{(1-d_{nominal})^n}}{\frac{\sum_{n=1}^{N} Q_n}{(1-d_{nominal})^n}}$$

Where,

Q_n (kWh) Electricity generated by the system in year n shown in the Energy row in the project cash flow. The performance model calculates this value based on weather data and system performance parameters. It includes the effect of factors that you specify on the Performance Adjustment page.

N Analysis period in years as defined on the Financing page

$C0$ The project's initial cost, shown in the Year zero column of the *After Tax Cost* row of the cash flow table.

$C_{AfterTax}$ The annual project cost in Year n, shown in the *After Tax Cost* row of the cash flow table.

> **Note.** The "After Tax Cost" values in the cash flow table are different from the "After Tax Cashflow" values used in the project NPV equation. The cost does not include the value of electricity generated by the system.

d_{real} The real discount rate defined on the Financing page. This is the discount rate without inflation. See LCOE Definition for an explanation of discount rates in the LCOE calculation.

$d_{nominal}$ The nominal discount rate shown on the Financing page. This is the discount rate with inflation.

LCOE for Utility and Commercial PPA Financing

For a project with the commercial PPA or one of the utility financing options, the LCOE represents the amount that the project must receive for each unit of electricity it sells to cover financing, installation, and operating costs, and to meet the financial constraints on the Financing page, accounting for salvage value and incentives.

SAM assumes that these projects are power generation projects installed on the utility side of consumer power meters. The projects sell electricity at a price negotiated by the project and electricity purchaser.

For these projects, the LCOE is effectively a levelized *price* of electricity because it is based on the present worth of the project's revenue stream, which you can see in the project cash flow as either

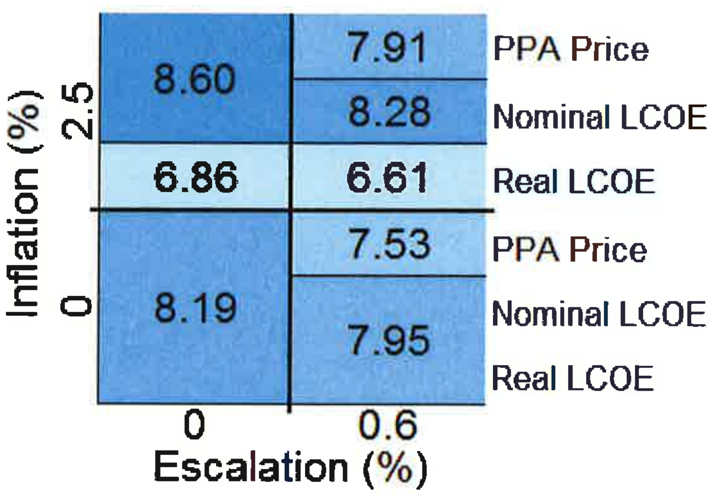
Energy Value for

- Commercial PPA,
- Utility IPP,

or *Total PPA Revenue* for

- Single Owner,
- All Equity Partnership Flip,
- Leveraged Partnership Flip,
- Sale Leaseback.

The following table shows the relationship between PPA price, nominal LCOE, and real LCOE. It is for a 64 MW sample wind farm that generates 176 GWh of electricity in its first year with a total installed cost of $2,000/kW and a 2.2 cent/kWh production tax credit. The shades of color in the table show the relative magnitude of the values (higher values are darker than lower values):



The table shows the following:

- When the inflation rate and PPA price escalation rate are both zero, the PPA Price, nominal LCOE and real LCOE are equal.
- When the inflation rate is zero, the real and nominal LCOE are equal.
- When the PPA price escalation rate is zero, the PPA price and nominal LCOE are equal.

> **Note.** Because the LCOE for the commercial PPA and utility financing options depends on the PPA price, it can be very sensitive to the values that you specify for the target PPA price or target IRR and other assumptions on the Financing page. In some cases, it is possible to specify constraints that make the project capital investment a relatively insignificant factor in the LCOE calculation.

SAM uses the real and nominal discount rates from the Financing page to calculate the present worth of future costs. The real discount rate accounts for the time value of money and the relative degree of risk for alternative investments.

For the real LCOE, the real discount rate appears in the denominator's total energy output term:

$$\text{real LCOE} = \frac{\sum_{n=1}^{N} \frac{R_n}{(1+d_{\text{nominal}})^n}}{\sum_{n=1}^{N} \frac{Q_n}{(1+d_{\text{real}})^n}}$$

Similarly, for the nominal LCOE, the nominal discount rate appears in the total energy output term:

$$\text{nominal LCOE} = \frac{\sum_{n=1}^{N} \frac{R_n}{(1+d_{\text{nominal}})^n}}{\sum_{n=1}^{N} \frac{Q_n}{(1+d_{\text{nominal}})^n}}$$

Where,

Q_n (kWh) Electricity generated by the project in year n, calculated by the performance model based on weather data and system performance parameters. The first year output is reported in the Metrics table on the Results page and in the year one column of the project cash flow. Year two and subsequent output is the first year output reduced by the amount specified for the **Year-to-year decline in output** rate on the Performance Adjustment page.

N Analysis period in years as defined on the Financing page.

R_n Project revenue from electricity sales in year n , equal to the system's annual electric output multiplied by the annual PPA price. For the commercial PPA and utility IPP financing options, SAM displays the value in the cash flow as *Energy Value*, for the single owner, partnership flip, and sale leaseback options, as *Total PPA Revenue*.

d_{real} The real discount rate defined on the Financing page. This is the discount rate without inflation. See LCOE Definition for an explanation of discount rates in the LCOE calculation.

d_{nominal} The nominal discount rate shown on the Financing page. This is the discount rate with inflation.

Replicating LCOE Calculations in Excel

If you would like to better understand SAM's LCOE calculations, you can follow the procedures described below to replicate the calculations using a spreadsheet program.

You can also use the **Send to Excel with Equations** button to create a spreadsheet populated with Excel formulas that replicate SAM's calculations.

For the residential, commercial, commercial PPA, and utiilty IPP financing options, you can download the spreadsheets on the Financial Models page of the SAM website (https://sam.nrel.gov/financial) to see how SAM calculates the LCOE and NPV.

> **Note for Mac users.** SAM can not exchange data with Microsoft Excel on Mac computers. This means that the Excel Exchange feature is disabled on Mac versions of the software, and that SAM cannot directly export data to Excel workbooks.
>
> To use the SAM data in Excel or another spreadsheet program, you can export the data to a comma-separated text file (CSV), and then import the CSV file to the spreadsheet program.

To replicate LCOE calculation in Excel:

1. On the Results page, click **Cash Flows** to display the project cash flow.
2. Click **Send to Excel** to export the cash flow table to an Excel worksheet, or click **Save as CSV** to save the data as a text file then open it in Excel.
3. Type the project's discount rate and inflation rates as percentages into two blank cells in the worksheet. You can find these values on SAM's Financing page.
4. Type the following formula into a third empty cell to calculate the nominal discount rate:
   =(1+[inflation rate])(1+[real discount rate])-1*

Replace the words in brackets with cell references to the appropriate values in the worksheet. This value should be equivalent to the nominal discount rate that SAM displays as a calculated value on the Financing page.

5. Type the following formula into a blank cell to calculate the real LCOE:
   =NPV([nominal discount rate],[energy value or total ppa revenue])/NPV([real discount rate],[energy])
   The energy value and energy are series of values from Year One to the final year in the analysis period. Energy is in the first row at the top of the table, and energy value is in the third row.
6. Use the following formula to calculate the nominal LCOE:
   =NPV([nominal discount rate],[energy value or total ppa revenue])/NPV([nominal discount rate],[energy])

Notes.

You can also replicate the calculations in Excel using the summations shown in the equations above in place of the NPV formulas.

The Cash Flows table displays the intermediate values for the LCOE calculation in the rows under the heading "LCOE," near the top of the table for the residential, commercial, utility IPP, and commercial PPA financing options, and near the middle of the table for the single owner, leveraged partnership flip, all equity partnership flip, and sale leaseback options.