UNIVERSITY OF CALIFORNIA

University of California
Life Cycle Cost Analysis (LCCA) Guidelines

Version May 31, 2023

GLUMAC
A TETRA TECH COMPANY

TABLE OF CONTENTS

I. UC LCCA GUIDELINES

EXECUTIVE SUMMARY

Life Cycle Cost Analysis (LCCA) is a method of evaluating the cost effectiveness of project design decisions. It is a holistic approach to capital planning and design that considers the near and long-term financial implications for a facility or project. The University of California LCCA Guidelines (Guidelines) are developed in support of the UC Sustainable Practices Policy. These Guidelines are intended to establish a basic LCCA process framework that is consistent systemwide, provide recommendations to UC practitioners for developing project-specific LCCAs, and serve as a resource to support decision-making for UC capital projects.

These Guidelines are relevant to multiple stakeholders, including UC leadership and representatives, UC Capital Program offices, and associated design professionals and facilities and asset managers.

For UC leadership, the Guidelines provide a summary of the LCCA process framework, and a broad validation of the benefit LCCA delivers to the UC enterprise and its mission.

For UC practitioners, the Guidelines are intended to be utilized as a practical tool and resource, and to help facilitate collaboration and communication within and among project teams and consultants. UC practitioners generally include campus and location departments and their individual constituents, such as Capital Programs, Design and Construction, Capital and Space Planning, Facilities and Asset Management, Energy Services, Sustainability, and Project Management among others.

For UC consultant teams, the Guidelines are intended to provide overall instructions for how LCCAs should be implemented, and how LCCA outcomes and resulting recommendations should be communicated when working on UC capital projects.

With an understanding that every project is unique in its origin and circumstance, the contents of these Guidelines are not intended to be requirements for strict adherence, but rather serve as a reference when approaching an individual project or use case. The UC LCCA Guidelines is a living document and intended to be informed by and updated based upon lessons learned among the UC community network.

To provide feedback or ask follow up questions, please contact UC Office of the President Executive Director of Capital Programs.

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II. INTRODUCTION

TOTAL COST OF OWNERSHIP

A life cycle cost analysis (LCCA) evaluates the total cost of ownership for a building, which includes both upfront construction costs and ongoing operational costs. Over the course of a building's life, the cumulative maintenance, utility, and renewal costs are substantial, and in some cases, are comparable to or higher than initial costs of construction, as shown in the example in Figure 1. These guidelines provide information on how to evaluate the costs associated with equipment life expectancy, maintenance schedules, future utility trends, and building construction.

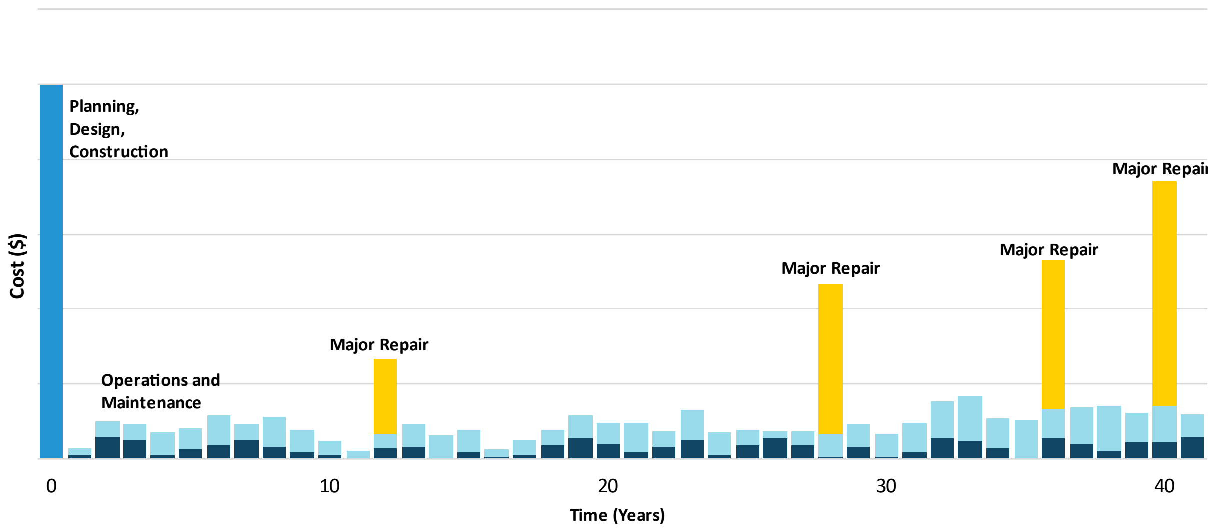


Figure 1. Example Building Life Cycle Costs

The UC LCCA Guidelines (Guidelines) may be used in conjunction with the *NIST Handbook 135: Life Cycle Costing Manual for the Federal Energy Management Program*[1] which provides in-depth information on components of a LCCA.

[1] https://nvlpubs.nist.gov/nistpubs/hb/2022/NIST.HB.135e2022-upd1.pdf

FUNDAMENTALS

A LCCA incorporates the various cost components of multiple design options into a single financial analysis. This provides project teams detailed insight into how current designs will impact long-term costs. This analysis has the potential to demonstrate how low-upfront-cost design options may result in high maintenance, operation, and renewal costs in the long run. Figure 2 shows an example total cost of ownership comparison between a baseline option and two alternative options. While the Baseline option has the lowest initial cost, over time it will result in an overall cost that is $100-$150 million above the overall costs of Options 2 and/or 3. And while Option 2 has a quicker payback period, making the investment in Option 3 will save an additional $50 million over the life of the project.

Performing an LCCA involves combining design characteristics with sensible assumptions and applying the correct financial analysis. The primary output of an LCCA must be defined by the project team to achieve the specific goals of the project and is typically a performance metric such as net present value (NPV), return on investment (ROI), or internal rate of return (IRR). By distilling the lifetime costs into a single value, the financial merits of each design alternative can be compared and weighed in the decision-making process.

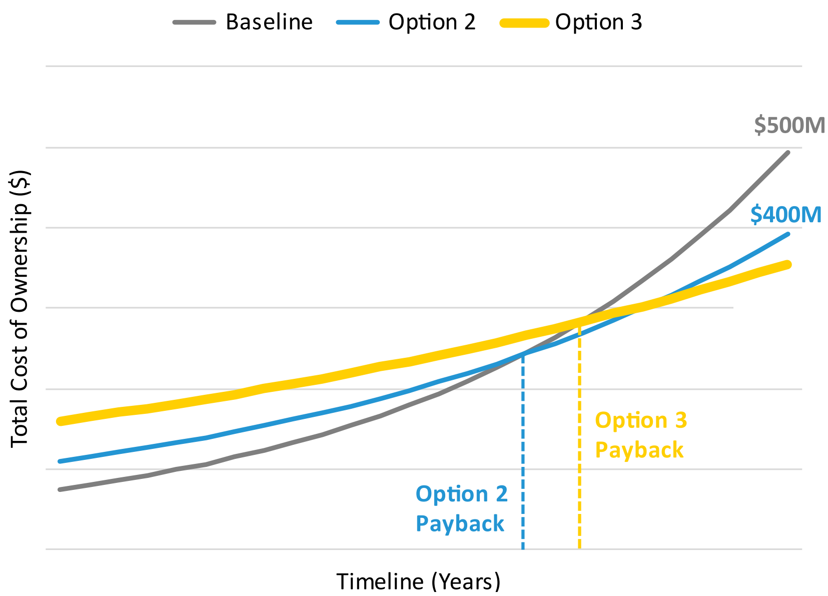


Figure 2. Example Total Cost of Ownership Comparison

APPLICATION

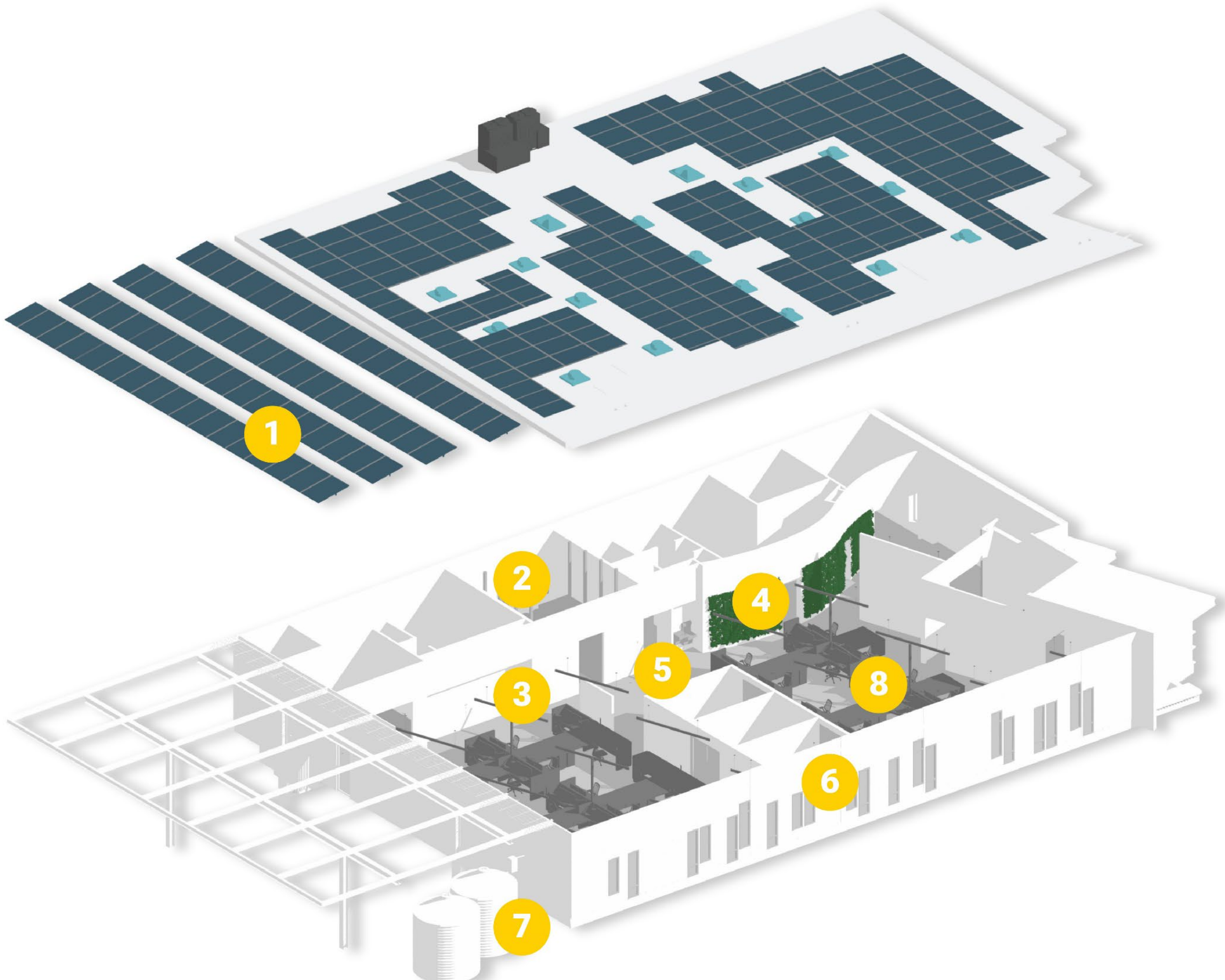
The UC LCCA Guidelines can be applied to capital projects ranging from large new construction development to specific building system renewals and upgrades. The right application is unique to each project and should be determined by project teams. A LCCA can be implemented as part of any project delivery method and at various phases of planning and design. Performing LCCA as early as practical and reiterating or refining at appropriate stages of planning and design will result in the greatest benefit and value added to the project.

The UC LCCA Guidelines should be utilized in conjunction with other University of California policies, standards, and guidelines including the UC Sustainable Practices Policy[2] and the UC Facilities Manual[3].

[2] https://ucop.edu/sustainability/policy-areas/index.html
[3] https://www.ucop.edu/construction-services/facilities-manual/

BUILDING SYSTEMS

A LCCA can be used to evaluate design options for various building systems. Figure 3 displays an example of building systems for consideration. The most common building design options to be included in a LCCA are Energy Resources, Mechanical systems, and Plumbing systems because these systems often have a significant impact on utility and operation costs. It is important to note that not all building systems require an extensive LCCA. Project teams must identify and define the scope of LCCA throughout the relevant building systems on a project-specific basis.



1 **ENERGY RESOURCES**
Solar PV, Energy Storage, Microgrid Controls

2 **MECHANICAL**
System Selection, Equipment Selection, Controls

3 **ELECTRICAL**
Lighting Design, Lighting Controls, Metering

4 **PLUMBING**
Water Heaters, Fixtures, Reclaimed Water

5 **MASSING**
Layout & Floor Plans, Structural Systems

6 **ENVELOPE**
Windows, Insulation, Shading Devices

7 **SITE**
Stormwater Retention, Landscaping

8 **INTERIOR**
Flooring, acoustic ceilings, computer-access flooring, partitions

Figure 3. Example Building System Components

Project teams should consider the following when providing a LCCA for specific building systems:

1) Energy Resources – Energy resources have a significant impact on a project's energy cost and carbon emissions. Energy resources to consider for a LCCA include technologies such as solar photovoltaics (PV), battery energy storage, and microgrids.

2) Mechanical – Mechanical systems have a significant impact on the total cost of ownership of a building. Mechanical systems include various technologies and equipment to provide heating, ventilation and air-conditioning (HVAC). Selecting a lower upfront-cost HVAC system may result in higher costs over time.

3) Electrical – Electrical systems to consider for a LCCA include lighting, plug load control, power distribution, and metering systems. When evaluating lighting, the useful lifetime of lamps should be carefully considered. For light emitting diode (LED) retrofit projects, lamp life and facilities labor costs may vary across different retrofit scopes.

4) Plumbing – Plumbing systems to consider for a LCCA include water consumption and energy use associated with domestic hot water heaters, industrial steam and hot water heaters, pool heating systems, and reclaimed water systems. The importance of the plumbing systems will depend on the uses and water demands of a specific building. For instance, residential and aquatic facilities will have a significantly higher water demand compared to classroom space types.

5) Massing – The shape, dimension and structure of a building has a significant impact on construction costs and carbon emissions. A LCCA is appropriate when various massing options are being considered. Embodied carbon considerations should be included when evaluating various structural systems including steel, concrete and mass timber.

6) Envelope – Envelope systems include windows, wall assemblies, insulation and external shading devices. Envelope considerations enable the project team to understand the impact and potential trade-offs of energy use, construction costs, and long-term maintenance costs. It is recommended that energy modeling software is utilized to assess energy and carbon impacts.

7) Site – Site systems include stormwater retention and landscaping.

8) Interior – Interior building systems include flooring systems, surface materials and ceiling systems. The durability of the materials will impact maintenance, repair, and replacement cost.

Selecting which building system(s) should be included in a LCCA should be determined based on the potential impact to the total cost of ownership and the complexity and effort involved in evaluating design options. Figure 4 shows an example comparison to help guide project teams. The vertical axis shows the potential impact to project costs and the horizontal axis shows the relative complexity of modeling and analyzing design options. For example, evaluating Mechanical and Envelope options requires a whole building energy model whereas an analysis of solar photovoltaic (PV) systems can be provided with easy-to-use solar modeling programs, such as PVWatts and Helioscope, and further, each building system will have a distinct potential to impact overall costs. It is important for project teams to understand and weigh the time and cost for implementing LCCA on specific building systems against the potential value added in overall cost savings.

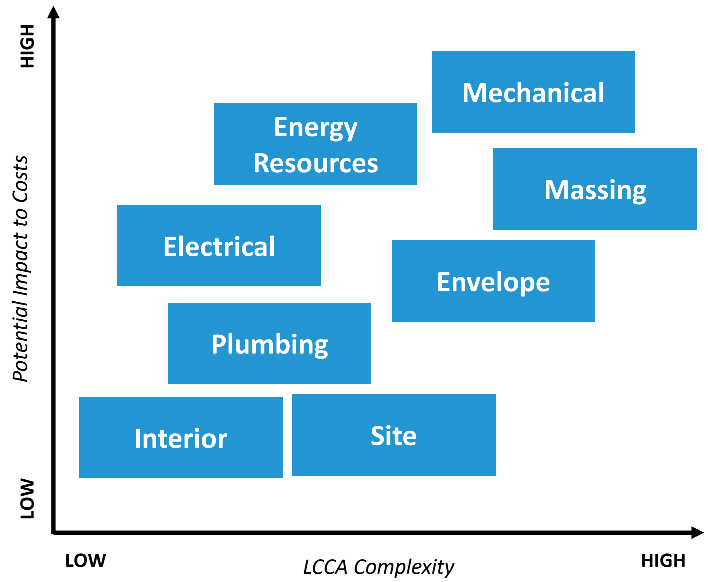


Figure 4. Example LCCA Priority Map

DESIGN PROCESS

A LCCA should be applied as early as practical to inform major design decisions. Further, it can also be a useful tool to support decision-making for later stage design options or during value engineering exercises. At the onset of a project, teams should determine at what stages LCCA will be applied to achieve project specific goals and requirements. Figure 5 shows a general project timeline overlaid on UC's Capital Project Phases, and provides suggestions on when LCCAs can be integrated into the capital development process. UC campuses and project teams should use their discretion on the best application of LCCA for specific projects. A LCCA may not be required at all stages to appropriately inform project decisions.

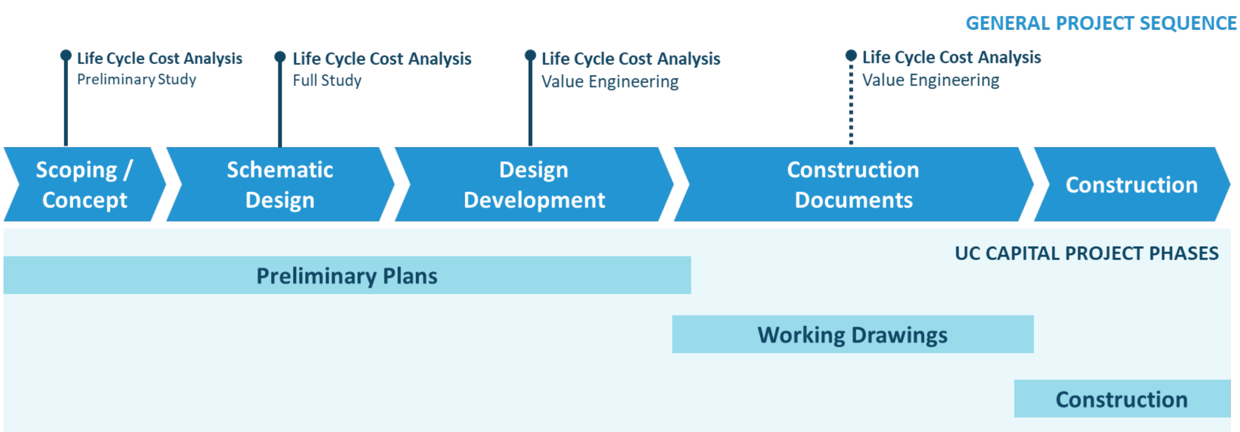


Figure 5. Example LCCA Application Timeline

The level of detail provided by a LCCA will vary based on the project phase and availability of information. Schematic Design is a good phase for a LCCA to inform a design approach and establish performance criteria for Preliminary

Plans. As a project progresses into Design Development and Construction Document phases a LCCA can be provided to inform more detailed design decisions or be included as part of any value engineering (VE) exercise.

Prequalification and Selection Process

UC campuses should consider how project teams will integrate LCCA principles into the design process during the consultant/contractor prequalification and selection process. When a project team selection process includes design competitions, it is important to provide any existing LCCA reports.

Design Competitions

Projects that include design competitions to assess design concepts as part of the award and selection process have additional considerations. A LCCA can be provided by design criteria consultant teams to inform performance requirement and system selections, or by Design Build teams as part of their response to a Request for Proposal. UC campuses should individually review each design competition to determine the right approach for how and when LCCAs should be provided.

QUALITY ASSURANCE AND QUALITY CONTROL

LCCA Inputs

Project teams should include quality assurance and quality controls when using a LCCA to inform design decisions. All inputs and assumptions included in a LCCA need to be verified to ensure results are correct and accurate. To reduce the potential for error, it is recommended that campuses provide project teams with the required inputs to be used within the LCCA. This includes key financial metrics and other campus specific information such as central plant efficiencies and utility rates. Refer to the Example LCCA Inputs included in Section V. Additional Resources.

Energy Modeling

Project teams should provide energy modeling as part of a LCCA to quantify energy costs. This is especially relevant for new construction projects where existing utility and operational data is not available. UC campuses should review energy model inputs to confirm the building operational assumptions are correct. Factors such as improper assignment of weather files, occupancy profiles, and mechanical sequences can impact the results of a LCCA.

Measurement and Verification

Measurement and verification (M&V) is the process of assessing the performance of a building or system once operational. Campuses should consider reviewing post-occupancy building performance data against projections included in a LCCA. This can help identify lessons learned and improve future projects.

III. UC LCCA PROCESS

The UC LCCA process includes a five-step framework to initiate and complete a life cycle cost analysis. Figure 6 provides an overview. This framework serves as a baseline example to be a utilized and adapted to meet the unique needs of individual projects.

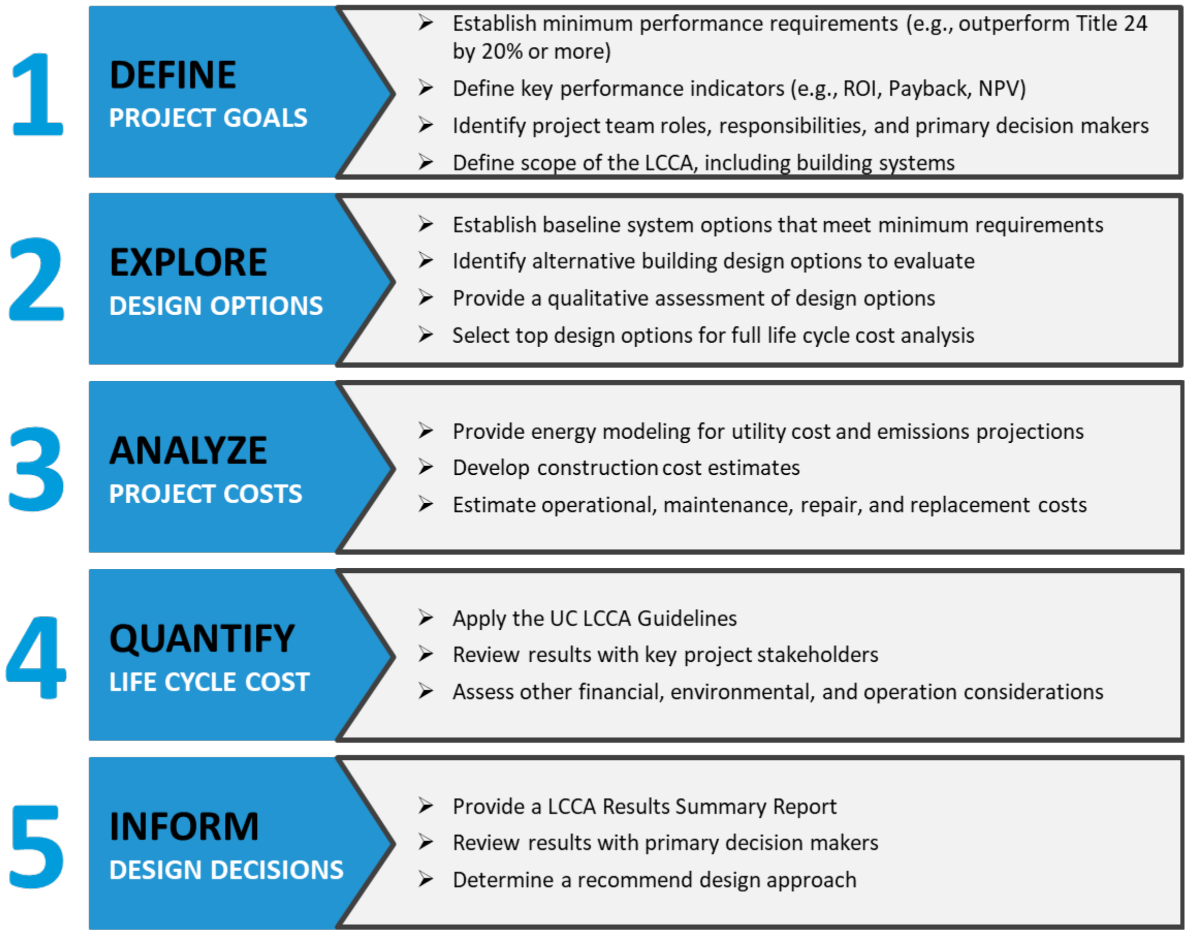


Figure 6. UC LCCA Process Framework

STEP 1: DEFINE PROJECT GOALS

The first step of a LCCA is to define the project goals. This is critical for providing a successful analysis. This includes identifying energy and sustainability requirements and goals, defining the scope of analysis, identifying key performance indicators (KPIs), and establishing project team roles and responsibilities.

Energy and Sustainability Requirements and Goals

The project team must define the key energy and sustainability goals for the project to ensure that all design options meet the minimum performance requirements.

Below is an example set of project goals for a new construction project:

- 20% savings compared to a Title 24 standard building design
- LEED Platinum rating achieving 18 of 18 Optimize Energy Performance points
- 30 kBtu/SF energy use intensity (EUI) or lower

LCCA Study Scope

The project team must define what building systems should be included in the analysis. A LCCA can be used to evaluate multiple building systems collectively (e.g., Mechanical, Energy Resources, and Plumbing), or used for individual, specific building systems where there are various design options being considered (e.g., Mechanical HVAC systems). See *Step 2: Explore Design Options* for additional information.

Quality Management

Project teams define the quality assurance and quality control requirements for an LCCA study. At minimum, the project team should establish uniform LCCA inputs which are reviewed by key UC stakeholders. Additional post-occupancy measurement and verification (M&V) processes can be included to review operational data against projections included in a LCCA. When post-occupancy M&V is included, project teams should ensure the building design includes monitoring and controls that allow for data collection.

Key Performance Indicators (KPI)

After determining the scope of the analysis, the project team should determine the appropriate KPIs. This involves defining the criteria by which different options will eventually be compared and assessed. It is important to define KPIs early in the LCCA process because options could potentially be favorable in certain KPIs but not in others. Defining which KPIs are most important in achieving project goals will bring clarity to the results.

Table 1. LCCA Key Performance Indicators includes typical KPIs for consideration. It is recommended that the Net Present Value (NPV) and Carbon Reduction Effectiveness are used as the standard KPI, unless specific project requirements warrant using different metrics.

Table 1. LCCA Key Performance Indicators

KPI	DESCRIPTION
Net Present Value (NPV)	Cumulative cash flows discounted to show value added in today's dollars
Internal Rate of Return (IRR)	The discount rate at which NPV is equal to zero. A higher IRR indicates better intrinsic performance.
Savings to Investment Ratio (SIR)	Comparison between lifetime savings and cost. Used to prioritize deployment of different projects.
Carbon Reduction Effectiveness ($/MTCO2E)	A ratio of project costs and carbon reduction. Represents the dollar costs to reduce a metric ton of carbon.

Roles and Responsibilities

Clearly defined roles and responsibilities should be established for each project. For a LCCA to be successful, various stakeholders and consultants will need to provide input throughout the process. Table 2 provides an example of stakeholders groups, and the need to provide input and review during the LCCA process. A primary decision maker should be established at the start of the LCCA process.

Table 2. Example LCCA Owner Roles and Responsibilities

STAKEHOLDER GROUP	EXAMPLE OF INPUT PROVIDED	EXAMPLE SCOPE OF REVIEW
Finance	Financial terms and KPIs	Financial inputs
Project Management	Project requirements, system options	LCCA results
Sustainability	Carbon offsets	Sustainability considerations
User Groups	Project goals and user requirements	Project goals

A LCCA should consider input from various members of the project design teams. Table 3 outlines example roles and responsibilities within a consultant team.

Table 3. Example LCCA Consultant Team Roles and Responsibilities

CONSULTANT TEAM	ROLE & RESPONSIBILITY
Architect	System options, space programing, design considerations
General Contractor	Constructability, cost estimates
Subcontractors (Trades)	Constructability, cost estimates
Cost Estimator	Cost estimates
MEP Engineers	System options, design considerations
Energy Consultant	Energy modeling, utility costs, LCCA lead
Sustainability Consultant	Sustainability goals & considerations
Other Design Disciplines	Design considerations

STEP 2: EXPLORE DESIGN OPTIONS

The second step of a LCCA is to identify and explore potential design options. For each LCCA building system to be assessed, project teams should establish a baseline system and identify several alternative design options for consideration. The baseline system can be a traditional design (e.g., in-kind replacement), or a design option that is common to similar projects or buildings. The baseline system provides a control scenario by which the alternative design options can be compared and assessed. Alternative design options must be vetted for feasibility through qualitative assessments before moving forward with a detailed financial analysis.

Figure 7 outlines an example process of exploring design options for an Energy Resource building system. A baseline design was established as having no onsite distributed energy resources, and other potential alternative options were identified for consideration. A qualitative assessment then determined that geothermal and hydrogen fuel cells were not viable options based on project constraints, such as site conditions and high capital costs. As a result, a LCCA will move forward considering the baseline option, and the remaining alternative options.

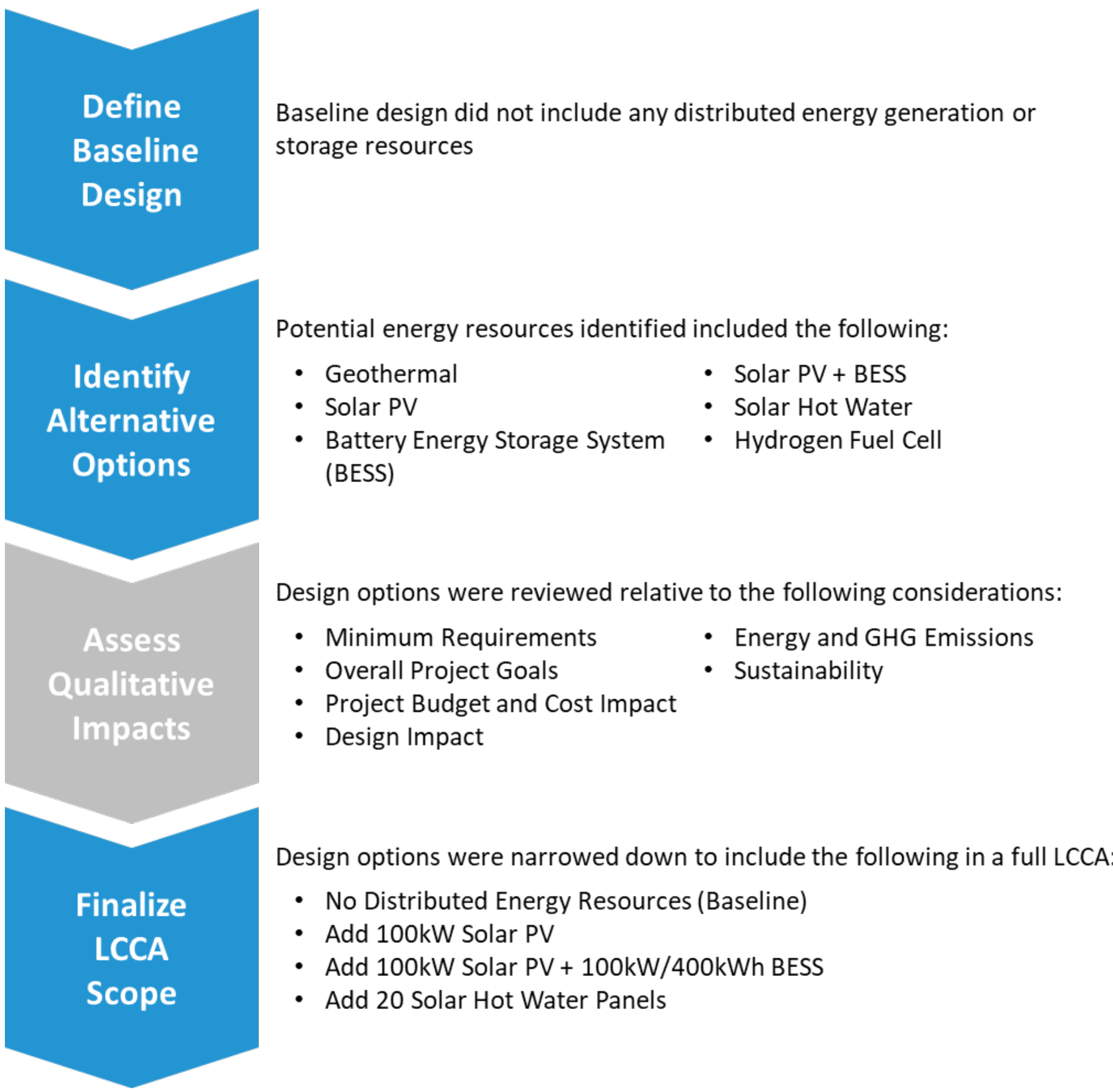


Figure 7. Example of Exploring Energy Resource Options

STEP 3: ANALYZE PROJECT COSTS

The third step of a LCCA is to estimate and analyze the comprehensive costs associated with all options resultant from the previous step of exploring of design options. This includes construction cost estimates, utility cost modeling, operation & maintenance costs, and future repair or replacement costs. Table 4 provides an overview of design option cost components, and example data sources to aid in the development and estimation of costs.

Table 4. LCCA Cost Components

COST COMPONENTS	EXAMPLE DATA SOURCE
CONSTRUCTION Upfront capital required for initial construction	• Detailed cost estimate from Cost Estimator/Contractor/Consultant • Industry guidelines (e.g., RS Means) • Previous campus project
O&M, REPAIR AND REPLACEMENT General operation & maintenance (O&M), periodic equipment repairs and end of life replacement costs	• Industry guidelines (e.g., RS Means, CBRE Cost Lab, Whitestone Manual) • Estimates from Facilities and Asset Departments • Industry organizations (e.g., Building Owners and Managers Association (BOMA), International Facility Management Association (IFMA), Association of Physical Plant Administrators (APPA))
ENERGY & UTILITIES Current rates and expected escalation of electricity, natural gas, water, sewer, etc.	• Utility rates • Energy Model results
HEATING & COOLING Efficiency and cost of generating and distributing heating and cooling	• Central Plant efficiency • Heating & Cooling recharge rates • Energy Model demands
CARBON Embodied carbon associated with project materials and processes. Operational GHG emissions from utilities, heating & cooling, lighting, refrigeration	• Compliance Offsets (Cap & Trade) • Voluntary Offsets • Social Cost of Carbon[1]
USEABLE BUILDING AREA[1] Value of building area if design options impact the amount of usable square footage available to achieve project programming goals and objectives	• Impact on useable space • Value of space ($/SF)
RESIDUAL VALUE[1] Value of an asset or material after it has fully depreciated or has reached/is beyond its useful life	• Industry guidelines • Estimates from Facilities and Asset Departments

NOTE

1. It is best practice to consider all cost components of design options, however UC systemwide, as well as industry-wide, consensus on categories such as Social Cost of Carbon, Useable Building Area, and Residual Value are still being explored. At this time, UC campuses and locations should consider all cost components of design options and provide justification and reasoning for incorporating or not incorporating costs associated with such categories until substantial consensus is reached and additional guidance is available. Furthermore, a sensitivity analysis can be provided for these cost categories.

Construction Costs

Construction costs include the upfront capital expenditures associated with a project. For example, costs related to design, land acquisition, permitting, materials, equipment, construction, and project administration. Construction costs are typically viewed as non-recurring items that are needed to get the project or system operational. Determining capital costs in early project phases can be challenging as direct quotes and bids may not be available, and the project may not be fully defined. If possible, it is recommended to engage an experienced contractor or professional cost estimator to advise on construction costs. For early-stage or preliminary plan phase cost estimates, construction cost databases may help provide rough order of magnitude estimates.

Project teams must clearly communicate the relative uncertainty associated with cost estimates. Table 5 outlines the categorization of cost estimates into four Classes as defined by the Association for the Advancement of Cost Engineering (AACE). UC stakeholders must specify the cost estimate Class needed at various project phases, and Contractor/Consultant teams must advise on the Class of the cost estimate being furnished. As project design progresses the accuracy of the cost estimate should also increase.

Table 5. AACE Classification of Cost Estimates

PROJECT PHASE	AACE CLASS	DESCRIPTION
Scoping / Concept	Class 4	Order of magnitude feasibility study
Feasibility Study	Class 3-4	Budgetary estimate
Schematic Design	Class 3	Budgetary estimate
Design Development	Class 2	Bidding and pricing control
Construction Documents	Class 1	Bidding and pricing control

See Section V. Additional Resources for further information regarding construction cost estimation.

Operations & Maintenance, Repair and Replacement

Operations & Maintenance (O&M), Repair and Replacement costs include expenditures required to keep the building system running and achieving project goals throughout its useful life. These include recurring costs such as facilities personnel labor, replacement of spent items and materials, insurance, and preventative maintenance. Additionally, these costs include non-routine expenditures related to reactive maintenance in response to non-planned issues or disruptions, such as equipment failure or malfunction.

O&M, Repair and Replacement costs may be difficult to estimate since there is wide variability in how building systems are utilized. Generalized O&M costs may be referenced from industry guidelines such as Whitestone Research publications, CBRE Cost Lab, and RS Means from Gordian. These resources provide a breakdown of life cycle costs including annual maintenance, periodic repairs, and end of life replacements.

Additionally, historical data from specific or aggregated UC campus or location Facilities and Asset Management Departments (e.g., Integrated Capital Asset Management Program (ICAMP), Maximo) can be used to develop estimates for improvement projects to existing buildings, or new buildings of comparable size, systems, and other characteristics. When and if utilizing historic data to develop projections within and among different campuses and locations, it is important that project teams clearly communicate assumptions made and the impact to cost estimate uncertainties. While all campuses and locations have similarities, they also have unique features in their organization and procedures.

While equipment may be utilized beyond it’s expected useful life, when performing a LCCA it is suggested to assume the manufacturer’s recommended replacement timeline – and any desired adjustments must be confirmed among the project team and appropriate UC stakeholders.

Energy & Utilities

Energy and utility costs (e.g., electricity, water, gas) are a primary driver of potential project savings. Further, project teams should assess greenhouse gas emissions associated with energy and utility systems.

It is recommended to utilize energy calculations from professional engineering sources to determine predicted utility consumption. For projects that are served by campus utilities (e.g., electricity, chilled water, hot water), full burdened utility costs and projected escalation rates should be provided by campus Energy Managers. For projects that have dedicated utility meters, project teams should account for detailed time of use (TOU) rate structures rather than defaulting to blended utility rates.

Carbon

In support of the UC Sustainable Practices Policy, projects and design options that minimize or neutralize carbon emissions must be favorably prioritized by UC project teams. Reducing carbon emissions is critical for limiting UC's impact on climate change.

Carbon Sources

It is recommended that project teams provide a full accounting of the carbon emissions when possible. Operational emissions are typically categorized into Scope 1, Scope 2, and Scope 3 emissions measured in equivalent metric tons of carbon dioxide.

- **Scope 1 Emissions** – Direct emissions on campus. Examples include emissions from natural gas for space heating, ICE campus vehicles, diesel generators, and fugitive refrigerant emissions.
- **Scope 2 Emissions** – Indirect emissions from campus sources. Examples include all forms of non-renewable electricity purchased from a local utility.
- **Scope 3 Emissions** – All other indirect emissions that are a consequence of the activities of an institution but occur from sources not owned or controlled. Examples include commuting, waste, and purchased goods.

Embodied carbon of construction materials and building systems (e.g., emissions resulting from the manufacturing, transportation, and installation processes) should be included in a LCCA, when available, and especially when alternative design options have the potential for significant embodied carbon savings.

Carbon Cost

Full cost accounting for carbon is in the process of being standardized by the UC system. Until further guidance is established, UC campuses and locations must account for direct costs associated with carbon emissions, and reasonably account for adjacent costs associated with carbon emissions. Carbon emissions have a vast impact on environmental systems, community health and wellness, and business objectives and must be thoughtfully considered when making project design decisions. Direct and indirect costs associated with carbon emissions include the following:

- **Cap & Trade:** Compliance offsets that are required as part of the California emissions trading program. Cost projections should be confirmed with UC project teams, which may include Sustainability Departments.

- **Voluntary Offset:** Voluntary carbon offsets to meet organizational initiatives and goals.

- **Social Cost of Carbon (SCC):** An estimate of the economic damages that result from the emission of one additional metric ton of CO_2, including the financial harms caused to business and social productivity, and public health.

It is best practice to consider the total SCC when developing capital projects. Consensus on the SCC is being explored within the UC system, and across the industry. Additional guidance will be made available in the future, and project teams should consult with campus Sustainability Departments for additional resources and references for carbon accounting practices.

Residual Value and End of Life Costs

When building systems and/or individual pieces of equipment reach the end of their service life, there are associated cost impacts to consider in a LCCA. There may be some residual or salvage value for equipment with precious metals or usage beyond the University service life. For example, projects that have electric transportation systems/infrastructure, battery storage systems, or photovoltaic solar should consider residual value when performing a LCCA.

Typically, projects will have end of life costs rather than credits associated with residual or salvage value. Costs related to demolition and material removal, transport and disposal may need to be incorporated into a LCCA. In certain instances, demolition costs will be accounted for in future development capital costs, rather than the current proposed project. LCCAs should be performed with consistency across these types of assumptions.

STEP 4: QUANTIFY LIFE CYCLE COST

The fourth step of a LCCA is to develop long-term cashflows and compare financial KPIs of the alternative design options. This can be either the full total cost of ownership in absolute terms, or the relative cost difference between a baseline or business-as-usual design option.

Financial Inputs

Table 6 describes general financial inputs to be incorporated into a LCCA. See Section V. Additional Resources for additional information.

Table 6. Example LCCA Financial Inputs

<table>
<tr><th>LCCA FINANCIAL INPUTS</th><th>CONSIDERATIONS[1]</th></tr>
<tr><td>ANALYSIS PERIOD
Expected lifetime of a project, or standardized time period for LCCA review and assessment</td><td><table><tr><th>Program Space Type</th><th>Example Default (Years)</th></tr><tr><td>Academic/Admin Non-Complex</td><td>50</td></tr><tr><td>Housing</td><td>30</td></tr><tr><td>Lab/Complex</td><td>50</td></tr><tr><td>Medical</td><td>40</td></tr></table>
Analysis Period should be adjusted based on LCCA scope and project life to capture full life cycle costs</td></tr>
<tr><td>DISCOUNT RATE
Opportunity cost of capital for UC capital projects</td><td>Example Default Value: 3.0%
Discount rate to represent and understand the present and future value of money</td></tr>
<tr><td>GENERAL INFLATION
Increase in overall costs of goods and services</td><td>Example Default Value: 2.5%
Based on historical US inflation rates</td></tr>
<tr><td>CONSTRUCTION ESCALATION
Increase in costs of construction materials and labor</td><td>Example Default Value: 4.0%
Construction costs have historically outpaced general inflation in most of California</td></tr>
<tr><td>O&M ESCALATION
Increase in costs to operate & maintain buildings</td><td>Example Default Value: 3.0%
Default rate is set to match/align with general inflation</td></tr>
</table>

NOTE

1. "Default" values shown here are generalized figures based on common industry practice and assumptions. It is recommended that LCCA financial input values be developed, reviewed, and confirmed by the project team specific for each project.

Discounted Cash Flow

A discounted cash flow table enables the comparison of the net present value (NPV) of design options with consideration for relevant discount and escalation rates. Table 7 and Table 8 provide a simplified example comparing discounted cash flow tables. Design Option 1 has a NPV of about $31,154,000, and Design Option 2 has a NPV of about $27,788,000. The overall NPV cost of Design Option 2 is about $3,365,000 less than Design Option 1, even while Design Option 2 has an upfront capital cost $5,000,000 greater than Design Option 1.

Table 7. Example Financial Inputs

Capital Costs	
Design Option 1	$20,000
Design Option 2	$25,000

Financial Inputs	
Discount Rate:	3%
Construction Escalation:	4%
Maintenance Escalation Rate:	2%

Table 8. Example Discounted Cash Flow ($MM)

	Design Option 1			Design Option 2		
Year	Utility Costs[1]	Operational Costs[2]	NPV	Utility Costs[1]	Operational Costs[2]	NPV
0			$(20,000)			$(25,000)
1	$1,000	$200	$(1,165)	$200	$100	$(291)
2	$1,020	$204	$(1,153)	$204	$102	$(288)
3	$1,040	$208	$(1,142)	$208	$104	$(285)
4	$1,061	$212	$(1,131)	$212	$106	$(282)
5	$1,082	$216	$(1,120)	$216	$108	$(280)
6	$1,104	$220	$(1,109)	$220	$110	$(277)
7	$1,126	$225	$(1,098)	$225	$112	$(274)
8	$1,148	$229	$(1,088)	$229	$114	$(272)
9	$1,171	$234	$(1,077)	$234	$117	$(269)
10	$1,195	$239	$(1,067)	$239	$119	$(266)
	Total Life Cycle Cost – NPV		$(31,154)	**Total Life Cycle Cost – NPV**		$(27,788)
					NPV Savings from Option 2 to Option 1:	**$3,365**

NOTE

1. Utility Costs include purchased electricity, natural gas and biogas, and campus chilled water and steam.
2. Operational costs includes general operation & maintenance, equipment repair & replacement, and the costs of carbon (e.g., voluntary offsets, Cap & Trade, social cost of carbon).

There are multiple methodologies of LCCA, including how to address the time value of money. Two acceptable approaches for analyzing the time value of money are (1) constant-dollar-analysis and (2) current-dollar-analysis. Upon initiating a LCCA, the project team should choose one approach and remain consistent throughout the process. The chosen approach will impact how discount rates, inflation, and escalation rates are applied. Further, to ensure results are appropriately comparable, the project team must verify the data, and be prepared to make any necessary adjustments for data conformance to a consistent constant-dollar-analysis or current-dollar-analysis method.

Additionally, the analysis periods between design options must be the same. Comparisons of LCCAs with different analysis periods are not valid for the majority of KPIs. The analysis period should be set to that of the longest lifetime among the design options, and design options with shorter lifetimes should be iterated accordingly to match the set analysis period.

STEP 5: INFORM DESIGN DECISIONS

The final step of a LCCA is to develop a report or set of deliverables that clearly communicate a summary of LCCA results, and how these results may be used to inform project design decisions aligned with project goals and objectives. The report should include the following components.

- **Executive Summary:** High-level synopsis of the project and any relevant background, context or assumptions, project goals and objectives, design options being considered, results of the LCCA, and recommendations.
- **Process Description and Details:** Summary of LCCA procedures implemented (e.g., may include reference to these UC LCCA Guidelines), scope of LCCA, KPIs utilized, LCCA inputs and data sources.
- **LCCA Results:** Tables and graphics that simply and succinctly communicate LCCA results and KPIs – along with narrative text that explain this information.
- **Discussion of Results and Recommendations:** Additional communication of notable trends or nuances in the results, discussion of risks, opportunities, and consequences associated with design options, other factors for consideration, and guidance in interpretation of the results through the lens of achieving project goals.
- **Appendices and Supporting Data:** Facts, data, and information relevant to the preparation, implementation, and outcomes of the LCCA (e.g., detailed cost estimates, detailed cash flows, energy modeling reports).

Please refer to UC LCCA Reporting for additional information.

IV. UC LCCA REPORTING

LCCA REPORT COMPONENTS

A LCCA report succinctly conveys results of the LCCA process, provides relevant detail for review and validation of the methodology, and guides interpretation of outcomes with the perspective of achieving projects goals. Figure 8 outlines an example LCCA report format.

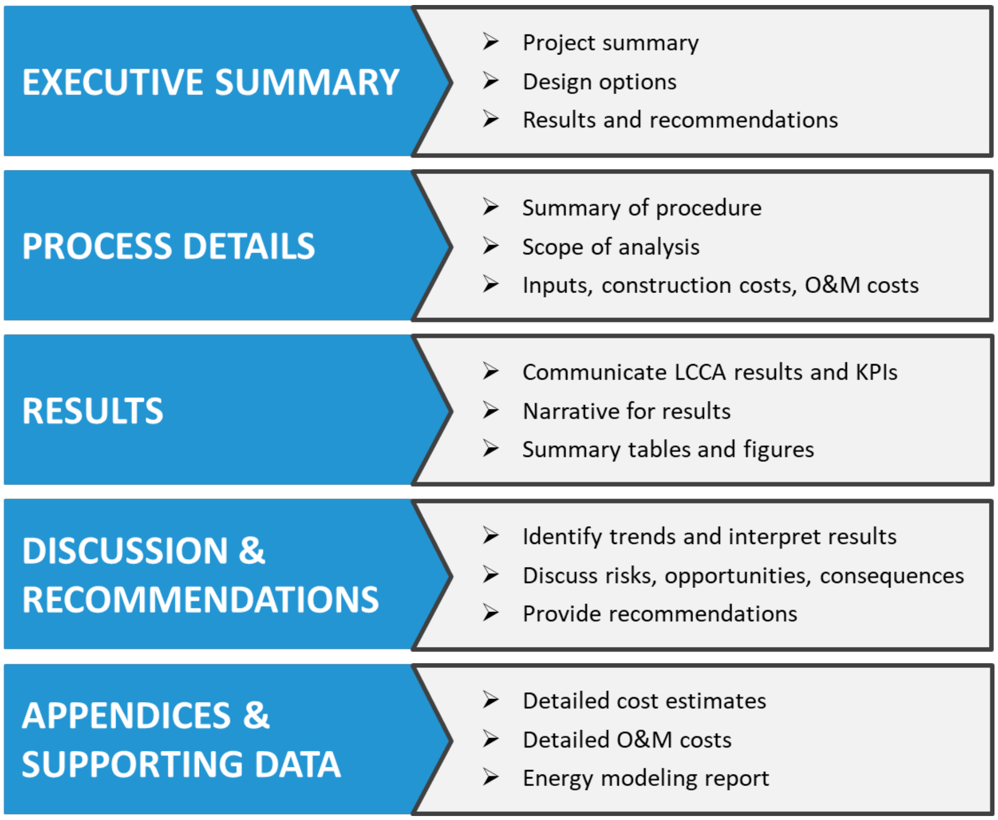


Figure 8: Example LCCA Report Format

EXAMPLE TABULAR AND GRAPHICAL DATA REPRESENTATIONS

The following tables and figures provide example data visualizations for incorporation into a LCCA report. The appropriate types of tables and figures may vary from project to project. KPIs and major costs should drive what information is highlighted in the report. Data and graphics must use consistent units and scales to ensure results are appropriate for comparison. When consistency is not possible, caveats and assumptions made must be clearly indicated, and additional explanation should be presented to provide clarity for interpretation of results. Table 9 provides an example summary table of a LCCA conducted for a building heating and cooling system.

Table 9. Example LCCA Report Table

		Add Heat Recovery Chiller, 375 tons		Option #3 + Air Source Heat Pump	
Utilities & Emissions					
Natural Gas (therms)	410,095	106,498	120,779	0	0
GHG Emissions (MTCO2E)	2,178	566	641	0	0
Cost Breakdown					
O&M	$80,168	$93,521	$97,949	$183,759	$110,645
GHG Emissions Offsets	$32,670	$8,484	$9,622	$0	$0
LCCA Results and KPIs					
Net Present Value (NPV)	$58,151,499	$55,743,228	$55,952,116	$63,414,005	$66,181,319
NPV Savings from Baseline	-	$2,408,271	$2,199,383	($5,262,506)	($8,029,820)
Simple Payback (Years)	-	12.1	9.2	149	N/A
Marginal Abatement ($/MTCO2E)	-	($60)	($57)	$97	$147

Figure 9 is a stacked bar chart comparing costs of design options – and identifies the relative cost difference from a baseline design option.

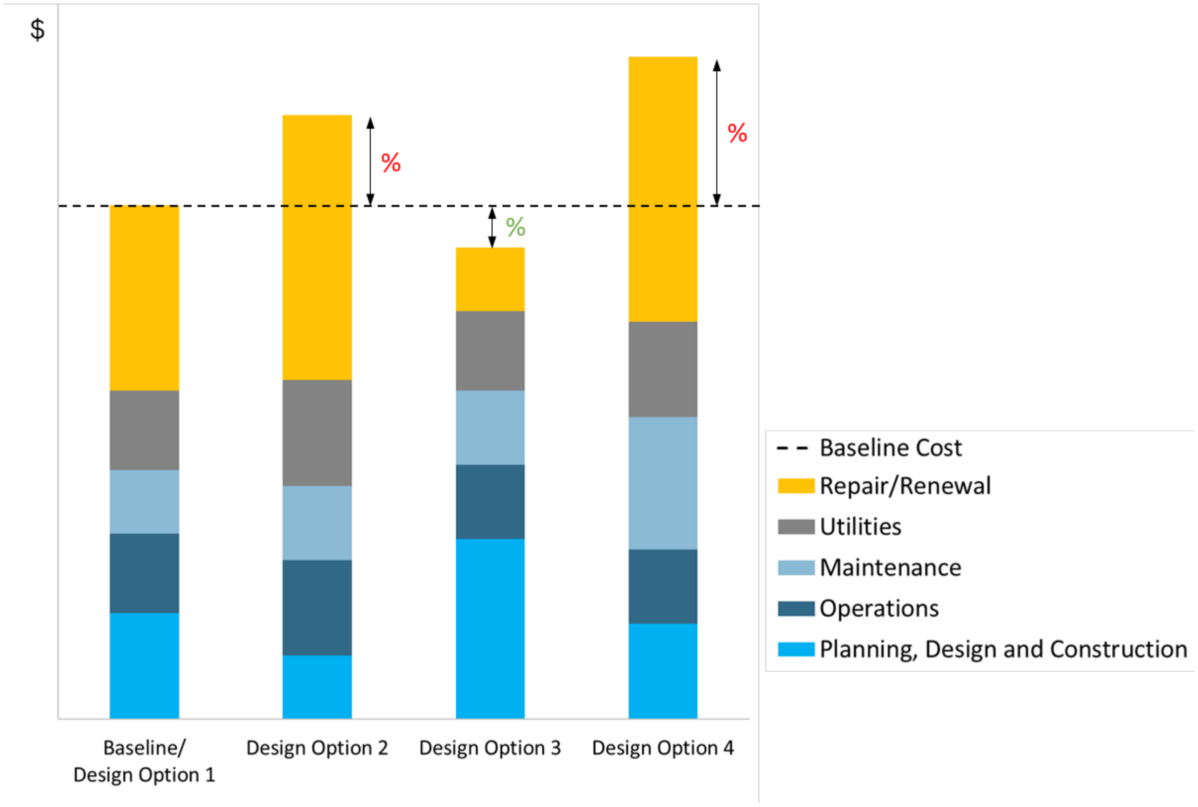


Figure 9. Example LCCA Results Graph

Figure 10 displays costs by category over the lifetime of an individual design option for a project.

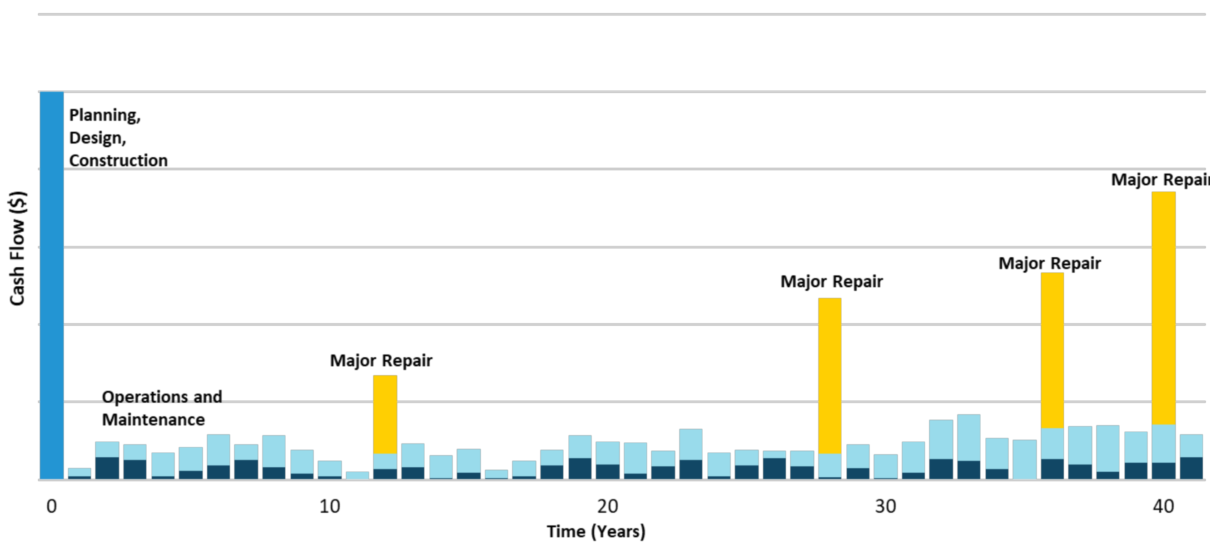


Figure 10. Example Life Cycle Cash Flow – Individual Design Option

Figure 11 displays the cumulative cash flow over time for an individual design option for a project. In this example chart, the financial break-even point can be identified at the transition from blue to green bars, demonstrating that the project is financially net positive.

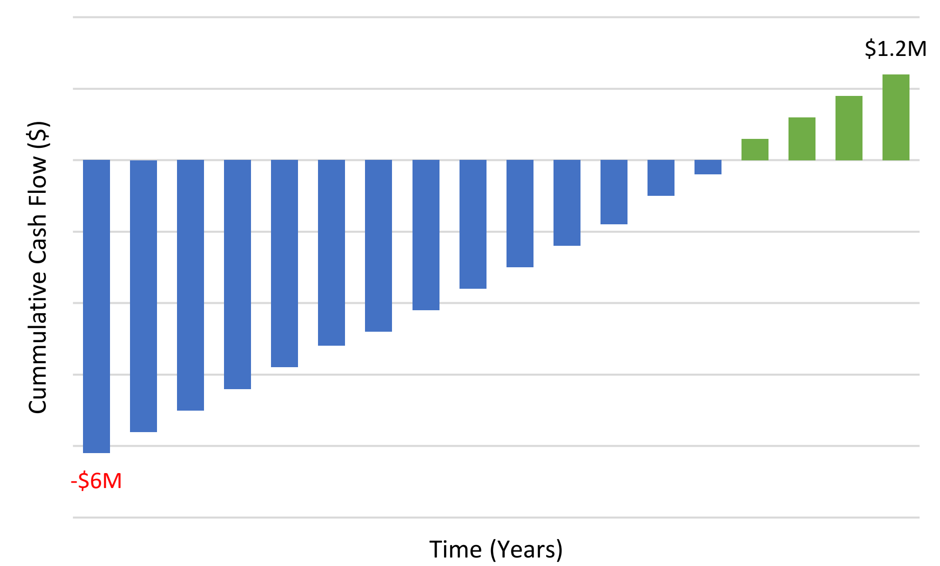


Figure 11. Example Individual Design Option Cumulative Cash Flow

Sensitivity and Scenario Analysis

The images below are screenshots of a LCCA Tool Dashboard capable of providing dynamic sensitivity analyses, to understand the impact of escalation and uncertainties throughout various cost categories.

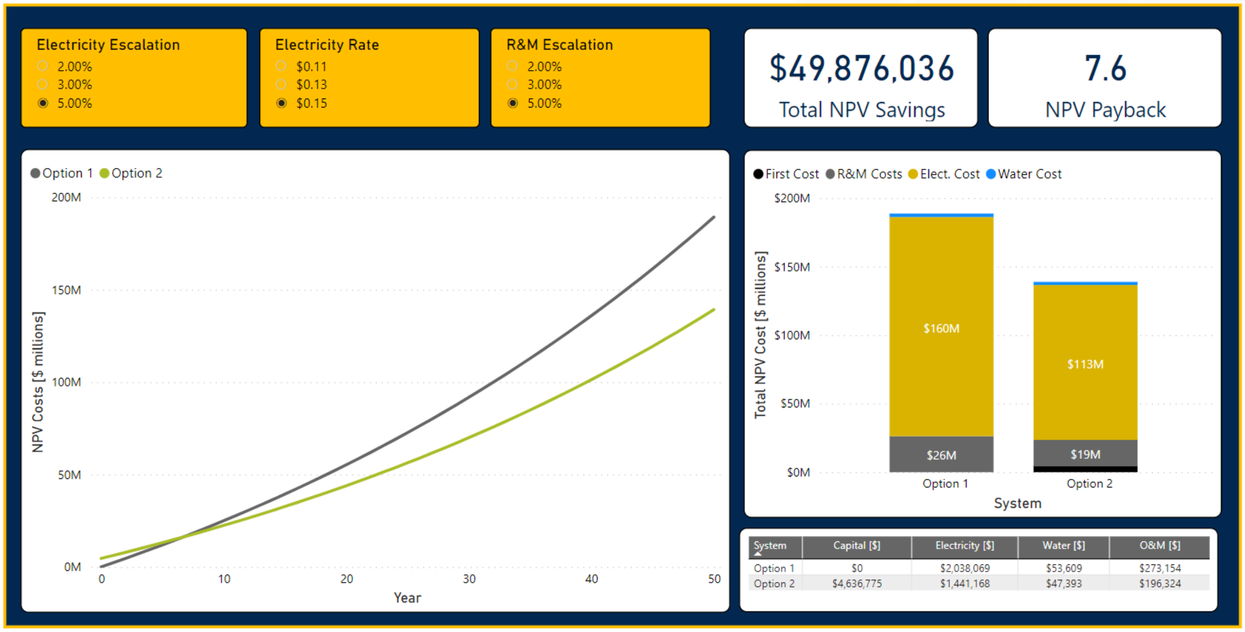


Figure 12. Example LCCA Sensitivity Dashboard – Scenario 1

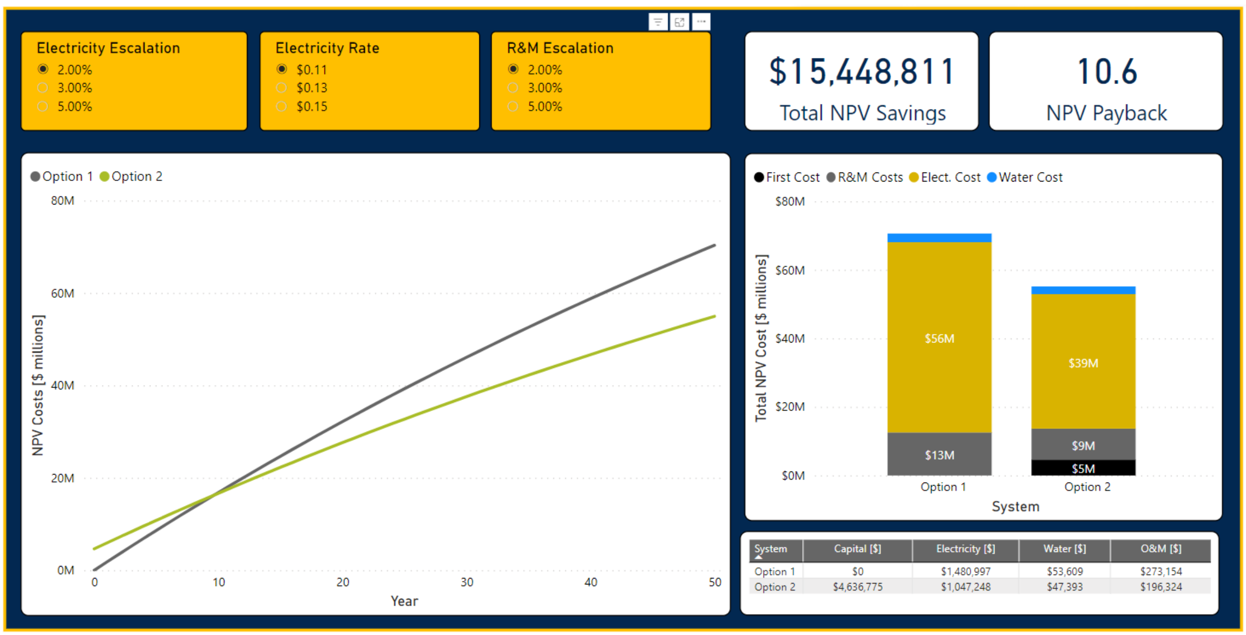


Figure 13. Example LCCA Sensitivity Dashboard – Scenario 2

V. ADDITIONAL RESOURCES

RESOURCES AND REFERENCES

RESOURCE	PURPOSE	DESCRIPTION
NIST Handbook 135 – Life Cycle Costing Manual	Overall LCCA resource	U.S. Department of Energy, Federal Energy Management Program manual for applying life cycle costs analysis. Price indices and discount factors are updated annually.
UC Sustainable Practices Policy	Design considerations and standards	The Sustainable Practices Policy establishes goals in 12 areas of sustainable practices: green building, clean energy, climate protection, transportation, sustainable operations, zero waste, procurement, foodservice, water, health, performance assessment, and health and well-being.
UC Facilities Manual	UC policies and procedures	The UC Facilities Manual contains University of California policies, procedures, and guidelines for its facilities. This includes planning, design, construction contracting, and facilities operations.
RS Means	Construction cost estimates	Data source for cost estimates of construction, labor, equipment, etc. Data can be adjusted/adapted based on project specifics, such as location and year.
Maximo	Maintenance cost estimates	Asset management software. Can show past building activity and actual costs associated with trouble calls, regular maintenance, and deferred maintenance.
CBRE-Whitestone Guidelines	Maintenance cost estimates	Data source for cost estimates of general maintenance, repair, and replacement of various building systems.
BOMA, IFMA, APPA	Facility services organizations	Industry resources for facilities management and construction.
ASHRAE Handbook	Codes, standards, and guidelines	Repository of heating, ventilation, and air conditioning information.
California Code of Regulations, Title 24	California Building Standards Code	Provides building standards and requirements – may be helpful in identifying and determining acceptable design options.
UC LCCA Library	Example LCCA reports	Collection of previous LCCA reports and studies across the UC system.

EXAMPLE LISTS OF LCCA INPUTS

The following are lists of LCCA inputs and factors that project teams may use as a reference guide. Please note, actual LCCA input values should be confirmed with relevant campus departments and personnel (e.g., Energy Managers, Sustainability, Capital Programs, Finance, Facilities and Assets, Capital Planning) for each project and use case. In addition, please contact UCOP Energy & Sustainability for any available UC systemwide default energy and energy costs assumptions. Contact UCOP Design and Construction Services for construction cost escalation and related factors.

Financial Inputs

FINANCIAL	LCCA INPUT	CONSIDERATIONS & NOTES
Analysis Period		Building lifetime
Discount Rate		Cost of capital
General Inflation		Long term
Construction Escalation		Near term inflation during design & construction
O&M Escalation		Long term escalation of maintenance/repair costs
Usable Area		Value of additional useable building square footage

Construction Cost Estimate

COST ESTIMATE	LCCA INPUT	CONSIDERATIONS & NOTES
Contingency		Confirm project specific requirements
Escalation		Align with project construction timeline
General Conditions/Requirements		Confirm project specific requirements
Contractor Overhead & Profit		Confirm project specific requirements
Insurance & Bonds		Confirm project specific requirements

Cost estimates at various project phases should be provided at the following level of detail at a minimum. UC campuses should confirm the level of detail required for each project phase.

PROJECT PHASE	AACE CLASS
Scoping / Concept	Class 4
Feasibility Study	Class 3-4
Schematic Design	Class 3
Design Development	Class 2
Construction Documents	Class 1

Utility Costs

UTILITIES (MAIN CAMPUS)	LCCA INPUT		CONSIDERATIONS & NOTES
Electricity		$/kWh	Consider blended campus electricity rate
Electricity Escalation			Consider utility and CA state projections
Electricity Emissions			
Natural Gas		$/therm	40% biogas starting in 2025
Natural Gas Escalation			
Natural Gas Emission		MTCO2E/therm	ENERGY STAR Portfolio Manager 40% biogas starting in 2025 (carbon free)
Water – Potable		$/HCF	
Water – Sewer		$/HCF	
Water & Sewer Escalation			

HEATING & COOLING	LCCA INPUT		CONSIDERATIONS & NOTES
Chilled Water Energy Cost		$/ton	Cost of energy to produce chilled water
Chilled Water Delivered Cost		$/ton	Total cost of delivering chilled water including energy, O&M, equipment repair & replacements
Chilled Water Efficiency		kW/ton	
Chilled Water Delivery Escalation			
Hot Water Energy Cost		$/MBtu	Cost of energy to produce hot water
Hot Water Delivered Cost		$/MBtu	Total cost of delivering hot water including energy, O&M, equipment repair & replacements
Hot Water Efficiency		Therms/MBtu	
Hot Water Efficiency		kWh/MBtu	
Hot Water Delivery Escalation			

GHG Emissions

CARBON INPUTS	LCCA INPUT	
Cap & Trade Rates		$/MMBtu
Voluntary Offsets		$/MTCO2E
Voluntary Offsets Escalation		
Social Cost of Carbon (equity weighted)		$/MTCO2
Social Cost of Carbon Escalation		

GLOSSARY OF TERMS AND ABBREVIATIONS

Analysis Period or Study Period – The time over which the LCCA is evaluated.

Association of Physical Plant Administrators (APPA) – Facilities and asset management industry organization.

Building Owners and Managers Association (BOMA) – Facilities and asset management industry organization.

Capital Investment – First or initial costs of a project.

Discount Rate – Factor which is used to incorporate the time value of money.

Energy conservation measure (ECM) – A project or building modification which aims to reduce energy

Energy use intensity (EUI) – Ratio of facility energy use to square footage. Typically expressed in the units of thousand British thermal units per square foot per year [kBtu/SF-yr].

Escalation rate – Factor which is used to account for rising costs of a specific good or service.

Future Value (FV) – Time equivalent value of present or past value.

Greenhouse gas (GHG) – Gases which absorb radiant energy and contribute towards the greenhouse effect.

Inflation – Factor which is used to account for rising costs of general goods and services.

Integrated Capital Asset Management Program (ICAMP) – UC asset inventory and condition assessment catalog.

Internal rate of return (IRR) – The lowest rate of return where the life cycle cost or net present value is equal to zero.

International Facility Management Association (IFMA) – Facilities and asset management industry organization.

Key Performance Indicator (KPI) – Significant metric aligned with project goals and objectives, used to evaluate performance.

Life Cycle Cost (LCC) – The value of all lifetime costs discounted to present value.

Life Cycle Cost Analysis (LCCA) – Evaluation of financial strength of project design options by determining total cost of ownership.

Measurement and Verification (M&V) – Process for assessing expected performance versus actual performance.

Minimum acceptable rate of return (MARR) – The minimum rate which the organization is willing to accept for a given project.

Monitor Based Commissioning (MBCx) – Process to continuously confirm building operates within expected ranges. Typically utilizes fault detection to inform facilities staff.

Net Savings (NS) – Savings less costs.

Present Value (PV) – Time equivalent value of today's dollar value.

Residual Value – The value of a project, building, or piece of equipment at the end of the useful life.

Savings to investment ratio (SIR) – Ratio of cost savings to project costs.

SF – Square foot/feet.

Value Engineering (VE) – Process of weighing costs against project requirements and eliminating unnecessary costs.