MARCH 2015

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LCCA for HVAC systems

Lifecycle cost analysis (LCCA) is a tool used to determine the most cost-effective option among HVAC system alternatives.

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Learning objectives

- Understand basic lifecycle cost analysis (LCCA) concepts and best practices.
- Learn to incorporate LCCA into an HVAC system selection process.
- Identify tools that simplify LCCA calculation and results documentation.

Practically speaking, there are multiple building design options that can meet programmatic needs and achieve acceptable levels of performance. From a purely financial perspective, the only appropriate design alternative is the solution that satisfies the owner's project requirements for the lowest total cost of ownership. Lifecycle cost analysis (LCCA) is a powerful tool used to determine the most cost-effective option among competing alternatives. Although LCCA has been used for decades to reliably identify cost-optimal design solutions, many building owners and architecture and engineering professionals still rely on simple payback to make project investment decisions.

LCCA is an economic method of project evaluation in which all costs arising from owning, operating, maintaining, and ultimately disposing of a project are considered to be potentially important to that decision. LCCA is particularly suitable for the evaluation of building design alternatives that satisfy a required level of building performance (including occupant comfort, safety, adherence to building codes and engineering standards, and system reliability), but may have different operating, maintenance, and repair (OM&R) costs, and potentially different useful lives.

Project-related costs that occur at different points in time cannot be directly combined for meaningful economic analysis because the dollars spent at different times have different values to the investor. LCCA provides a rational means to weigh the value of first costs versus future (e.g., operating) costs (see Equation 1).

$$LCC = (I + Repl - Res) + (E + OM\&R)$$

Where:

- LCC = total lifecycle cost in present-value dollars for a given alternative
- I = present-value investment costs
- Repl = present-value replacement costs
- Res = present-value residual value
- E = present-value energy costs
- OM&R = present-value non-fuel operating, maintenance, and repair costs

Equation 1: This simplified lifecycle cost formula is adapted from the NIST Handbook 135 (HB 135), "Lifecycle Costing Manual for the Federal Energy Management Program." All graphics courtesy: Kohler Ronan LLC

Adjusting to present value

Most individuals intuitively recognize that a dollar today does not have the same value as a dollar in the distant future. This concept, referred to as the time value of money, results from two considerations: 1) general inflation, which is the erosion of future purchasing power; and 2) opportunity cost, which for existing capital is the cost of forgone investment opportunities and for borrowed capital is the cost of borrowing (i.e., the loan rate). Lifecycle costing considers both effects in weighing the value of present costs against future costs.

General inflation and price escalation: General price inflation measures the decline in the purchasing power of the dollar over time. LCCA methodology provides two approaches for dealing with general price inflation: current dollar analysis and constant dollar analysis. Current dollars are dollars of any 1 year's purchasing power, inclusive of inflation. That is, they reflect changes in the purchasing power of the dollar from year to year. In contrast, constant dollars are dollars of uniform purchasing power, exclusive of inflation. Constant dollars indicate what the same good or service would cost at different times if there were no change in the general price level (no general inflation or deflation) to change the purchasing power of the dollar.

In general, LCCA calculations for building systems should treat general price inflation using a constant dollar approach. The constant dollar approach has the advantage of avoiding the need to project future rates of inflation or deflation, which adds unnecessary complexity and uncertainty. The price of a good or service stated in constant dollars is not affected by the rate of general inflation. For example, if the price of a piece of equipment is $1,000 today and $1,050 at the end of a year in which prices in general have risen at an annual rate of 5%, the price stated in constant dollars is still $1,000; no inflation adjustment is necessary. In contrast, if cash flows are stated in current dollars, future amounts include an assumed general inflation rate and an adjustment is necessary to convert the current-dollar estimate to its constant-dollar equivalent.

Few commodities have prices that change at exactly the rate of general

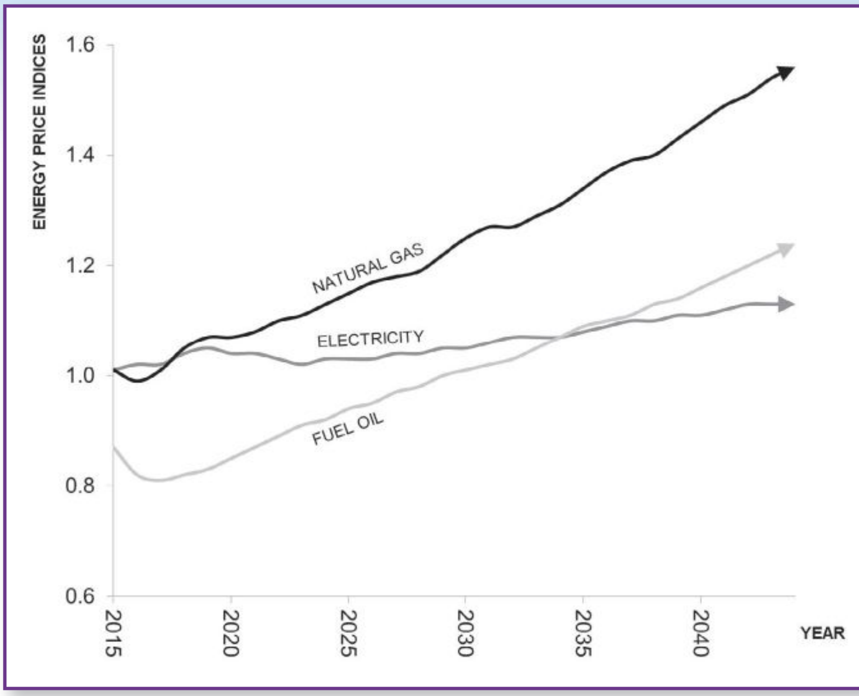

Figure 1: **Each year the National Institute of Standards and Technology publishes Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis—The Annual Supplement to NIST Handbook 135. The price indices shown here have been reproduced from the U.S. Energy Information Association "Table Ca-5 Projected fuel price indices (excluding general inflation) by end-use sector and fuel type-United States Average."**

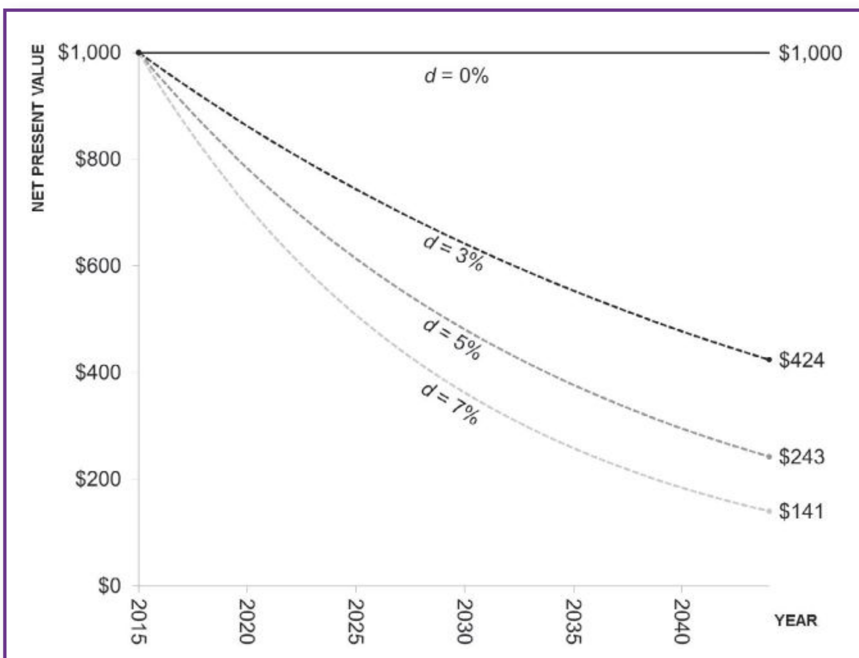

Figure 2: **The discount rate (d) is a special type of interest rate that makes an investor indifferent between cash amounts received at different points in time. An investor with a 3% discount rate would be willing to invest up to $424 dollars today in order to save $1,000 in year 30; an investor with a 7% discount rate would only be willing to invest up to $141 for the same return.**

inflation year after year, but many commodities have prices that change at a rate close to that of general inflation over time. Maintenance and repair costs and construction materials tend to follow general price inflation, while utility prices tend to be much more volatile. Typically, LCC methodology assumes that prices for all goods and services, other than for energy and water, will increase at approximately the same rate as general inflation. However, if there is a documentable basis for assuming that prices change at a rate different than general inflation (e.g., when price escalation rates are established in a maintenance contract), these rates can be used in the analysis.

While goods and services are assumed to inflate at the same rate (i.e., the general inflation rate), LCC procedures require that inflation of energy prices be treated separately. In other words, this assumes that energy prices will not inflate at the same rate as other goods and services. Accordingly, we distinguish general price inflation from energy price inflation by referring to the latter as energy price "escalation." As with the use of the discount rate, the energy price escalation rates are "real" (i.e., net or differential).

The US Energy Information Administration (EIA) publishes official projections for future energy prices annually each April for the residential, commercial, and industrial sectors broken down by region of the country for six energy types (electricity, natural gas, propane, distillate fuel oil, residual fuel oil, and coal). Figure 1 illustrates how the Dept. of Energy projects national average electricity, fuel oil, and natural gas prices are expected to move over the next 30 years in real dollar terms. These fuel escalation rates are suitable for most building-related LCCA studies. If using alternative escalation rates, be sure to use "real" rates that indicate how energy prices will increase above and beyond general price inflation (note that Equation 4 may also be used to convert a "nominal" escalation rate into a "real" escalation rate).

Given a present price and a real escalation rate Equation 2 may be used to determine an escalated future price. For example, assume the present price of natural gas is $1.00 per therm and that the price of natural gas is anticipated to escalate at a constant rate of 5%. At the end of year-10 natural gas will cost $1.63 per therm. In all likelihood, general price inflation will drive the actual price of natural gas higher than $1.63 per therm in year-10. However, constant dollar analysis focuses on incremental price change for energy by using "real" escalation rates. Note that this escalated price ($1.63) may not be used in Equation 1 until it is discounted to present value using Equation 3.

Opportunity costs and discount rates: Opportunity costs recognize that a fair comparison of the economic benefit of two or more project options must consider what else we might have done with our money (i.e., in the case of existing capital) had we chosen to invest in something other than the available project options or what it would cost us to borrow the capital if necessary (i.e., loan rate). In constant dollar LCCA methodology, opportunity cost is accounted for through the use of the "real" discount rate (d).

The discount rate is a special type of interest rate that makes the investor indifferent between cash amounts received at different points in time. That is, the investor would just as soon have one amount received earlier as the other amount received later. For example, with a discount rate of 5%, the present value

$$F_t = P_0 \times (1 + e)^t$$

Where:

F_t = future value of a present cost, P_0, in year t

P_0 = present cost of good/service in year 0

e = price escalation rate [real]

t = future year assumed in the calculation

Equation 2: **Future value of present cost may be used to determine a future price, given present price and a constant, real escalation rate. For example, assume the present price of natural gas is $1/therm and that the price of natural gas is anticipated to escalate at a constant rate of 5%. At the end of year 10, natural gas will cost $1.63/therm. Note that this escalated price must still be discounted to present value using Equation 3. The formula is adapted from NIST Handbook 135 (HB 135), "Lifecycle Costing Manual for the Federal Energy Management Program."**

$$PV = F_t \times \frac{1}{(1 + d)^t}$$

Where:

PV = present value of the future cost of good/service

F_t = future cost of good/service in year t

d = discount rate [real]

t = future year assumed in the calculation

Equation 3: **The present value of future cost equation may be used to calculate the present value equivalent of a future cost, such as the natural gas price previously determined using Equation 2. Although the future price of natural gas at the end of year 10 may be $1.62/therm, to an investor with a 3% discount rate, that therm of natural gas is only worth $1.21 today (net present value). With a 3% discount rate, the investor is only willing to spend up to $1.21 today in order to save a therm of natural gas 10 years from now. The formula is adapted from the NIST Handbook 135 (HB 135), "Lifecycle Costing Manual for the Federal Energy Management Program."**

Making decisions using LCCA

The design team agreed that the investment decision of whether to build an on-site plant or use the local energy options should be determined using LCCA.

In this example, an institutional client was trying to determine if it should install a central chiller and boiler plant on-site or purchase chilled water and steam from a local district energy system (DES base case). It was clear that installing an on-site plant would add significant upfront cost and additional maintenance cost; however, future operating costs would be substantially higher if energy was purchased through the DES supplier. The design team decided that the investment decision should be determined using LCCA.

- If the client decided to take advantage of the DES, over a 30-year period the client would avoid approximately $1 million worth of initial construction, future equipment maintenance, and replacement costs. However, over a 30-year period, energy costs through the DES would likely total $8.6 million in net present value
- Although installation of an on-site central plant would increase initial investment and future capital costs by approximately $1 million, compared to the DES alternative the central plant option would save the client approximately $2.4 million in energy expenditures over 30 years
- Based on total cost of ownership during the 30-year analysis period, the central plant option is the most economically viable alternative. Initial investment costs are likely to be recovered within a 9-year period (discounted payback period); over a 30-year period the central plant would likely provide the client with $1.4 million net savings (NS) compared to the DES alternative.

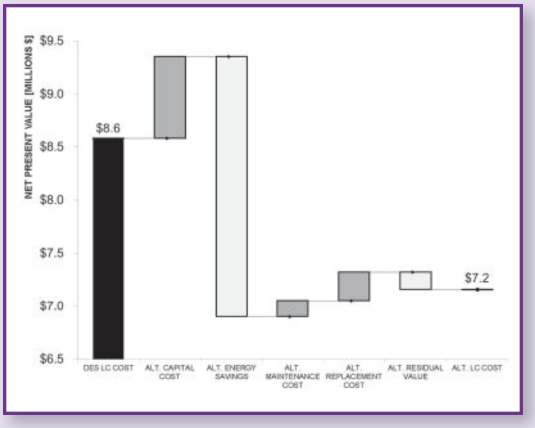

Figure 3: **The design team agreed that the investment decision of whether to build an on-site plant or use the local energy options should be determined using LCCA.**

Table 1: Example LCCA

Building characteristics	
Gross square footage	220,000
Winter temperature setpoint	70 F ±2.5 F
Summer temperature setpoint	75 F ±2.5 F
Central plant equipment	
Modular air-cooled chillers	$380,000
Water side economizers	$190,000
Condensing boilers	$175,000
Primary pumps and variable frequency drives	$30,000
Total incremental cost	$775,000
Plant performance	
Cooling (coefficient of performance)	3.2
Heating efficiency	92%
Incremental pump power	19 W/gpm
Lifecycle costing	
Base year	2017
Service year	2017
Study length	30 years
Discount rate	3%
Discounting convention	Year-end
Discount and escalation rate types	Real
Treatment of inflation	Constant dollar
30-year incremental cost data (not discounted)	
Capital cost	$775,000
Maintenance cost	$232,500
Replacement cost	$540,000
Residual equipment value	($396,540)
Total investment cost	$1,150,960
30-year annualized lifecycle costs	
Initial capital cost	$39,543
Energy cost	$312,633
Maintenance cost	$7,750
Capital replacements	$13,651
Residual value	($8,337)
Annualized lifecycle cost	$365,242
Compared to DES option	
30-year net savings	$1,421,861
Savings-to-investment ratio	2.62
Adjusted internal rate of return	6.36%
Simple payback period (years)	8
Discounted payback period (years)	9

Table 1: **The LCCA is calculated for both building a new central plant and for using the district energy system option. The central plant option turned out to be the most economically viable alternative.**

broken down by region of the country for a variety of fuel types. While these blended rates can be a good starting point, take care when applying them to metropolitan areas; utility prices in major cities tend to be significantly higher than regional averages.

With base-year energy costs calculated and energy cost escalation rates determined, future energy costs for each year in the study period may be calculated. Once future energy costs have been discounted to their net present value as of the base date they may be summed for use in Equation 1 (E).

Operations, maintenance, and repair costs: OM&R costs are often more difficult to estimate than other building expenditures. Because operating schedules and maintenance standards vary from building to building, there is great variation in associated costs even for buildings of the same type and age. It is therefore especially important to use engineering judgment when estimating these costs.

Cost estimating guides may be used to calculate initial assumptions, but the most direct and reliable method for estimating OM&R costs is to obtain preventive maintenance service contract quotes directly from equipment manufacturers. Remember, as with initial investment costs, only the incremental OM&R costs need to be considered. If OM&R costs are essentially the same between project alternatives, they do not have to be included in the LCCA.

Tools for calculating LCC

There are several software programs that simplify LCC calculation and results documentation. One of the most widely used is BLCC5, which was developed by the National Institute of Standards and Technology in support of the Federal Energy Management Program (FEMP). It computes the LCC for project alternatives, compares project alternatives to determine which has the lowest LCC, performs annual cash flow analysis, and computes supplementary measures of economic performance including net savings, savings-to-investment ratio, and adjusted internal rate of return for project alternatives over their designated study period.

While BLCC5 is useful for most LCCA studies, more advanced analysis techniques are not supported. LCCAid is a Microsoft Excel-based tool developed by the Rocky Mountain Institute that provides additional flexibility, including multi-parameter sensitivity testing. cse

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