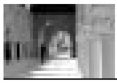
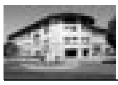
GUIDELINES FOR
LIFE CYCLE COST ANALYSIS

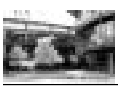


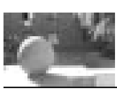

Stanford University
Land and Buildings
October 2005

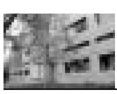
TABLE OF CONTENTS

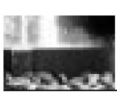












I. OVERVIEW

EXECUTIVE SUMMARY

Stanford University has a long history of designing and constructing quality building projects. In continuing this tradition, Stanford seeks to ensure that new and renovated buildings meet student, staff, and faculty needs as effectively and efficiently as possible. To this end, Stanford's Department of Land and Buildings has outlined a thorough Project Delivery Process (PDP) that addresses all aspects of planning, budgeting, design, and construction.[1]

Cost-effectiveness is a key component of design at Stanford, and initial project costs are the focus of many activities in the PDP. The long-term cost implications of building projects, however, range far beyond initial design and construction expenses. As the campus grows and ages, the cumulative cost of operating and maintaining facilities significantly impacts the overall institutional budget.

To improve the cost-effectiveness of its building and renovation programs, Stanford must invest in designs and systems with improved long-term performance. The *Guidelines for Life Cycle Cost Analysis* (LCCA) instruct Project Teams to consider not only the "first costs" of a building (design and construction expenses) but also long-term costs, including utilities, operations, and maintenance.

The Vice Provost for Land and Buildings convened a team of staff from departments within Land and Buildings, along with consultants from the design and construction fields, to develop the Guidelines for LCCA. These guidelines have been implemented as part of the broader PDP for all new building and renovation projects. These guidelines define LCCA, explain their relevance to Stanford projects, instruct Project Teams on their implementation, and provide technical specifications for preparing LCCA studies. They also establish standards and metrics to ensure accurate and consistent life cycle data collection and evaluation across projects.

These guidelines, like the PDP, are based on the principle of making informed decisions at the project level. They have been designed to dovetail with the existing PDP and to clarify decision making without adding unwieldy requirements. As the guidelines are repeatedly implemented, the data generated should result in increasingly accurate analyses for future projects.

[1] A detailed description of the PDP is provided in the 2001 Capital Planning & Management document, *The Project Delivery Process at Stanford: Process Phase and Control Summaries, Volume 1.*

WHAT IS LIFE CYCLE COST ANALYSIS?

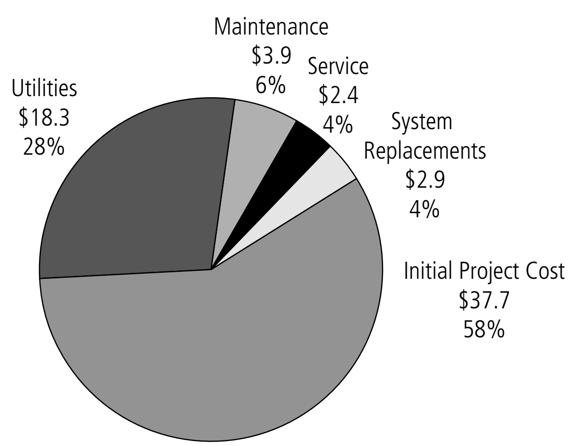
LCCA is a process of evaluating the economic performance of a building over its entire life. Sometimes known as "whole cost accounting" or "total cost of ownership," LCCA balances initial monetary investment with the long-term expense of owning and operating the building.

LCCA is based upon the assumptions that multiple building design options can meet programmatic needs and achieve acceptable performance, and that these options have differing initial costs, operating costs, maintenance costs, and possibly different life cycles. For a given design, LCCA estimates the total cost of the resulting building, from initial construction through operation and maintenance, for some portion of the life of the building (generally referred to as the LCCA "study life"). By comparing the life cycle costs of various design configurations, LCCA can explore trade-offs between low initial costs and long-term cost savings, identify the most cost-effective system for a given use, and determine how long it will take for a specific system to "pay back" its incremental cost. Because creating an exhaustive life cycle cost estimate for every potential design element of a building would not be practical, the Guidelines for LCCA focus on features and systems most likely to impact long-term costs.

WHY LCCA IS IMPORTANT

As the chart below illustrates, over 30 years of a building's life, the present value of maintenance, operations, and utility costs is nearly as great as the initial project costs.

Gates Computer Science Building
30-Year Life Cycle Cost
(in millions of dollars)



Funds secured or set aside to construct new campus buildings rarely extend to ongoing operational costs. Increasingly, campuses are experiencing shortfalls in their annual budgets for building operations. These lead to deferred maintenance and eventually to declining building utility and performance.

Designing new and renovated buildings with maintenance and operating costs in mind can result in significant savings. The Guidelines for LCCA help Project Teams calculate these costs and use them to inform planning, design, and construction decisions. Stanford's decision to implement LCCA as part of the PDP is a direct effort to reduce the total cost of building ownership.

LCCA'S RELATIONSHIP TO OTHER LAND AND BUILDINGS DOCUMENTS

Whenever possible, the LCCA process should incorporate the directives and guidance contained in other Stanford publications and guidelines. If a conflict arises between these documents and LCCA results, the Project Team will be responsible for resolving it, keeping in mind the ultimate goal of developing buildings with the highest value to the University.

Sustainability

Part of Stanford's commitment to quality building projects is a strong belief in the value of sustainability. Stanford's 2002 publication, *The Guidelines for Sustainable Buildings,* developed in collaboration with staff, faculty, and students, define sustainability as a balanced concern for community, economy, and ecology. Sustainable buildings use energy, water, and other natural resources efficiently and provide a safe and productive indoor environment.

As a quality assurance tool, LCCA is related to – but not synonymous with – sustainability. LCCA is a cost-based process; its goal is to identify the most cost-efficient building design and construction strategies over the life of the asset. LCCA addresses values that can be stated in dollars, not subjective issues such as occupant comfort or environmental impact. The most cost-effective solution is not always the most environmentally ideal choice. For example, a building system might consume very little energy but cost more to maintain than it saves in energy costs.

Very often, however, LCCA points to solutions that are environmentally desirable. Careful design choices that result in efficient use of energy and water often do yield long-term cost savings. Or, if environmentally favorable choices do not actually save money, LCCA may reveal that their additional cost over time is minimal. At the heart of "sustainability" is a balance between human concerns (e.g., cost, health, comfort) and environmental concerns (e.g., resource use, ecological degradation). LCCA is part of Stanford's overall effort to strike this balance.

Campus Planning and Design Documents

Documents from the University Architect/Campus Planning & Design Office inform the design and construction process. The Project Manager will determine which, if any, of these documents are applicable to the LCCA.

Facilities Design Guidelines

The *Facilities Design Guidelines* (FDG) specify basic requirements for campus buildings. Alternatives developed for LCCA should comply with the FDG wherever possible.

II. IMPLEMENTING THE LIFE CYCLE COST ANALYSIS PROCESS AT STANFORD

Life Cycle Cost Analysis will be implemented within the existing nine-phase PDP. Section III discusses in detail how to address LCCA at each stage. LCCA adds two major activities to the PDP: O&M Cost Benchmarking and Comparative Analysis. Each of these activities occurs at specific phases in the PDP, in conjunction with other Project Team tasks during those phases.

OPERATIONS & MAINTENANCE COST BENCHMARKING

During the Feasibility and Programming phases of the PDP, the Project Manager develops a "Benchmark Budget" with design and construction cost estimates based upon data from past projects. At this time, the Project Team will also develop an O&M Benchmark using historical operations and maintenance data from existing campus buildings for those LCCA components that apply to the project.

COMPARATIVE ANALYSIS

During the Schematic Design (SD) and Design Development (DD) phases of the PDP, the Project Team makes increasingly detailed decisions about the final design for the building, including mechanical, electrical, structural, telecommunications, and plumbing systems. During this period, the Project Manager will direct the team to conduct a series of analyses comparing the total costs of various building system options. Section IV of the Guidelines for LCCA defines steps to follow in conducting these analyses and provides constants (energy rates, discount rates, etc.) to be used.

STUDY CATEGORIES

The Project Team will assess the value to the project of up to 14 possible life cycle cost (LCC) comparisons in six general categories: Energy Systems, Mechanical Systems, Electrical Systems, Building Envelope, Siting/Massing, and Structural Systems. Within each category, the specific comparisons involve options for addressing the same need. The 14 comparison areas follow, with examples of options that might be considered in each. These examples are only for clarification; specific systems or options considered will vary with the type, scale, and intended use of the building.

Energy Systems

1. Central plant-connected vs. stand-alone systems (steam and chilled water)
2. Alternative energy systems (e.g., solar photovoltaics, solar thermal, fuel cells)
3. Equipment options for stand-alone systems (e.g., air-cooled chillers vs. refrigerant-based direct-expansion [DX] units)

Mechanical Systems

4. Air distribution systems (e.g., variable volume vs. constant volume, overhead vs. underfloor)
5. Water distribution systems (e.g., various piping systems and pumping options)

Electrical Systems

6. Indoor lighting sources and controls
7. Outdoor lighting sources and controls
8. Distribution (e.g., transformers, buss ducts, cable trays)

Building Envelope

9. Skin and insulation options
10. Roofing systems (various materials and insulation methods)
11. Glazing, daylighting, and shading options

Siting/Massing

12. Orientation, floor-to-floor height, and overall building height
13. Landscape, irrigation, and hardscape options

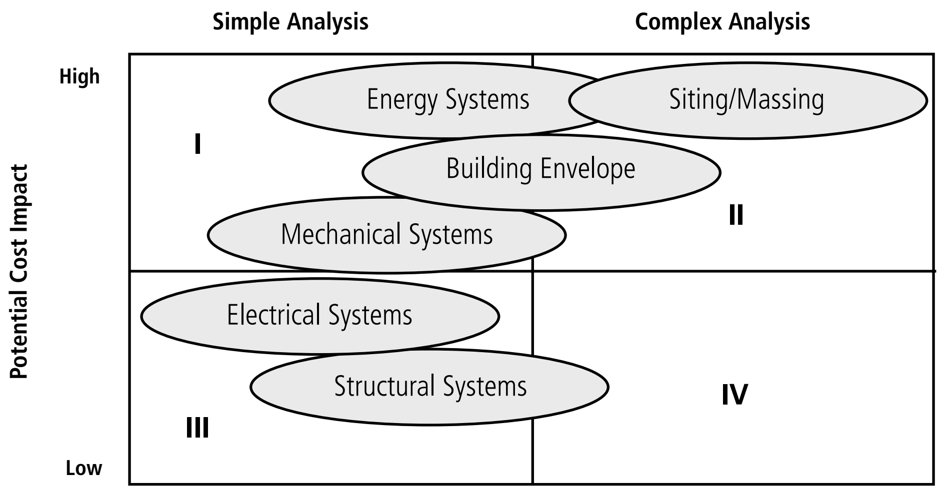
Structural Systems

14. Systems/materials selection (e.g., wood vs. steel vs. concrete, cast-in-place vs. pre-cast)

STUDY SELECTION

The Project Team will determine which of the six categories of studies and the 14 comparative analyses have the highest potential LCC benefit for the project. An LCCA Decision Matrix can assist in this determination. The team should create a customized matrix, using the example on page 6. The vertical axis represents the potential cost impact to the project. The horizontal axis reflects the complexity of the analysis required.

Sample LCCA Decision Matrix



When the six categories and/or 14 analyses are compared on such a matrix, they become easier to prioritize. Those in Quadrant I (simple analysis with high potential cost impact) should have the highest priority. Studies that require complex analysis but have a high potential impact should be prioritized next (Quadrant II). Simple analyses with low potential impact would be next (Quadrant III), followed by complex analyses with low potential impact (Quadrant IV). By taking the time to prioritize LCC analyses, the Project Team can focus on those studies most appropriate for the project.

Checklists to capture the results of the LCCA decision process are included in PDP Manual, Volume 2.

CONDUCTING COMPARATIVE ANALYSES

Each comparative analysis is developed on a project-specific basis. The Project Manager, Technical and Consultant Groups will decide together how to determine the details of each analysis. A "base case" will be established. The Project Team will then draw upon its collective experience to identify alternatives to the base case. For example, in analyzing mechanical distribution systems, the team might decide to consider a base case of overhead air distribution and an alternative underfloor approach.

Section IV discusses the format used to record the results of the comparative analyses. While this format is intentionally generic (to accommodate various types of studies), all Project Managers must use the same format so that the data collected and analyzed are documented consistently. The results of each team's studies will be incorporated into the Department of Project Management's LCCA library for future reference. In this way, Stanford will create a database of building studies as both a reference for future projects and a tool for understanding similarities and differences between building systems.

SELECTING COST-EFFECTIVE ALTERNATIVES

The Guidelines for LCCA give Project Teams the direction and tools to use LCCA to inform project decisions. The team should use LCCA incremental cost and payback findings in concert with other factors such as sustainability and user preferences to determine which elements to include in the final project design.

Alternatives that result in a payback of 5 years or less are required to be incorporated into the project. Alternatives that result in a payback of 6 to 10 years are strongly encouraged and require the approval of the Vice Provost for Land and Buildings to be exempted. Alternatives resulting in paybacks over 10 years are discretionary.

Documentation and appropriate explanations should be included to support the inclusion or exclusion of alternatives considered. See Section III for further details.

III. PROCESS PHASES

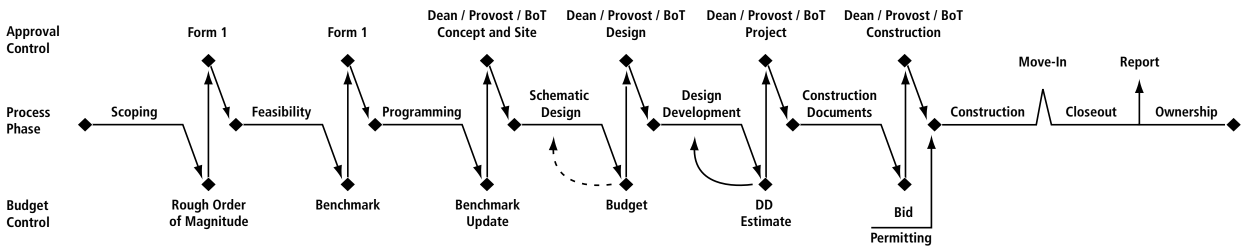
THE PROJECT DELIVERY PROCESS AT STANFORD

Nine distinct phases of Stanford's PDP – Scoping, Feasibility, Programming, Schematic Design, Design Development, Construction Documents, Permitting, Construction, and Closeout – are detailed in the 2001 Capital Planning & Management document, *The Project Delivery Process at Stanford: Process Phase and Control Summaries* (referred to here as *PDP Manual, Volume 1).* The Guidelines for LCCA and the *PDP Manual, Volume 1,* are designed to be used together. In addition, these guidelines outline a tenth phase – Ownership – that follows the nine PDP phases.

Each PDP phase requires the Project Team to complete set tasks and produce specific deliverables to obtain approval to move forward. A graphic representation of the phases, activities, deliverables, and approvals – the "Heartbeat" – follows.

The following discussion identifies the primary goal for each phase of the PDP and the related LCCA goals. It also describes the new Ownership phase. The Heartbeat illustrates the relationship of each phase to the overall process.

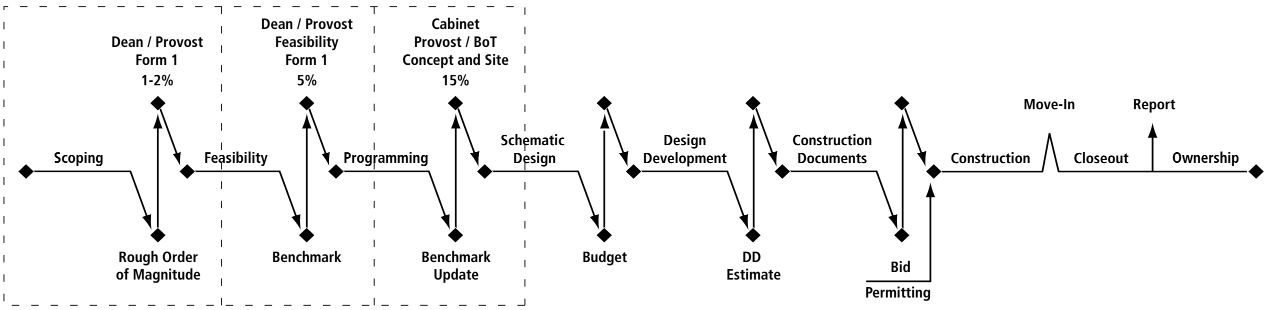
Heartbeat



LCCA Process Phase Summary

Process Phase	LCCA Goals	Leader
Scoping	• Assign O&M cost benchmark	Capital Planning
Feasibility/ Programming	• Develop O&M cost benchmark in addition to project benchmark (if not done at Scoping) • Hold LCCA work session • Develop LCCA Decision Matrix	Project Manager
Schematic Design (SD)	• Review LCCA Decision Matrix • Determine which LCCA studies to perform • Select cost-effective alternatives based on LCCA studies • Report results of LCCA	Project Manager
Design Development (DD)	• Review LCCA studies to confirm/verify results given project development	Project Manager
Construction Documents (CD)/Permitting	• Confirm value engineering decisions from earlier design phases with LCCA results	Project Manager
Construction	• Outline LCCA elements to contractor • Discuss commissioning and testing requirements	Project Manager
Closeout	• Conduct training program; perform eleventh-month evaluation	Project Manager
Ownership	• Validate LCCA study outcomes and assumptions	Facilities Operation Representative

SCOPING, FEASIBILITY, AND PROGRAMMING



Scoping

The goal of project Scoping is to translate academic or departmental initiatives into potential facility needs to determine if a capital construction project is necessary. The LCCA goal during this phase will be to assign an O&M Benchmark for the long-term costs of the building.

LCCA Tasks

- As part of the Capital Planning process, O&M costs will be estimated

Feasibility

The overall goal during the Feasibility phase is to further develop the options outlined through Scoping and approve one option for further consideration. The LCCA goal will be to reconfirm the O&M Benchmark. (See Operations & Maintenance Cost Benchmarking in Section II above.)

LCCA Tasks

- Department of Project Management (DPM) and Project Team will verify the O&M Benchmark

LCCA Deliverables

- Documentation of assumptions for the O&M Benchmark (e.g., if based on historical performance of similar buildings, list of buildings and their O&M costs)

Programming

During the Programming phase, the option approved by the Dean and Provost is further developed. As part of this process, the Project Manager should update the O&M Benchmark and arrange an LCCA work session to review the Guidelines for LCCA.

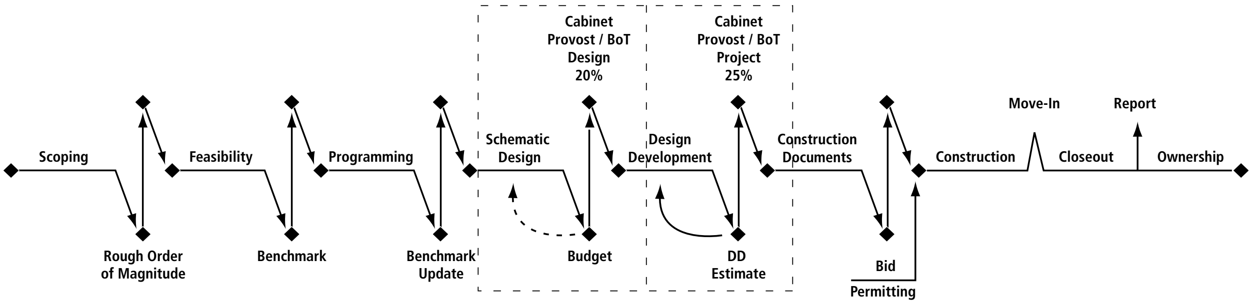
LCCA Tasks

- DPM and Project Team will create a project-specific LCCA Decision Matrix (see Section II) to determine which LCCA studies might render the greatest cost benefit to the project
- DPM will document cost and scheduling implications of LCCA studies

LCCA Deliverables

- Completed project-specific Decision Matrix
- Completed project schedule and budget, with breakdown of LCCA elements

SCHEMATIC DESIGN AND DESIGN DEVELOPMENT



Schematic Design

Schematic Design (SD) is a critical phase of the PDP during which the general scope, initial design, scale, and relationships among the components of the project are determined, and the greatest level of LCCA effort will take place. The Project Team will select the comparative analyses to be performed, assess the results, and determine which design elements would generate long-term cost savings. The results of the LCCA studies will be reported as a part of the SD submittal, which will clearly state LCCA elements that have (or have not) been incorporated into the project design. The LCCA results will document incremental University investments in building design elements with potential long-term benefits for the institution. LCCA results will also note elements that have not been incorporated into the project due to budget constraints, but that would benefit the University. These results will allow the University to reassess the project budget and scope, based on the potential to realize greater return on initial investment over the life of the building. The Project Manager will need to consider schedule and budget impacts of the LCCA options studied.

LCCA Tasks

Project Team will:

- Review the LCCA Decision Matrix and determine which studies should be completed
- Perform LCCA studies in conformance with the technical guidelines in Section IV
- Assess study results and select appropriate LCCA elements to be incorporated into the project
- Fully document LCCA results, along with budget and schedule implications

LCCA Deliverables

- Final LCCA Decision Matrix with selected studies highlighted
- Completed LCCA comparative studies
- Meeting minutes from workshop(s) to discuss LCCA results
- Documentation of LCCA elements incorporated or not incorporated into the project, with brief rationale for inclusion or exclusion
- Updated schedule and budget, with LCCA elements/impacts clearly highlighted (if applicable)

Design Development

During the Design Development (DD) phase, the approved schematic design begins to include a level of detail necessary to work out a clear, coordinated description of all aspects of the project. The Project Team will review the LCCA elements incorporated into the project to ensure that design conditions have not changed and that the LCCA return-on-investment calculations are still accurate.

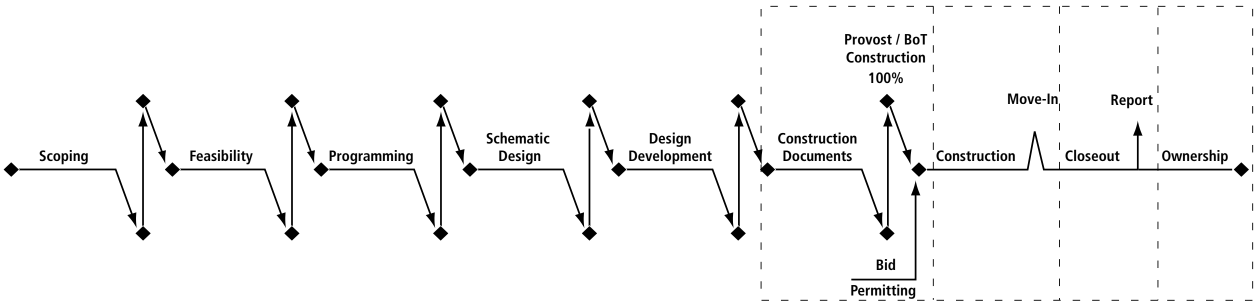
LCCA Tasks

- Project Team will review DD documents to ensure that design and specifications conform to LCCA study assumptions

LCCA Deliverables

- Documented review of LCCA elements, including design changes or LCCA modifications made during DD phase

CONSTRUCTION DOCUMENTS/PERMITTING, CONSTRUCTION, CLOSEOUT, AND OWNERSHIP



Construction Documents/Permitting

During the Construction Documents (CD) phase, the Project Team prepares a comprehensive, fully coordinated set of construction documents and specifications to obtain the necessary permits and construct the project.

LCCA Tasks

- At 50% CD, the Project Manager will ensure that the contract documents (plans, details, and specifications) are consistent with the designs evaluated in the original LCCA studies
- During Bidding, the Project Manager will ensure that any Value Engineering (VE) options address the impact on the LCCA elements in the project

LCCA Deliverables

- Documentation of changes made to LCCA elements as a result of VE process

Construction

The objective of the Construction phase is to safely build the project as represented in the contract documents within the parameters approved by senior management and/or the Board of Trustees. There are no specific LCCA tasks or deliverables during this phase.

Closeout

Closeout of facilities, occupancy and the turnover of the finished and fully commissioned project to the user group and facilities operations representative. It is important for building occupants and maintenance personnel to understand how their facility is designed to function, particularly as this relates to specific user behavior.

LCCA Tasks

Project Team will:

- Ensure that the Building Manager and the facilities operations representative understand specific user requirements associated with the LCCA features in the building (e.g., requirements that users turn off lights manually at certain times of the day because of special daylighting control systems, or that they close windows when the air conditioning is on)
- Confirm that O&M manuals are complete and include any specific information related to LCCA elements in the building
- Ensure that commissioning and training on systems highlight LCCA expectations for system performance, so that any significant variances from these expectations can be identified and investigated
- During "lessons learned" session, evaluate implementation of the Guidelines for LCCA and procedures

LCCA Deliverables

- Appropriate documents and training for building users and facilities operations representative related to the LCCA features in their building
- Documentation of LCCA "lessons learned" to be included in the eleventh-month evaluation

Ownership

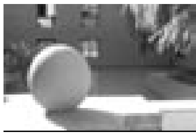
The Ownership phase begins once the initial project construction is complete and the building is handed over to facilities operations. During this period, key assumptions and anticipated outcomes established through LCCA studies need to be validated. As LCCA continues to evolve, the process for this evaluation will become more established and consistent.

LCCA Tasks

- The facilities operations representative will monitor utility consumption and O&M costs. These data are critical to evaluate the effectiveness of the Guidelines for LCCA and facilitate future LCCA work
- DPM and the facilities operations representative will conduct eleventh-month evaluations to assess performance of LCCA elements

LCCA Deliverables

- Meeting minutes, survey results, etc. from eleventh-month evaluations conducted regarding LCCA elements



IV. TECHNICAL GUIDELINES

The technical guidelines in this section are intended to establish adequate background and provide clear directions so that users of Stanford's Guidelines for LCCA can implement LCCA studies effectively and consistently.

THE STANFORD LCCA PROCEDURE

Designing for Minimum Life Cycle Costs

LCCA is a method of evaluating the cost-effectiveness of project design decisions. LCCA is comprehensive because it properly accounts for many project cost variables. These include a wide variety of project costs (construction, operations, maintenance, replacements, utilities, etc.). They also encompass the time value of money, including a project-specific discount rate, inflation, and cost escalations for a variety of goods and services.

The LCCA Process

Performing an LCCA study involves (1) establishing objectives for the analysis, (2) determining the criteria for evaluating alternatives, (3) identifying and developing design alternatives, (4) gathering cost information, and (5) developing a life cycle cost for each alternative.

Step 1. Establish Clear Objectives

To be successful, an LCCA study must have clear objectives, and they must be objectives that this type of study is well suited to address. LCCA can capture dollar cost variations between alternatives and show which option will have the lowest overall cost. It can only address values quantifiable in dollars. For example, an LCCA study of high-performance glazing can capture the overall cost-effectiveness of different options as compared to a base case. LCCA is not the right tool to explicitly evaluate improved comfort or occupant satisfaction with the different glazing products.

Step 2. Determine LCCA Metrics (total cost and payback)

The two primary metrics to be used and calculated in LCCA are the life cycle costs of each alternative and its payback over a certain study life. That is, consideration should be given to total costs and the time it takes to recover an incremental initial investment incorporating the time value of money.

When two alternatives have similar O&M costs over the study life, "first" costs (i.e., construction costs) will most likely drive the decision. This approach is further supported by the consideration of uncertainty (see below under Calculating Life Cycle Costs).

Step 3. Identify the Base Case and Develop Alternative Designs

The Stanford LCCA approach is geared towards evaluating design alternatives. The alternative that captures the "standard" design or minimum requirements for a project is called the "base case." The design team must develop alternatives to evaluate against the base case. These alternatives must be developed in sufficient detail to derive good cost estimates, which are required to run the life cycle cost calculations and to capture the incremental cost differences of the options.

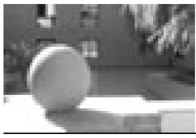
An infinite number of alternatives can be developed for any project. The intent of these guidelines is to capture as much cost benefit as possible given a reasonable amount of effort and investment. The goal should be to develop roughly one to five alternatives for a given building component. The design team should develop the alternatives, using its experience and judgment in selecting relevant building and system component options.

Analysis of alternatives should consider the effects of diminishing returns. Often, energy efficiency measures look less attractive in combination than when modeled individually. Where possible, effects should be calculated for each measure individually as well as for the measures in combination. For example, shading devices and high-performance glazing could each have a five-year payback, whereas the two in combination may have a seven-year payback if they have a higher combined cost and address the same energy use issues.

Step 4. Gather Cost Information

Cost information can come from a variety of sources, including cost estimating consultants, contractors, vendors, and designers.

For each alternative, gather all of the cost information described below under Cost Components of LCCA (e.g., construction, utility, maintenance, service, and in some cases remodeling costs). Identify additional soft cost requirements for the alternatives as well.



Construction costs can be informed by recent Stanford projects. Utility and maintenance costs can be informed by Stanford Facilities Operations. Project Managers will manage the development of this information.

Step 5. Perform Life Cycle Cost Calculations

For each alternative, calculate the metrics listed in Step 2 above, using the parameters listed under Life Cycle Cost Parameters below. Test each alternative against the two metrics and make a recommendation on which to incorporate into the design.

Cost Components of LCCA

An LCCA may include project, utility, maintenance, service, remodeling, and end-of-life costs, as well as benefits to campus infrastructure.

Project Costs

Project costs, sometimes referred to as initial or first costs, include both "hard" or construction costs (labor, materials, equipment, furnishings, etc.) and "soft" costs (design fees, permit fees, etc.). Cost estimates and information from contractors, vendors, and design teams can be used to develop project costs for LCCA alternatives.

In LCCA studies, the cost differences between alternatives are usually what is important, not the absolute costs. Project costs therefore only need to be developed for the components that vary between alternatives. For example, in comparing two HVAC systems that have the same zonal equipment (e.g., VAV boxes) but varying central equipment (e.g., air handlers), the zonal equipment costs can be ignored and only the costs of the central equipment developed. It is important to be as complete and thorough as possible when considering project cost variations between alternatives; all costs that vary must be captured in order to make a valid comparison.

Design and other soft costs should be identified and built into the LCCA calculations.

Utility Costs

Energy Costs

Stanford's central utilities provide the majority of Stanford facilities with steam, chilled water, and/or electricity, though Pacific Gas & Electric Company is the provider in outlying areas. For each type of utility service there is a cost per unit of energy delivered that will be charged to the building. The rates and units for these utilities are listed below under Life Cycle Cost Parameters.

Energy Estimating Methods

Typically the mechanical and/or electrical engineers on a design team will estimate the amount and rate of building energy use. The most comprehensive and widely used method of performing these estimates involves detailed hourly computer simulation of building operation with programs like DOE-2. If the level of effort to build a DOE-2 or similar computer model of a building is not appropriate for a project, simplified methods exist for estimating energy use. These include:

- Equivalent full-load hours
- Degree-day methods
- Outside temperature bin methods

The mechanical and/or electrical engineers can decide which method is most appropriate for a given project, in consultation with the Project Manager. Stanford strongly encourages the use of DOE-2 or similar programs to develop energy estimates.

Non-Energy Utility Costs

Domestic water and sewer service are two non-energy utility costs that need to be developed when affected by alternatives being modeled.

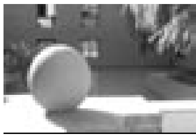
Maintenance Costs

Maintenance refers to the costs incurred to keep building systems running properly. The wide array of activities performed by Stanford's maintenance staff fall into four cost categories: preventive, reactive, planned, and deferred. These data should be based on historical data provided by facilities operations.

Preventive

Preventive maintenance is routine, scheduled activity intended to keep a system running at its best. This maintenance is performed whether or not there are any problems with a system. It is designed to prevent breakdowns. Changing filters and lubricating bearings are examples of preventive maintenance activities.

Preventive maintenance costs associated with equipment and systems should be incorporated into LCCA calculations.



Reactive

Reactive maintenance is performed in response to problems. If a fan belt breaks, for example, a technician issues a work order to replace the belt and address any associated damage to get the system running again.

Reactive maintenance is unpredictable. In theory, if systems are running well and all required preventive maintenance is performed, then reactive maintenance should be minimal. In practice, unplanned failures will occur and will require repairs.

For a project to retrofit an existing building that has ongoing reactive maintenance needs, the LCCA base case should include these costs, and the alternatives can model reasonable and appropriate reductions.

Planned

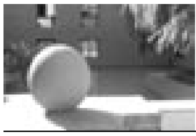
Stanford uses the term "planned maintenance" to refer to larger-scale maintenance that is not addressed under preventive maintenance. Planned maintenance is the replacement of building subsystems at the end of their useful lives.

LCCA calculations expressly include planned maintenance in the form of replacement costs of equipment and systems. For example, if the time frame of a study is 30 years and a component of a mechanical system (e.g., a heat pump) needs to be replaced every 10 years, then the life cycle costs need to include the cost of that replacement at year 10, year 20, and year 30.

Factoring system and component replacement costs into LCCA calculations requires making a number of assumptions about the useful life of these items. These assumptions should be clearly stated and documented so that they can be confirmed by the appropriate members of the Project Team. Where possible, building component replacement frequencies should be consistent with those in the *Annual Investment in Plant Assets* analysis performed as part of the annual budget plan. The list below provides general guidance based on that study.

Annual Investment in Plant Assets – Subsystem Life Cycles

	Subsystem Categories	**Average Life Cycle**
1a.	Roofing – Tile	80 years
1b.	Roofing – Metal, Concrete	50 years
1c.	Roofing – Membrane, Built-up, Shingle, Bitumen, Foam	20 years
2a.	Building Exteriors, Doors, and Windows (Hard)	80 years
2b.	Building Exteriors (Soft)	20 years
3.	Elevators and Conveying Systems	25 years
4.	HVAC – Equipment and Controls	20 years
5.	HVAC – Distribution Systems	40 years
6.	Electrical Equipment	30 years
7.	Plumbing Fixtures	30 years
8.	Plumbing – Rough-in	50 years
9.	Fire Protection Systems	40 years
10.	Fire Detection Systems	20 years
11.	Built-in Specialties and Equipment	25 years
12.	Interior Finishes	15 years
	Other Categories	
13.	Foundations	Lifetime
14.	Subgrade drainage and waterproofing	As needed
15.	Vertical Elements	Lifetime
16.	Horizontal Elements	Lifetime
17.	Interior Partitions	As needed
18.	Electrical – Rough-in	Lifetime
19.	Site Preparation	Lifetime
	Categories Included as Infrastructure	
20.	Site Development – Softscape	Infrastructure
21.	Site Development – Hardscape	Infrastructure
22.	Site Development – Distribution	Infrastructure
23.	Site Utilities	Infrastructure



Deferred

Deferred maintenance represents a backlog of planned maintenance. It is Stanford's goal to keep deferred maintenance to a minimum, but at present deferred maintenance does exist.

Deferred maintenance is not considered in LCCA for new buildings. For renovation projects, the deferred maintenance cost can be included in the base case. It should be addressed as appropriate for alternatives that reduce these maintenance needs in other ways, such as system or component replacement.

Service Costs

Service costs include items such as janitorial services, pest control, and elevator maintenance. Since these costs depend more on the programmatic elements of a building than on the architecture, systems, and other components, they are typically not considered in LCCA. However, they should be included if for some reason they differ among the design alternatives.

Remodeling Costs

Remodeling costs may or may not be included in LCCA, depending on the specific building program. Typically they are not included, but some systems or components specifically require them (e.g., underfloor air delivery or wireless). It is within the Project Team's discretion to decide whether and how to capture these costs.

End-of-Life Costs

Residual Value

Assume all buildings have zero residual value at the end of the study life. This assumption may change in the future, but in the interest of keeping the initial LCCA studies as simple as possible, it will be used consistently across studies.

Demolition

Usually this cost is assigned to the new project on a site. When the extent or nature of the required demolition varies among alternatives, it is appropriate to include these costs.

Calculating Life Cycle Costs

This section explains fundamental concepts behind LCCA and presents the standard Stanford LCCA approach.

Fundamental Concepts

A number of basic concepts underlie LCCA.

Time Value of Money

The value of money today and money that will be spent in the future are not equal. This concept is referred to as the "time value of money."

The time value of money results from two factors: (1) inflation, which is erosion in the value of money over time, and (2) opportunity cost. For cash or existing capital, opportunity cost is equivalent to the benefit the cash could have achieved had it been spent differently or invested. For borrowed money, opportunity cost is the cost of borrowing that money (e.g., the loan rate).

Inflation

Inflation reduces the value or purchasing power of money over time. It is a result of the gradual increase in the cost of goods and services due to economic activity.

By eliminating inflation from all escalation and discount rates, estimates of future costs can be made in current dollars and then returned to present value with the proper formulas. An estimate of the future behavior of inflation rates can be avoided.

The following formula factors inflation out of any nominal rate:

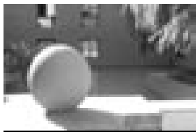
$$REAL = \frac{1 + NOMINAL}{1 + INFLATION} - 1$$

Where:

REAL is the real rate
NOMINAL is the nominal rate
INFLATION is the inflation rate

Discount

Project costs that occur at different points in the life of a building cannot be compared directly due to the varying time value of money. They must be discounted back to their present value through the appropriate equations. The discount rate is defined in terms of opportunity cost.



The basic discount equation is as follows:

$$PV = \frac{F_Y}{(1 + DISC)^Y}$$

Where:

PV is the present value (in Year 0 dollars)
F_Y is the value in the future (in Year Y dollars)
DISC is the discount rate
Y is the number of years in the future

Escalation

Most goods and services do not have prices that change at exactly the same rate as inflation. On average over time, however, the rate of change for established commodities is close to the rate of inflation.

Like discount rates, escalation rates are adjusted to remove the effects of inflation. The Escalation Rates table under Life Cycle Cost Parameters below lists the "real" escalation rates of various types of goods and services. Where the real escalation rate is close to zero or zero, the escalation rate for that category is essentially the same as the inflation rate.

The formula for calculating the future cost of an item with a known cost today and a known escalation rate is:

$$COST_{YEAR-Y} = COST_{YEAR-0}(1+ESC)^Y$$

Where:

$COST_{YEAR-Y}$ is the cost at Y years into the future
$COST_{YEAR-0}$ is today's cost (at Year 0)
ESC is the escalation rate
Y is the number of years into the future

Study Life

The study life in LCCA is the period over which the costs of a project will be examined and will influence LCCA decisions. The study life may not be the same as the building life but may be the same as that of the longest-lived subsystem option under review. To make LCCA comparisons valid, the study life must be the same for all alternatives.

LCCA Calculation Method

LCCA properly weights money spent today versus money spent in the future. All costs should be converted to common, current dollars and then summed to develop a total cost in present dollars for each alternative. This quantity is sometimes referred to as the net present value or the total cost in today's dollars.

With the net present value calculated for each alternative, comparisons are simple because units are consistent. The best option is simply the alternative with the lowest life cycle cost or net present value.

The basic formula is as follows:

$$LCC = C + PV_{RECURRING} - PV_{RESIDUAL\text{-}VALUE}$$

Where:

LCC is the life cycle cost
C is the Year 0 construction cost (hard and soft costs)
$PV_{RECURRING}$ is the present value of all recurring costs (utilities, maintenance, replacements, service, etc.)

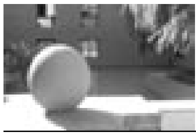
$PV_{RESIDUAL\text{-}VALUE}$ is the present value of the residual value at the end of the study life (note: these guidelines recommend this to be $0)

Payback Calculation

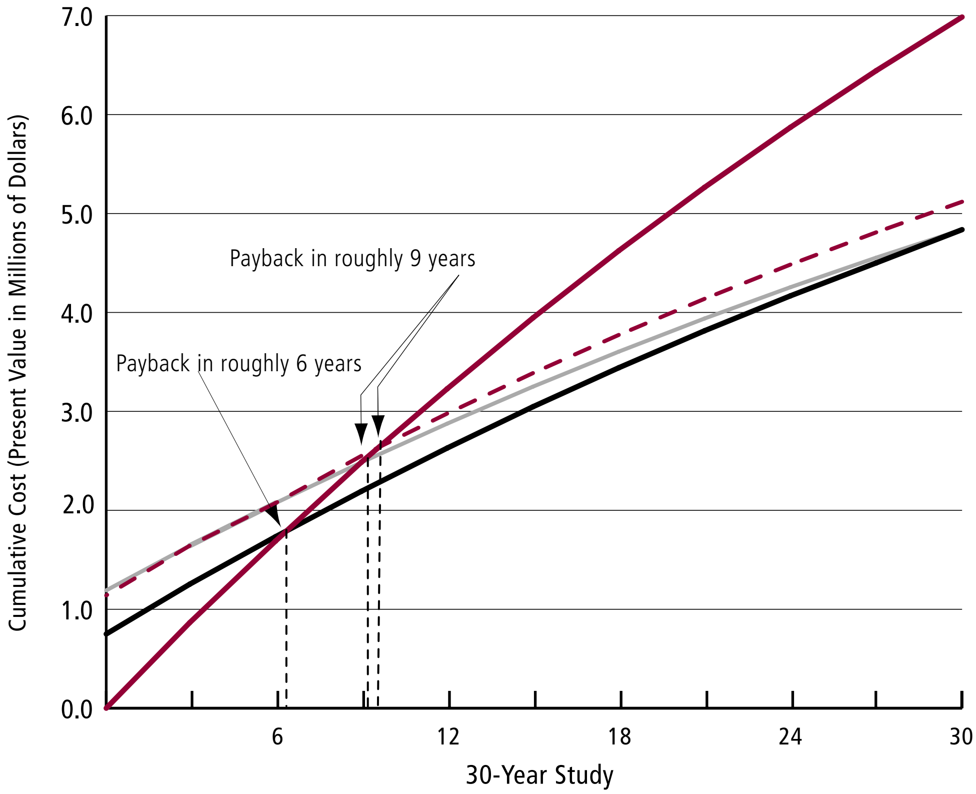
One way to evaluate the cost-effectiveness of LCCA alternatives is to look at their "payback" against the base case. The payback term is the time it takes an option to have the same life cycle cost as the base case. For example, the chart on the following page shows the cumulative cost of three LCCA alternatives compared to a base case. The point at which each alternative line crosses the base-case line is the payback point, where the options have the same cumulative cost.

In this example, the red solid line shows the cumulative cost of doing nothing in a retrofit project scenario. This option requires zero initial cost. The LCCA alternatives under study each require some initial project cost, represented by their y-axis intercept points. The option represented by the black solid line has a lower initial cost than the options represented by the red dash and gray solid lines.

The option represented by the black solid line crosses the solid red base-case line at about the six-year mark,



Sample Payback Analysis



resulting in a six-year payback. The red dash and gray solid lines intersect the red solid base-case line at roughly the nine-year mark, showing that they have nine-year paybacks.

"Payback" here is not exactly the same as "simple payback." Simple payback typically does not consider time-value-of-money terms such as discount and escalation, or impacts such as maintenance. Payback analysis can easily include these more complex factors.

Uncertainty in LCCA Calculations

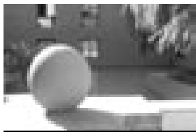
Uncertainty can be explicitly addressed in LCCA calculations, but it makes them much more complex. Each parameter used can be assigned a degree of uncertainty; these uncertainties can then be aggregated in statistically justifiable ways to measure the overall uncertainty of the result.

To make LCCA calculations as simple and straightforward as possible, the Stanford LCCA approach makes uncertainty an external qualitative consideration rather than a quantitative analytical one. Users should consider uncertainty throughout their LCCA studies and weigh the results qualitatively. For example, if an LCCA comparison of a variety of options shows a small difference in overall life cycle costs (e.g., 1%), then these costs should be considered equal. In other words, a small cost differential should not determine the best approach. In this case, the alternative with short-term benefits such as lower first cost, favorable environmental impact, or increased comfort for building occupants should be selected in accordance with project goals and budgets.

Assumptions in LCCA Calculations

Many assumptions need to be made over the course of an LCCA study in order to generate enough data to produce results. These assumptions will strongly affect the results.

All assumptions used in LCCA must be clearly stated and documented so that appropriate members of the Project Team can validate them through the design process as costs, goals, and budgets change.



LIFE CYCLE COST PARAMETERS

To provide a reference for users and allow for periodic updates, all of the values for parameters in the Stanford LCCA procedure are presented below. For each parameter, a responsible office is indicated so that users can obtain updated information or determine appropriate values for a specific project.

Study Life

Description	Value Range	Authority
New Construction Projects	30 years	Project Manager
Retrofit or Renovation Projects	15 years	Project Manager
Labs or High-Tech Buildings	10 years	Project Manager

Last Revised: August 2005

Campus Time-Value-of-Money Rates

The following rates were appropriate at the time these guidelines were published. See the Land and Buildings website (http://land-buildings.stanford.edu) for a listing of updated rates to be used in the future. Verify the rates used with the Project Manager.

Description	Near-Term Value (Years 0 – 5)	Long-Term Value (Years 6+)	Authority
"Nominal" Stanford Discount Rate	6%	7%	Land and Buildings
Inflation	1.5%	3.0%	Land and Buildings
"Real" Stanford Discount Rate (adjusted to take out inflation)	4.4%	3.9%	(calculated)

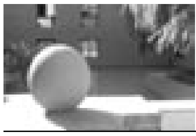
Last Revised: August 2005

Escalation Rates

The following rates were appropriate at the time these guidelines were published. See the Land and Buildings website (http://land-buildings.stanford.edu) for a listing of updated rates to be used in the future. Verify the rates used with the Project Manager.

Description (All rates here are "real" – they have been adjusted to take out inflation)	Near-Term Value (Years 0 – 5)	Long-Term Value (Years 6+)	Authority
Maintenance, Labor, and Materials	0%	1%	Facilities Operations
Energy and Water Utilities	0.5%	1%	Utilities

Last Revised: August 2005



Utility Rates

See the Facilities Operations website (http://facilities.stanford.edu/sections/recharge.html) for a listing of current rates for the following utilities. See the preceding table for energy and water utilities escalation rates.

Utilities

- Steam (per 1,000 lb)
- Chilled Water (per ton-hour)
- Electricity (per kWh) *
- Natural Gas (per therm) **
- Domestic Water (per 1,000 gal)
- Lake Water (per 1,000 gal)
- Sewer (per 1,000 gal)

* There are no time-of-use rates or demand charges in effect.

** PG&E supplies natural gas to the campus, and the price varies with the rate schedule for the size and type of building. The most common rate on campus is the small commercial rate (G-NR1). Refer to www.pge.com/tariffs for current rates.

SAMPLE STUDIES

The following examples are presented to help users understand and implement the Guidelines for LCCA by demonstrating previous applications and results. The first is a lab retrofit project analysis using a computer model to calculate the LCC. The second is a comparison of different glazing options using a simplified spreadsheet approach.

1. HVAC Retrofit of an Existing Laboratory Building

Project Description

The William M. Keck Science Building was built in 1986 and contains 71,000 gross square feet of laboratory and office space. Of that area, roughly 38,000 square feet are assignable. It is a three-story building with a partial basement containing mechanical, electrical, and plumbing services.

The building is designed for easy reconfiguration and was originally used as a lab surge building. As a result, the building contains approximately six feet of interstitial space above the laboratory and office ceilings.

Because the building contains laboratories where hazardous chemicals and materials are used in the course of academic research, maintaining safe conditions for occupants is a primary building function. To achieve this goal, the building uses a 100 percent outdoor air HVAC system and delivers constant-volume supply air to all areas of the building 24 hours a day, seven days a week.

The HVAC systems are zoned floor by floor, with each floor served in halves from air handlers located in mechanical rooms at the east and west ends. The systems are single-fan, dual-duct units and serve multiple dual-duct constant-volume box zones located throughout the floor.

Objectives

The goal of the study is to evaluate a number of HVAC retrofit approaches and determine which, if any, are worth implementing.

LCCA Metrics and Criteria

The life cycle cost of each alternative will be calculated and compared.

Alternatives to be Studied

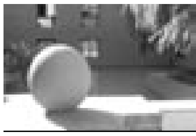
Because this is an existing building, the base case is to do nothing. Other alternatives for study are:

- Variable-air-volume (VAV) distribution system for non-laboratory areas
- VAV distribution system for laboratory areas
- The above measures in combination

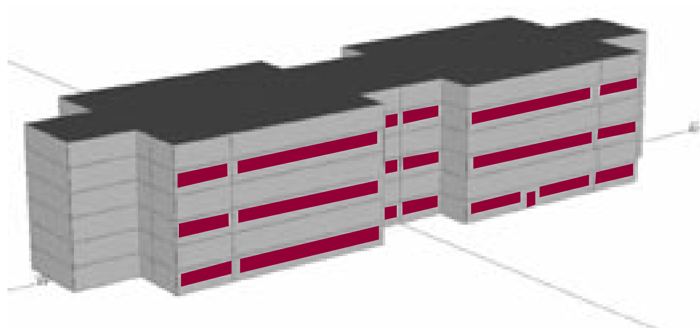
Cost Information

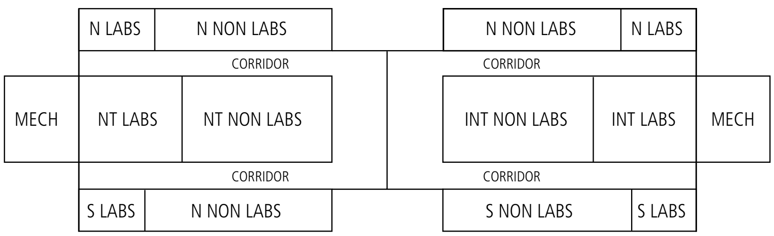
Since the primary focus of this study is to evaluate the LCC impacts of a variety of energy efficiency retrofits to the building, a detailed DOE-2 energy model was developed and the base-case model was calibrated to existing building utility data.

With the calibrated base case as a starting point, each energy efficiency retrofit option was developed and run in the DOE-2 model. This process produced the energy and utility cost impact for each alternative. The images on the following page show the DOE-2 model building geometry and zoning.



DOE-2 Model Building Geometry and Zoning





Preventive maintenance (routine, scheduled activity) and planned maintenance (replacement of building subsystems) were considered on a rough order-of-magnitude scale and did not significantly influence the results.

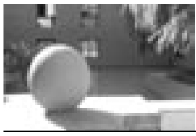
To estimate construction costs, an HVAC contractor provided budget pricing information for each option.

Project costs are summarized below.

Keck Building Energy Efficiency Retrofit
First Cost and Energy Cost Summary by Alternative

(in dollars)

		Annual Utility Cost					
Alternatives	**First Cost**	**Electricity**	**Chilled Water**	**Steam**	**Total Utility Costs**	**Annual Energy Savings Against**	
Base Case	–	460,847	209,485	235,004	905,336	N/A	N/A
Non-Lab VAV	500,000	389,535	166,583	104,032	660,150	(245,186)	(27.08)%
Lab VAV	650,000	436,363	199,588	194,015	829,966	(75,370)	(8.33)%
Non-Lab + Lab VAV	875,000	324,271	138,892	63,809	526,972	(378,364)	(41.79)%



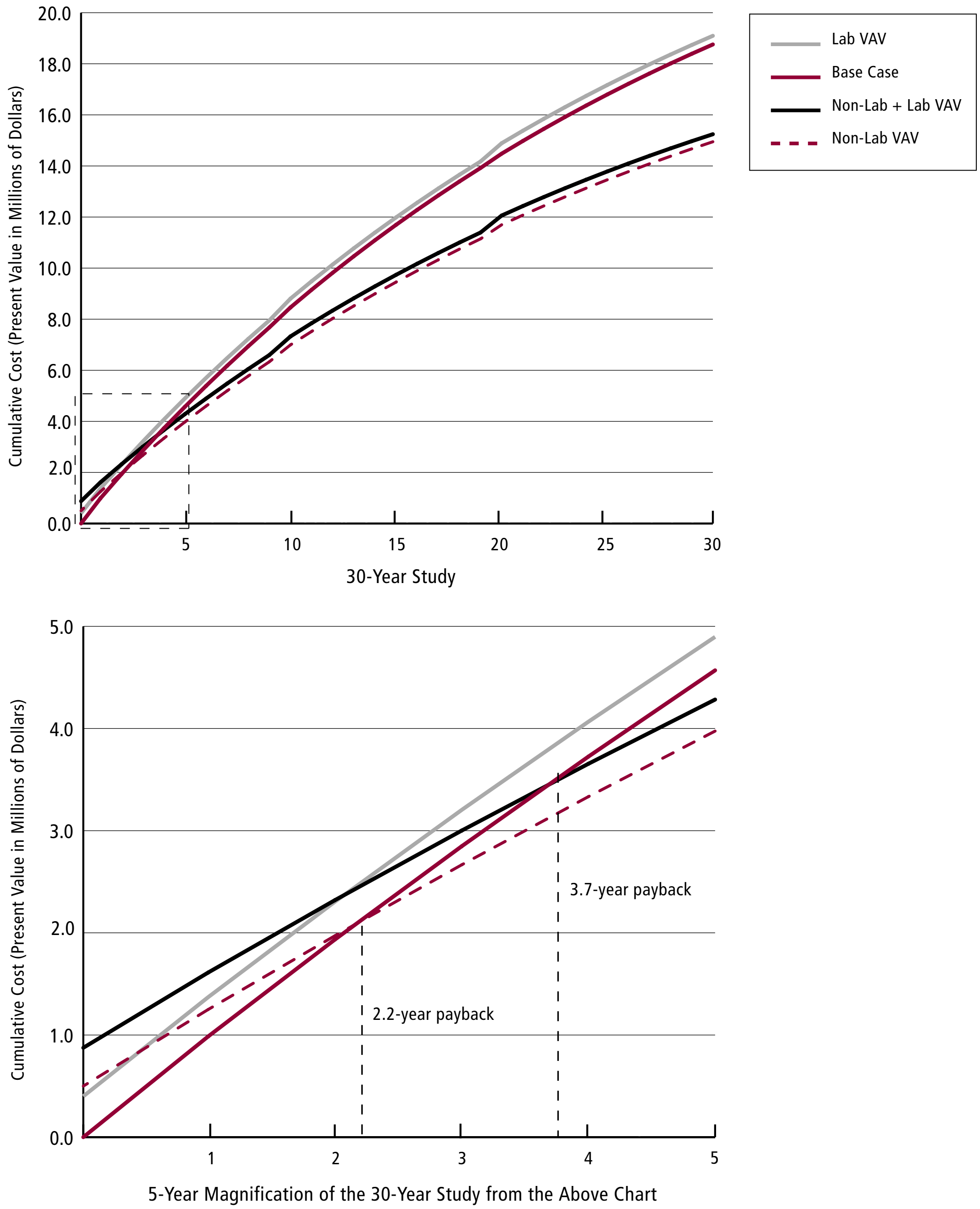
Life Cycle Cost Calculations – Payback Analysis

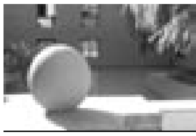
A 30-year study life was used to better understand the long-term cost implications.

The analysis shows that the "Non-Lab + Lab VAV" retrofit has the highest first cost (highest y-axis intercept) and the most energy savings. However, because the "Non-Lab VAV" first cost was significantly less and energy savings only slightly less, the "Non-Lab VAV" retrofit option was seen as the best choice, balancing first-cost impacts with energy savings.

Keck Building Energy Efficiency Retrofit, Life Cycle Cost Analysis – Payback Analysis

(in millions of dollars)





2. Clark Center Glazing Option Analysis

Project Description

In 2001, the James H. Clark Center Project Team considered eight glazing options during the design process. Since glazing is a large part of the building exterior, this decision would have a large impact on both the aesthetics and the energy performance of the building.

Objectives

The goal of this study is to evaluate an improved glazing option.

LCCA Metrics and Criteria

The life cycle costs of the seven options were reviewed, and the one that best met the criteria was compared to the base case.

Alternatives to be Studied

The Project Team narrowed the selection to one option and the base case after considering the following criteria:

- First cost
- Energy performance (U-factor, solar heat gain coefficient [SHGC], and visible transmittance [VT])

Cost Information

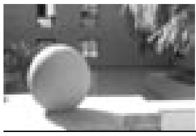
The general contractor provided the cost of the two options. As shown in the table below and in detail in Appendix A, the base case (Glazing Option 1) had a first cost of $400,000 and the alternative (Glazing Option 2) a first cost of $517,000. Since the glazing had not yet been purchased, only the $117,000 incremental cost of the more expensive glazing was considered. (The installation and maintenance costs for both options were considered to be the same.) The project HVAC consultant adjusted the glazing characteristics in the energy modeling software to arrive at approximately $20,000 per year avoided energy cost with the alternative (Glazing Option 2).

Life Cycle Cost Calculations – Payback Analysis

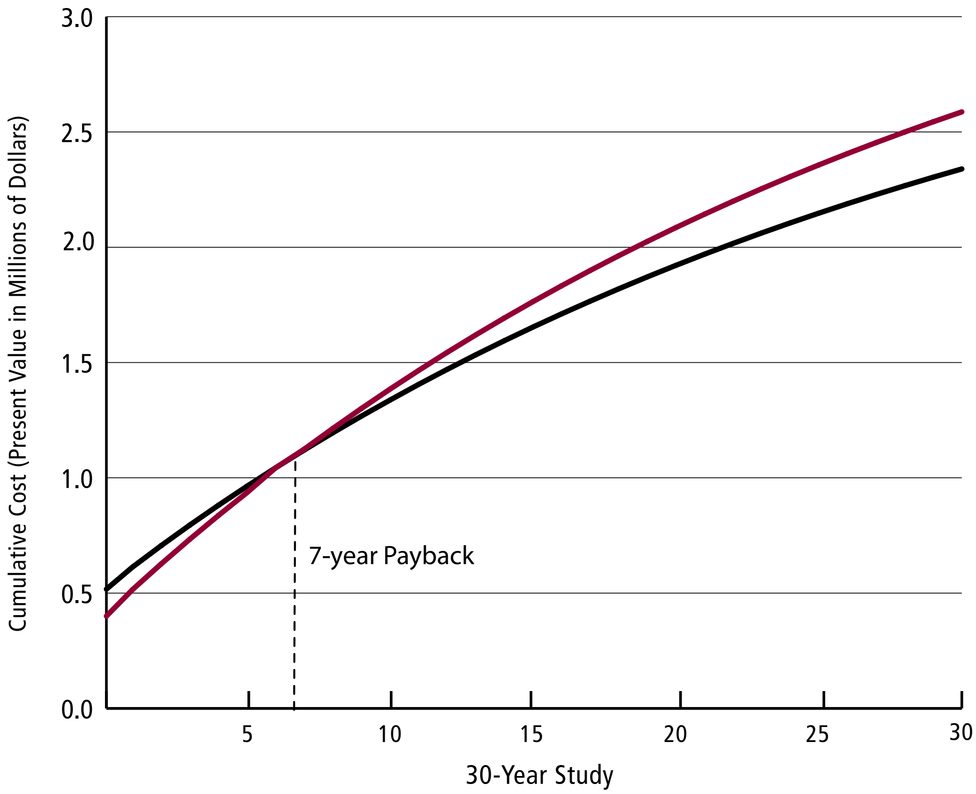
The LCCA showed that despite the $117,000 increase in first costs for the improved glazing, the avoided cost of approximately $20,000 per year in steam and chilled-water costs resulted in a payback of less than seven years. As a result, the alternative, Glazing Option 2, was selected.

Clark Center Glazing Options
First Cost and Energy Cost Summary by Alternative
(in dollars)

		Annual Utility Cost					
Alternatives	**First Cost**	**Electricity**	**Chilled Water**	**Steam**	**Total Utility Costs**	**Annual Energy Savings Against**	
Base Case (Option 1)	400,000	715,500	668,250	724,500	2,108,250		
Double Glazing (Option 2)	517,000	715,500	657,581	715,169	2,088,250	(20,000)	(2.21)%



Clark Center Glazing Options



APPENDIX A CLARK CENTER GLAZING STUDY – LCCA CALCULATIONS – OPTION 1

NON-ANNUAL RECURRING COSTS							Electricity			Steam	
	Investment-Related Costs (e.g. 1st cost replacement, residual)			Operations-Related Costs (e.g. non-annual maintenance)			Annual Recurring Electric Constant	Electric Differential Escalation %	Discounted Electric PV	Annual Recurring Steam Constant	Steam Differential Escalation %
Year #	Description of Cost	Constant	Discounted PV	Description of Cost	Constant	Discounted PV					
0	First Cost	400,000	400,000	n/a	n/a	n/a	715,500	0.50%		724,500	0.50%
1		0	0		0	0	715,500	0.50%	688,772	724,500	0.50%
2		0	0		0	0	715,500	0.50%	663,042	724,500	0.50%
3		0	0		0	0	715,500	0.50%	638,273	724,500	0.50%
4		0	0		0	0	715,500	0.50%	614,429	724,500	0.50%
5		0	0		0	0	715,500	0.50%	591,476	724,500	0.50%
6		0	0		0	0	715,500	1.00%	572,214	724,500	1.00%
7		0	0		0	0	715,500	1.00%	553,578	724,500	1.00%
8		0	0		0	0	715,500	1.00%	535,550	724,500	1.00%
9		0	0		0	0	715,500	1.00%	518,109	724,500	1.00%
10		0	0		0	0	715,500	1.00%	501,236	724,500	1.00%
11		0	0		0	0	715,500	1.00%	484,912	724,500	1.00%
12		0	0		0	0	715,500	1.00%	469,120	724,500	1.00%
13		0	0		0	0	715,500	1.00%	453,842	724,500	1.00%
14		0	0		0	0	715,500	1.00%	439,061	724,500	1.00%
15		0	0		0	0	715,500	1.00%	424,763	724,500	1.00%
16		0	0		0	0	715,500	1.00%	410,929	724,500	1.00%
17		0	0		0	0	715,500	1.00%	397,547	724,500	1.00%
18		0	0		0	0	715,500	1.00%	384,600	724,500	1.00%
19		0	0		0	0	715,500	1.00%	372,074	724,500	1.00%
20		0	0		0	0	715,500	1.00%	359,957	724,500	1.00%
21		0	0		0	0	715,500	1.00%	348,234	724,500	1.00%
22		0	0		0	0	715,500	1.00%	336,893	724,500	1.00%
23		0	0		0	0	715,500	1.00%	325,922	724,500	1.00%
24		0	0		0	0	715,500	1.00%	315,307	724,500	1.00%
25		0	0		0	0	715,500	1.00%	305,039	724,500	1.00%
26		0	0		0	0	715,500	1.00%	295,104	724,500	1.00%
27		0	0		0	0	715,500	1.00%	285,494	724,500	1.00%
28		0	0		0	0	715,500	1.00%	276,196	724,500	1.00%
29		0	0		0	0	715,500	1.00%	267,201	724,500	1.00%
30		0	0		0	0	715,500	1.00%	258,499	724,500	1.00%
		400,000			**0**	**0**	**21,465,000**		**13,087,372**	**21,735,000**	

Assumptions: Analysis Month/Year: 4/2001 Years of Project Service: 30

Years before "On-Line": 0 Years in Analysis Period: 30 Disc. Rate: 4.4%

	Chilled Water			ANNUAL RECURRING COSTS		TOTAL COSTS			CUMULATIVE COSTS	CUMULATIVE SAVINGS	Payback
Discounted Steam PV	Annual Recurring Chilled Water Constant	Chilled Water Differential Escalation %	Discounted Chilled Water PV	Annual Recurring (e.g. maintenance) Constant	Discounted Recurring PV	Year Date	Undiscounted Total Costs PV	Discounted Total Costs PV	Discounted Cumulative Costs PV	Discounted Cumulative Savings PV	Discounted Payback yrs
	668,250	0.50%		0			400,000	400,000	400,000	0	
697,435	668,250	0.50%	643,287	0	0	2001	2,118,791	2,029,494	2,429,494	0	
671,382	668,250	0.50%	619,256	0	0	2002	2,129,385	1,953,679	4,383,173	0	
646,301	668,250	0.50%	596,123	0	0	2003	2,140,032	1,880,697	6,263,870	0	
622,158	668,250	0.50%	573,854	0	0	2004	2,150,732	1,810,441	8,074,310	0	
598,916	668,250	0.50%	552,417	0	0	2005	2,161,486	1,742,810	9,817,120	0	
579,411	668,250	1.00%	534,426	0	0	2006	2,183,101	1,686,051	11,503,171	0	
560,542	668,250	1.00%	517,021	0	0	2007	2,204,932	1,631,142	13,134,313	0	
542,287	668,250	1.00%	500,184	0	0	2008	2,226,981	1,578,020	14,712,333	0	
524,626	668,250	1.00%	483,894	0	0	2009	2,249,251	1,526,629	16,238,962	0	
507,540	668,250	1.00%	468,135	0	0	2010	2,271,743	1,476,911	17,715,873	0	
491,011	668,250	1.00%	452,889	0	0	2011	2,294,461	1,428,812	19,144,685	0	
475,020	668,250	1.00%	438,140	0	0	2012	2,317,406	1,382,280	20,526,965	0	
459,550	668,250	1.00%	423,871	0	0	2013	2,340,580	1,337,263	21,864,228	0	
444,584	668,250	1.00%	410,067	0	0	2014	2,363,985	1,293,713	23,157,941	0	
430,105	668,250	1.00%	396,712	0	0	2015	2,387,625	1,251,580	24,409,521	0	
416,098	668,250	1.00%	383,792	0	0	2016	2,411,501	1,210,820	25,620,341	0	
402,547	668,250	1.00%	371,293	0	0	2017	2,435,616	1,171,387	26,791,728	0	
389,437	668,250	1.00%	359,202	0	0	2018	2,459,973	1,133,238	27,924,967	0	
376,755	668,250	1.00%	347,503	0	0	2019	2,484,572	1,096,332	29,021,299	0	
364,485	668,250	1.00%	336,186	0	0	2020	2,509,418	1,060,628	30,081,927	0	
352,615	668,250	1.00%	325,238	0	0	2021	2,534,512	1,026,086	31,108,013	0	
341,131	668,250	1.00%	314,646	0	0	2022	2,559,857	992,670	32,100,683	0	
330,021	668,250	1.00%	304,399	0	0	2023	2,585,456	960,341	33,061,024	0	
319,273	668,250	1.00%	294,485	0	0	2024	2,611,311	929,066	33,990,090	0	
308,876	668,250	1.00%	284,895	0	0	2025	2,637,424	898,809	34,888,899	0	
298,817	668,250	1.00%	275,616	0	0	2026	2,663,798	869,537	35,758,437	0	
289,085	668,250	1.00%	266,640	0	0	2027	2,690,436	841,219	36,599,656	0	
279,670	668,250	1.00%	257,957	0	0	2028	2,717,340	813,823	37,413,479	0	
270,562	668,250	1.00%	249,556	0	0	2029	2,744,514	787,319	38,200,799	0	
261,751	668,250	1.00%	241,429	0	0	2030	2,771,959	761,679	38,962,477	0	
13,251,993	**20,047,500**		**12,223,112**	**0**	**0**		**72,758,179**	**38,962,477**	**38,962,477**	**n/a**	

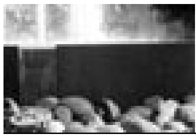
APPENDIX A CLARK CENTER GLAZING STUDY – LCCA CALCULATIONS – OPTION 2

NON-ANNUAL RECURRING COSTS							Electricity			Steam	
	Investment-Related Costs (e.g. 1st cost replacement, residual)			Operations-Related Costs (e.g. non-annual maintenance)							
Year #	Description of Cost	Constant	Discounted PV	Description of Cost	Constant	Discounted PV	Annual Recurring Electric Constant	Electric Differential Escalation %	Discounted Electric PV	Annual Recurring Steam Constant	Steam Differential Escalation %
0	First Cost	517,000	517,000	n/a	n/a	n/a	715,500	0.50%		715,169	0.50%
1		0	0		0	0	715,500	0.50%	688,772	715,169	0.50%
2		0	0		0	0	715,500	0.50%	663,042	715,169	0.50%
3		0	0		0	0	715,500	0.50%	638,273	715,169	0.50%
4		0	0		0	0	715,500	0.50%	614,429	715,169	0.50%
5		0	0		0	0	715,500	0.50%	591,476	715,169	0.50%
6		0	0		0	0	715,500	1.00%	572,214	715,169	1.00%
7		0	0		0	0	715,500	1.00%	553,578	715,169	1.00%
8		0	0		0	0	715,500	1.00%	535,550	715,169	1.00%
9		0	0		0	0	715,500	1.00%	518,109	715,169	1.00%
10		0	0		0	0	715,500	1.00%	501,236	715,169	1.00%
11		0	0		0	0	715,500	1.00%	484,912	715,169	1.00%
12		0	0		0	0	715,500	1.00%	469,120	715,169	1.00%
13		0	0		0	0	715,500	1.00%	453,842	715,169	1.00%
14		0	0		0	0	715,500	1.00%	439,061	715,169	1.00%
15		0	0		0	0	715,500	1.00%	424,763	715,169	1.00%
16		0	0		0	0	715,500	1.00%	410,929	715,169	1.00%
17		0	0		0	0	715,500	1.00%	397,547	715,169	1.00%
18		0	0		0	0	715,500	1.00%	384,600	715,169	1.00%
19		0	0		0	0	715,500	1.00%	372,074	715,169	1.00%
20		0	0		0	0	715,500	1.00%	359,957	715,169	1.00%
21		0	0		0	0	715,500	1.00%	348,234	715,169	1.00%
22		0	0		0	0	715,500	1.00%	336,893	715,169	1.00%
23		0	0		0	0	715,500	1.00%	325,922	715,169	1.00%
24		0	0		0	0	715,500	1.00%	315,307	715,169	1.00%
25		0	0		0	0	715,500	1.00%	305,039	715,169	1.00%
26		0	0		0	0	715,500	1.00%	295,104	715,169	1.00%
27		0	0		0	0	715,500	1.00%	285,494	715,169	1.00%
28		0	0		0	0	715,500	1.00%	276,196	715,169	1.00%
29		0	0		0	0	715,500	1.00%	267,201	715,169	1.00%
30		0	0		0	0	715,500	1.00%	258,499	715,169	1.00%
		517,000			**0**	**0**	**21,465,000**		**13,087,372**	**21,455,070**	

Assumptions: Analysis Month/Year: 4/2001 Years of Project Service: 30

Years before "On-Line": 0 Years in Analysis Period: 30 Disc. Rate: 4.4%

	Chilled Water			ANNUAL RECURRING COSTS		TOTAL COSTS			CUMULATIVE COSTS	CUMULATIVE SAVINGS	Payback
Discounted Steam PV	Annual Recurring Chilled Water Constant	Chilled Water Differential Escalation %	Discounted Chilled Water PV	Annual Recurring (e.g. maintenance) Constant	Discounted Recurring PV	Year Date	Undiscounted Total Costs PV	Discounted Total Costs PV	Discounted Cumulative Costs PV	Discounted Cumulative Savings PV	Discounted Payback yrs
	657,581	0.50%		0			517,000	517,000	517,000	(117,000)	
688,453	657,581	0.50%	633,016	0	0	2001	1,437,822	2,010,241	2,527,241	(97,747)	
662,735	657,581	0.50%	609,369	0	0	2002	1,445,011	1,935,145	4,462,386	(79,213)	
637,978	657,581	0.50%	586,605	0	0	2003	1,452,237	1,862,856	6,325,242	(61,372)	
614,145	657,581	0.50%	564,692	0	0	2004	1,459,498	1,793,266	8,118,508	(44,197)	
591,203	657,581	0.50%	543,597	0	0	2005	1,466,795	1,726,276	9,844,784	(27,664)	
571,949	657,581	1.00%	525,894	0	0	2006	1,481,463	1,670,057	11,514,841	(11,669)	
553,322	657,581	1.00%	508,767	0	0	2007	1,496,278	1,615,668	13,130,508	3,805	6.8
535,302	657,581	1.00%	492,198	0	0	2008	1,511,241	1,563,050	14,693,559	18,775	
517,869	657,581	1.00%	476,168	0	0	2009	1,526,353	1,512,146	16,205,705	33,257	
501,004	657,581	1.00%	460,661	0	0	2010	1,541,616	1,462,900	17,668,605	47,268	
484,687	657,581	1.00%	445,659	0	0	2011	1,557,033	1,415,258	19,083,863	60,822	
468,903	657,581	1.00%	431,145	0	0	2012	1,572,603	1,369,167	20,453,030	73,935	
453,632	657,581	1.00%	417,104	0	0	2013	1,588,329	1,324,577	21,777,607	86,621	
438,858	657,581	1.00%	403,520	0	0	2014	1,604,212	1,281,440	23,059,047	98,894	
424,566	657,581	1.00%	390,378	0	0	2015	1,620,254	1,239,707	24,298,754	110,767	
410,739	657,581	1.00%	377,665	0	0	2016	1,636,457	1,199,333	25,498,087	122,254	
397,363	657,581	1.00%	365,366	0	0	2017	1,652,822	1,160,275	26,658,362	133,366	
384,422	657,581	1.00%	353,467	0	0	2018	1,669,350	1,122,488	27,780,850	144,117	
371,902	657,581	1.00%	341,955	0	0	2019	1,686,043	1,085,932	28,866,782	154,517	
359,790	657,581	1.00%	330,819	0	0	2020	1,702,904	1,050,566	29,917,348	164,579	
348,073	657,581	1.00%	320,045	0	0	2021	1,719,933	1,016,352	30,933,700	174,313	
336,737	657,581	1.00%	309,622	0	0	2022	1,737,132	983,253	31,916,953	183,730	
325,771	657,581	1.00%	299,539	0	0	2023	1,754,503	951,231	32,868,184	192,840	
315,161	657,581	1.00%	289,784	0	0	2024	1,772,048	920,252	33,788,437	201,654	
304,898	657,581	1.00%	280,346	0	0	2025	1,789,769	890,282	34,678,719	210,180	
294,968	657,581	1.00%	271,216	0	0	2026	1,807,667	861,289	35,540,008	218,429	
285,362	657,581	1.00%	262,383	0	0	2027	1,825,743	833,239	36,373,247	226,410	
276,068	657,581	1.00%	253,838	0	0	2028	1,844,001	806,103	37,179,349	234,130	
267,078	657,581	1.00%	245,572	0	0	2029	1,862,441	779,850	37,959,200	241,599	
258,380	657,581	1.00%	237,574	0	0	2030	1,881,065	754,453	38,713,653	248,825	
13,081,318	**19,727,430**		**12,027,963**	**0**	**0**		**49,619,622**	**38,713,653**	**38,713,653**	**n/a**	**6.8**



APPENDIX B – TECHNICAL RESOURCES

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* The web addresses are current at the time of printing and are subject to change.

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