Analyzing the Cost of Building Green

U.S. Green Building Council
National Capital Region Chapter

The Association for the
Advancement of Cost Engineering
National Capital Section

A Joint Meeting & Presentation
That Integrates the Cost (AACEI)
With Building Green (USGBC)

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CCC, LEED AP BD+C

Analyzing the Cost of Building Green

Understanding

Life Cycle Cost Analysis
Cost-Benefit Analysis

in the
Evaluation of Design Options
for LEED Credits

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The Cost of LEED Certification

- Does a LEED Silver Building cost 10% more?
- Does a LEED Platinum Building cost 25% more?
- Is it True that the Energy Savings of a LEED Certified Building will Return the Additional Cost within the First Year?

With proper analysis the answer to these questions can be surprising.

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Learning Objectives

The Initial and Life Cycle Cost are important factors in the evaluation of design options for LEED credits.

This presentation will provide everyone with a fundamental understanding of the evaluation process.

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Learning Objectives

- Introduction & Overview of Life Cycle Cost (LCC)
- Life Cycle Cost Criteria
- LCC Publications & Standards
- Types of Life Cycle Cost Analysis (LCCA)
- Discount & Inflation Rates
- LCC / LCCA Software
- Cost-Benefit Analysis
- LCCA in the Evaluation of LEED Design Options

  Case Study: U.S. Treasury Annex LEED Platinum Study

THIS CASE STUDY WILL SHOW HOW BENEFICIAL PERFORMING LCCA CAN BE.

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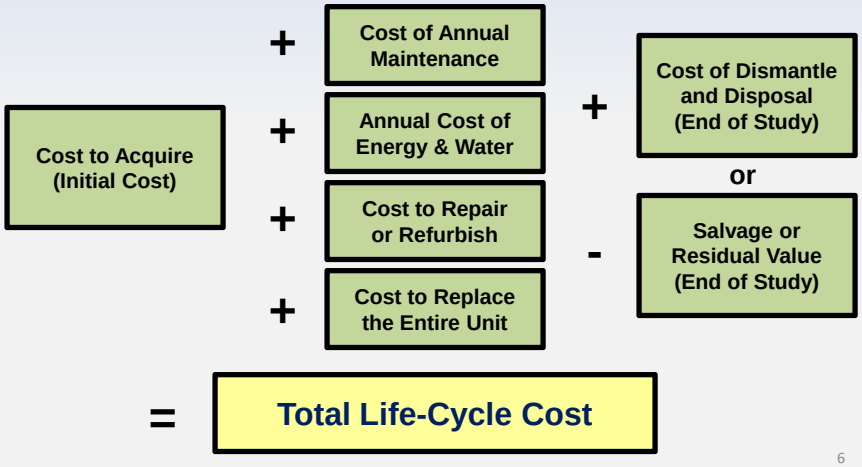
What is Life-Cycle Cost?

***Life-Cycle Cost (LCC)* assesses the total cost of acquiring, operating, maintaining, and disposing of a product or system, over a specified length of time (study period).**



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What is the criteria used to determine Life-Cycle Cost?

The method used to determine **Life-Cycle Cost uses the same criteria for each of the product or system alternatives**. The criteria that is typically used in calculating the LCC includes the following:

Basic Criteria

- **The initial cost – complete with all components & installation**
- **Operating, maintenance, and repair costs**
- **Energy requirements and fuel costs**
- **Life expectancy and replacement costs**
- **The study period length**

Additional Criteria

- **Type of usage / hours of operation and the environment**
- **Residual value including salvage, resale or disposal costs**
- **Discount and inflation rates**

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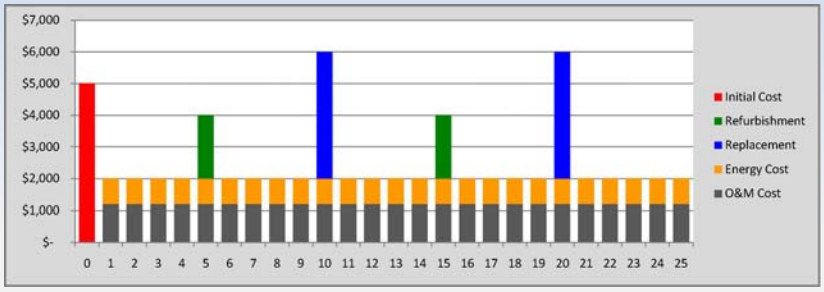
Life Cycle Cost Basics



This is an example of a simplified or basic life cycle cost.

- For this item or system the **initial cost is $5,000**.
- The cost **per year** for **operation & maintenance** is **$1,200**.
- The cost **per year** for **energy** is **$800**.
- The life expectancy is 10 years when it will be **replaced at** a cost of **$4,000**.
- Half way through its life it will need to be **refurbished at** a cost of **$2,000**.
- The length of the study is **25 years**.

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Life Cycle Cost Calculation

Calculating the "Basic" Total Life Cycle Cost

The following will calculate the total 25 year life cycle cost, not including inflation, discount rates or salvage.

Initial Cost	1	x	$5,000	=	$ 5,000
O & M	25 Yrs	x	$1,200	=	$30,000
Energy	25 Yrs	x	$ 800	=	$20,000
Refurbished	2	x	$2,000	=	$ 4,000
Replacement	2	x	$4,000	=	$ 8,000

25 Year Cost TOTAL **$67,000**

Notice how minimal the Initial Cost is when compared to the Total Life Cycle Cost

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Life Cycle Cost Published Standards

The one publication that is recognized by government agencies and other public and private organizations as the guide to understanding the Life-Cycle Cost methodology is the –

U.S. Department of Commerce
NIST Handbook 135 –
LIFE-CYCLE COSTING MANUAL
for the Federal Energy Management Program

There are various other publications and articles that explain the process and provide information on how to perform Life-Cycle Cost Analysis, but the methodology is the same as outlined in the NIST handbook.

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Life Cycle Cost + *Analysis*

With an understanding of how to prepare a basic Life Cycle Cost the next step is performing the ***Analysis***.

Life-Cycle Cost Analysis (LCCA) **uses the information from the LCC to evaluate options or alternatives.**

Fundamentally there are two types of Life Cycle Cost Analysis.

- **Comparison Analysis**
  Compares 2 or more products or systems for a specific application like flooring, HVAC, roofing, etc.
- **Payback / ROI Analysis**
  Compares the cost of a product or system to the savings it will generate to determine the payback or return on investment. An example would be to analyze the LCC of a Solar PV (electric) system to the reduction in cost of electricity from the utility company.

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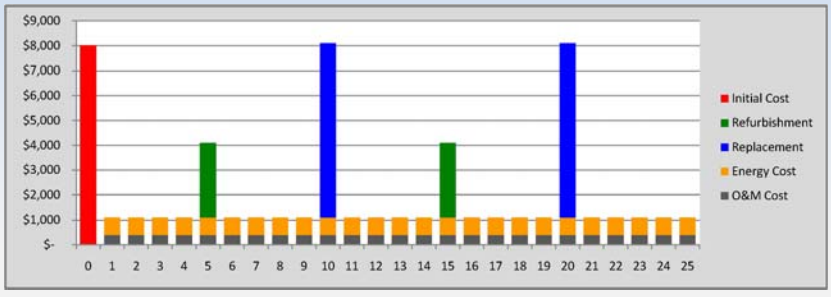
Comparison Life Cycle Cost *ANALYSIS*



To perform a Comparison LCC analysis add a second unit.

- For this item or system the **initial cost is $8,000**.
- A self cleaning feature reduces operation & maintenance **$400 / year**.
- A more efficient motor reduces the energy to **$700 / year**.
- The life expectancy is still 10 years but **replacement** will cost **$7,000**.
- Half way through its life it will need to be **refurbished** at a cost of **$3,000**.
- The length of the study is **25 years**.

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Life Cycle Cost Calculation # 2

Calculating the Total Life Cycle Cost of the 2nd Unit

The following will calculate the total 25 year life cycle cost, not including inflation, discount rates or salvage.

Initial Cost	1	x	$8,000	=	$ 8,000
O & M	25 Yrs	x	$ 400	=	$10,000
Energy	25 Yrs	x	$ 700	=	$17,500
Refurbished	2	x	$3,000	=	$ 6,000
Replacement	2	x	$7,000	=	$14,000

25 Year Cost TOTAL **$55,500**

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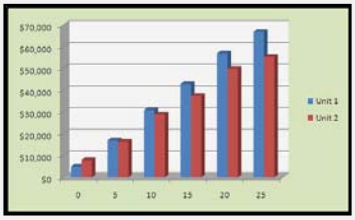
Comparison Initial & Life Cycle Cost Analysis

Cost Analysis of the Two Units

	Unit 1	Unit 2	Delta	
Initial Cost	**$ 5,000**	**$ 8,000**	**+$ 3,000**	**+ 60.0%**
5 Yr LCC	$17,000	$16,500	- $ 500	- 3.0%
10 Yr LCC	**$31,000**	**$29,000**	**- $ 2,000**	**- 6.5%**
15 Yr LCC	$43,000	$37,500	- $ 5,500	- 12.8%
20 Yr LCC	**$57,000**	**$50,000**	**- $ 7,000**	**- 12.3%**
25 Yr LCC	$67,000	$55,500	- $11,500	- 17.2%

(Unit 1 is the Baseline for the cost delta)



As you can see the initial cost can be out weighed by the Life Cycle Cost. The entire LCC process can be extensive, but as a **minimum requirement for all projects, a basic LCC should be performed on the major systems**.

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Energy Requirements and Fuel Costs

Energy Usage and the Related Costs

- **Important part of** comparing the **LCC** of alternatives
- Calculations are **primarily a function of engineering**
- May require the use of **computer simulation energy modeling**

Energy Prices

- Used to **convert** the annual **usage** to the annual **cost**
- **Prefer to use energy prices that are the site specific utility rates**
- The Department of Energy (DOE) annually publishes the average prices for various types of fuels by regions

Energy Escalation

In addition to the energy rates, the **escalation in fuel pricing should be included in the LCC study**. If available the escalation should be based on the information from the local utilities, but if that is not available, the escalation for the four major regions of the united States is published by the DOE as the Annual Supplement to Handbook 135 on an annual basis.

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The Additional Criteria

So far we have only looked at the basic LCC criteria. As mentioned in a previous slide, there is additional criteria that should be included in calculating the LCC.

Additional Criteria

- **Type of usage / hours of operation and the environment**
- **Residual value including salvage, resale or disposal costs**
- **Discount and inflation rates**

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The Additional Criteria

Type of usage / hours of operation and the environment

- **Type of usage**
  An example of a type of usage would be in the **classification of flooring as light, medium, and heavy traffic areas**.
- **Hours of Operation**
  This is important to understand the **length of usage**. A floor in a main lobby that is open 8AM to 6PM, Monday through Friday has less usage than a lobby being used 24/7/365.
- **Environment**
  The environment **includes both the regional climate factors** like monthly rain, hours of sun, heating / cooling degree days, etc. **and / or the conditioning of the space**.

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The Additional Criteria (Type of Usage)

Type of Usage – Impact on Flooring

Frequency of Maintenance

Description	U/M	Qty	Light	Medium	Heavy	U/M
Carpet - Vacuuming	SQFT	1	2	3	5	Weekly
Carpet - Spot Removal	SQFT	1	1	2	3	Weekly
Carpet - Rinse Cleaning	SQFT	1	2	3	4	Annually
Carpet - Deep Cleaning	SQFT	1	1	2	3	Annually

Full Replacement

			Life Expectancy			
Description	U/M	Qty	Light	Medium	Heavy	U/M
Remove Carpet	SQFT	1	168	120	72	Months
Carpet - Commercial Grade - Heavy Duty	SQFT	1	168	120	72	Months
Carpet Pad - Rebond (Bonded Urethane Foam) - Heavy Duty (8 LB)	SQFT	1	168	120	72	Months

The Frequency of Maintenance and the Life Expectancy of carpet flooring and the associated costs are directly related to the level of usage.

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The Additional Criteria (Hours of Operation)

Hours of Operation – Impact on Flooring

Month	Hours per Day	Days per Week	Weeks per Month	Total Hours
January	9	5	4	180
February	9	5	4	180
March	9	5	3.4	153
April	9	5	4.3	193.5
May	9	5	4	180
June	9	5	1	45
July				0
August				0
September	9	5	4	180
October	9	5	4.3	193.5
November	9	5	4	180
December	9	5	3	135
	Hours per Year	Days per Year	Weeks per Year	Months per Year
Per Year	1620	180	36	8.3

Sample of Elementary School Hours of Operation

From the previous screen, the Frequency of Maintenance will be impacted by the weeks per year and the Life Expectancy by the months per year.

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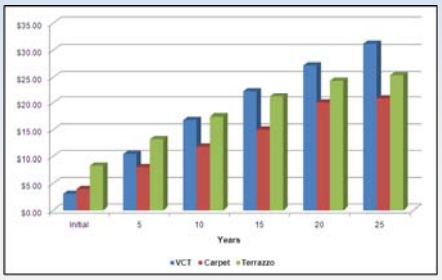
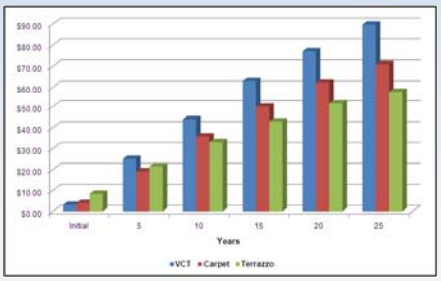
Project Specific Criteria

Using Project Specific Criteria is Essential





School Hours – Light Traffic ← → **24/7/365 Hours – Heavy Traffic**

	Selection 1 VCT	Selection 2 Carpet	Selection 3 Terrazzo
Cumulative Life Cycle Cost Per Year			
Initial	2011	$3.01	$3.92	$8.31
5	2016	$10.43	$8.06	$13.24
10	2021	$16.84	$11.81	$17.44
15	2026	$22.48	$15.63	$21.21
20	2031	$27.24	$20.82	$24.56
25	2036	$31.24	$20.79	$25.39

Same Products Different Criteria

	Selection 1 VCT	Selection 2 Carpet	Selection 3 Terrazzo
Cumulative Life Cycle Cost Per Year			
Initial	2011	$3.01	$3.92	$8.31
5	2016	$24.99	$19.10	$21.50
10	2021	$43.95	$35.73	$33.01
15	2026	$62.88	$49.98	$42.94
20	2031	$76.99	$62.07	$51.49
25	2036	$89.68	$70.89	$57.74

As shown here the hours of operation and type of usage have a direct impact on the outcome of the Life Cycle Cost Analyses.

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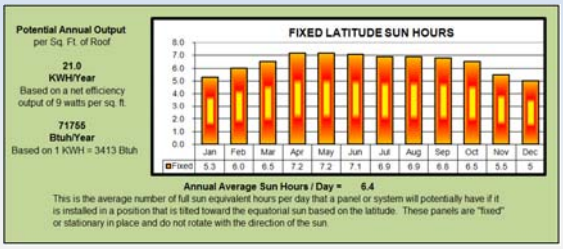
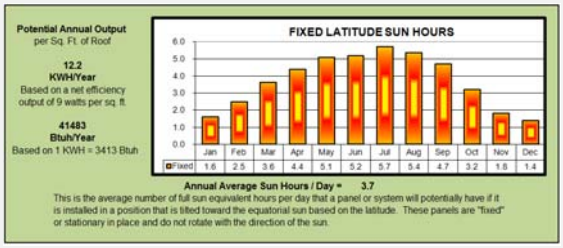
The Additional Criteria (Environment)

Region Factor – Solar Potential

Albuquerque New Mexico



Seattle Washington



The Climate data for the specific area will have a direct impact on the outcome of the Life Cycle Cost (Payback) Analysis.

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The Additional Criteria (Residual Value)

Residual value including salvage, resale or disposal

- **Residual Value**
  This is the prorated value that a system is worth if the expected life of the system extends beyond the end of the study period. This value is shown as a cost credit in the LCC.

- **Salvage or Resale Value**
  The net value at the end of the study period that the item or system is worth as salvaged parts, scrap or in resale / reuse value. This value is shown as a cost credit in the LCC.

- **Disposal Cost**
  If there is no salvage or resale value at the end of the study period, than the cost to properly remove and dispose of the item or system is included in the LCC.

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The Additional Criteria (Residual Value)

Examples of Residual Values

- **Residual Value**
  A Terrazzo floor has a life expectancy of 40 years. At the end of a 20 year LCC study the residual value would be 20/40 or 50% which will be a credit to the LCC cost.
- **Salvage or Resale Value**
  The exterior windows have a resale value of $400 and will cost $250 to remove and ship. Their value at the end of the study will be a credit of $150.
- **Disposal Cost**
  A large boiler will have to be cut apart to be removed in pieces at a cost of $10,000. The metal will be sold as scrap for $6,000. The net disposal cost of $4,000 will be added at the end of the LCC study.

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Contingency

When should a Contingency be added to the cost?

A contingency is dependent on the level of detail available for each of the alternatives.

If sufficient detail is available and all of the components are included with the estimated cost then a contingency is not required.

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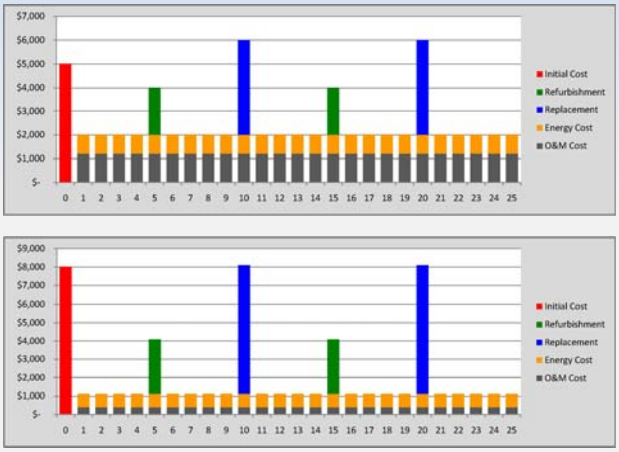
The Additional Criteria (Discount & Inflation Rates)

Discount and Inflation Rates



In the previous examples the sequence of time for the two units was aligned. Applying discount and inflation adjustments to the costs will not alter the outcome of the analysis.

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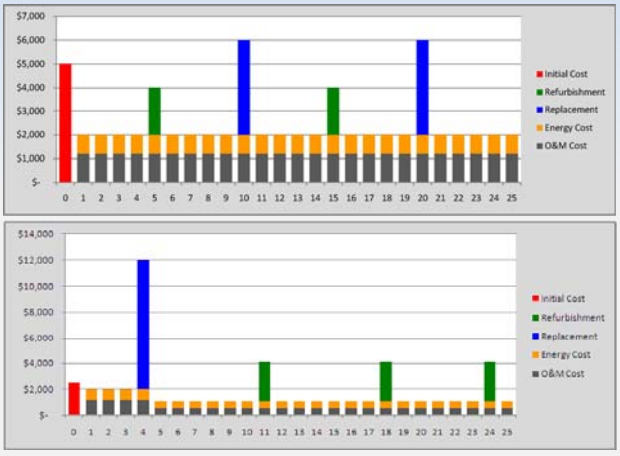
The Additional Criteria (Discount & Inflation Rates)

Discount and Inflation Rates



In the example above the sequence of time for the two units is not aligned. The use of discount and inflation rate adjustments allows for the analysis of alternates with different life cycles.

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The Additional Criteria (Discount & Inflation Rates)

Discount and Inflation Rates

- **Discount Rate**
  The **Discount Rate is** the rate of interest that is used in Discount Formulas and is **reflective of the Time Value of Money** (TVM). TVM is based on the idea that **money** available at the present time is **worth more** than the same amount **in the future due to** its **potential earning capacity**. The discount rate is used to discount future cash flows to present value for the comparison of alternatives with different life cycle periods.

- **Inflation Rate**
  The inflation rate is the percentage in reduction of the purchasing power of a currency over time. Conversely stated it is the **percentage in cost that an item increases over time**.

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The Additional Criteria (Discount & Inflation Rates)

Discount Rates

The discount rates are **published by banking institutions, insurance companies, private businesses and government agencies**.

- **Office of Management and Budget (OMB)**
- **Department of Energy (DOE)**

While the methodology is similar, there is no established criteria that is universally accepted by the various organizations and it is typically the decision of the owner or analysis team to select the rate to be used for all of the studies

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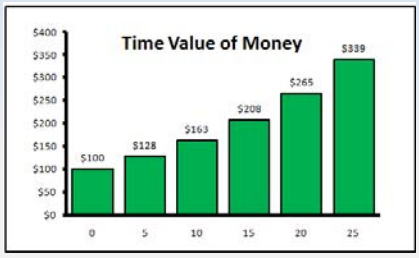
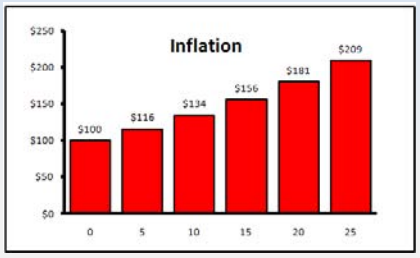
The Additional Criteria (Discount & Inflation Rates)

The following example should further explain what is meant by TVM, the discount and inflation rates.



The TVM of $100 in an account paying 5% annual interest compounded annually.



The escalation in the cost of a $100 item if the annual inflation rate is 3%.

As shown in these two figures the amount that the $100 investment earns is greater than the increase in the cost of an item that initially cost the same as the investment.

The discount rate is used to establish this difference so the analysis of alternatives with different life cycle periods can effectively be evaluated.

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The Additional Criteria (Discount & Inflation Rates)

Real / Nominal Discount Rates

The ***Real discount rate*** is based purely on the TVM discount rate and does not include inflation
The ***nominal discount rate*** includes the inflation

For example if the discount rate is 3% and inflation is 2% then the
real rate is 3% and the
nominal rate is 5.06% (3% + 2% + (3% x 2%)).

Discount / Interest Rate Formulas and Factors

There are many formulas that use the discount and inflation rates to calculate the value or worth of money at annual periods in a LCC study.

Additional information on these formulas and adjustment factors can be found in chapter 3 of the NIST Handbook 135

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What are Supplementary Measures?

Supplementary measures are used in conjunction with the LCC for performing economic evaluation analysis of an alternative to a base case such as:

- **Net Savings**
- **Savings-to-Investment Ratio**
- **Adjusted Internal Rate of Return**
- **Payback Period**

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Supplementary Measures

- **Net Savings (NS)**
  How much less an alternative LCC cost is than the base case LCC.
- **Savings-to-Investment Ratio (SIR)**
  The relationship (ratio) between an alternatives LCC savings and its increased investment cost.
- **Adjusted Internal Rate of Return (AIRR)**
  A measure of the annual percentage yield as compared to the minimal acceptable rate of return (MARR) or discount rate. If the AIRR is greater the alternative is economic.
- **Payback Period**
  Two types are Simple Payback and Discounted Payback. The Payback Period is the time at which cumulative savings equal the investment cost. Simple Payback is the most common for fundamental studies and does not use discounted cash flows or energy escalation. Discounted Payback includes the discounting and escalation.

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LCCA Software

There are numerous life cycle cost and LCCA software programs available from private developers and from the DOE2 website.

Two systems are available for free from www.DOE2.com

Building Life Cycle Cost version ***5 (BLCC5)***

A structured program that includes the NIST Handbook 135 standards

USER-FRIENDLY BUILDING LIFE-CYCLE COST ANALYSIS

An extensive Microsoft Excel spreadsheet developed by M.S. Addison and Associates for DOE2

Both systems can perform complete LCC studies and require the user to have a good understanding of the process in order to use them effectively.

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LCCA Software

Life Cycle Cost Analysis

Input Data

Description of Item or System: ***Asphalt Satur. Built-Up Roof - 4" Polyiso Ins. - 4 Felt Plies + Gravel***

The unit of measure used for this analysis is: ***SQFT***

The ***Initial Installation Cost*** consists of the following:

Description	U/M	Qty	Unit Price	Ext Price
Composite Roof Deck Insulation - 2" Polyiso. with 1" Perlite Face	SQFT	1	$1.420	$1.420
Built-Up Roofing (BUR) - Asphalt Flood Coat - 4 Felt Plies + Gravel	SQFT	1	$1.730	$1.730
Polyisocyanurate Roof Deck Insulation - 2" Thick	SQFT	1	$0.820	$0.82
TOTAL INITIAL INSTALLATION COST				$3.970

The ***General Maintenance Cost*** is based on the following:

Description	U/M	Qty	Frequency (Times Per)	Unit Price
Built-Up Roofing (BUR) - Asphalt Flood Coat - Inspection & Minor Repair	SQFT	1	Annually	$0.060

Complete Replacement Cost is based on the following:

Description	U/M	Qty	Replace Every		Unit Price
Remove Built Up Roof with Gravel	SQFT	1	16	Years	$1.015
Composite Roof Deck Insulation - 4" EPS with 1" Perlite Face	SQFT	1	16	Years	$1.510
Built-Up Roofing (BUR) - Asphalt Flood Coat - 4 Felt Plies + Gravel	SQFT	1	16	Years	$1.730
Polyisocyanurate Roof Deck Insulation - 2" Thick	SQFT	1	16	Years	$0.820

Some of the private developer systems include databases with standard generic data for the more common systems.

The the one shown here is from the Kisent System.

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What is Benefit Analysis?

Cost-Benefit Analysis (CBA)

or

Benefit-Cost Analysis (BCA)*

1. **A purely "Monetary Benefit Analysis" is the Return on Investment that and alternative will provide.**
2. **Provides the ability to incorporate the LCCA information with costs that are not included in the study but are effected by the outcome.**
3. **Allows non-monetary benefits for which there is no objective way of assigning a dollar value to be added to the analysis.**
4. **Commonly utilizes a "Weighted Criteria" to evaluate options or alternatives.**

*** For this presentation Cost-Benefit Analysis (CBA) is used but Benefit-Cost Analysis (BCA) is also very common.**

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Cost-Benefit Analysis

Types of Criteria Included in Cost-Benefit Analysis

- **Return on Investment (ROI).**
  A simple analysis of which option has the highest percentage return when compared to the initial investment.
- **Reduction in space required with a smaller unit.**
  An alternative mechanical unit requires less space in the building which can reduce the building footprint and overall cost.
- **Better ventilation improves worker productivity.**
  The indirect value associated with the increase in worker productivity and output can be added to the analysis.
- **Improved schedule.**
  A reduction in downtime or the benefit of occupying the space can be addressed in the analysis.

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Weighted Criteria Evaluation

Weighted criteria adds the ability to rank the importance of each of the criteria in the study and to include non-monetary benefits that are not included in the life cycle cost analysis.

Weighted Criteria Matrix	Weight Factor	Option 1		Option 2		Option 3		Option 4	
		Base Score	Weighted Score	Base Score	Weighted Score	Base Score	Weighted Score	Base Score	Weighted Score
Initial Cost	4	5	20	2	8	3	12	4	16
Life Cycle Cost	6	2	12	4	24	3	18	5	30
Energy Reduction	10	2	20	5	50	4	40	3	30
Schedule	3	2	6	2	6	1	3	4	12
Space Requirement	7	2	14	1	7	2	14	3	21
Environmental Comfort	8	2	16	4	32	3	24	1	8
Totals		15	88	18	127	16	111	20	117

Base Score = 1 to 5 Weight Factor = 1 to 10

Sample of a Weighted Criteria Matrix

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Does the U.S. Government require LCCA / CBA?

Section 401 of the Executive Order 13123 – Greening the Government Through Efficient Energy Management requires that

"Agencies shall use life-cycle cost analysis in making decisions about their investments in products, services, construction, and other projects to lower the Federal Government's costs and to reduce energy and water consumption."

Section 1.8 of the U.S. General Services Administration (GSA) P100 Facilities Standards for the Public Buildings Service states

"LCC is expected to support selection of all building systems that impact energy use: thermal envelope, passive solar features, fenestration, HVAC, domestic hot water, building automation and lighting."

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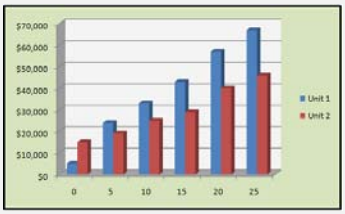
LCCA / CBA and Options for LEED Credits

Does LCCA / CBA help with the evaluation of LEED credit alternatives?

YES!

Life-Cycle Cost and Cost-Benefit Analysis are essential to properly evaluate alternatives that will contribute to achieving LEED credit points.

An alternative product or system might have a higher initial cost but have a short payback period by using less energy or requiring less maintenance.



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LCCA / CBA and Options for LEED Credits

The Holistic Analysis Starts with Individual Components

- Start with analyses of the individual components.
- The final report will be ***HOLISTIC*** and include the LCC and CBA of the entire system including the simulated energy model that integrates the preferred components.

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LCCA / CBA and Options for LEED Credits

This case study will be used to further explain the process of individual components and the holistic system analysis.

The Prospectus Development Study for the Modernization of the U.S. Treasury Annex Building for LEED Platinum Certification was done in 2009

for the

Department of the Treasury

By

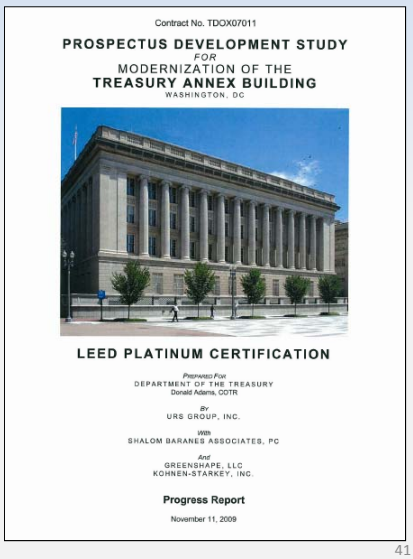
URS Group, Inc.

Shalom Baranes Associates, PC

GreenShape LLC

Kohnen-Starkey, Inc.

Case Study


Contract No. TDOX07011

PROSPECTUS DEVELOPMENT STUDY
FOR
MODERNIZATION OF THE
TREASURY ANNEX BUILDING
WASHINGTON, DC

LEED PLATINUM CERTIFICATION

Prepared For
DEPARTMENT OF THE TREASURY
Donald Adams, COTR

By
URS GROUP, INC.

With
SHALOM BARANES ASSOCIATES, PC

And
GREENSHAPE, LLC
KOHNEN-STARKEY, INC.

Progress Report

November 11, 2009

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LCCA / CBA and Options for LEED Credits

Overview

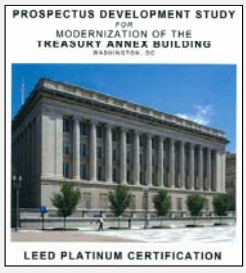
There were various studies conducted by the URS and Shalom Baranes Associates Team for the Modernization of the

U.S. Treasury Annex Building.

The main focus of the final study was to evaluate additional upgrades, especially energy efficiency, that could contribute to the building modernization achieving a

LEED Platinum Certification.

Case Study


PROSPECTUS DEVELOPMENT STUDY
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WASHINGTON, DC

LEED PLATINUM CERTIFICATION

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LCCA / CBA and Options for LEED Credits

Key Components and Systems Reviewed

Envelope Upgrades

- Types of Insulation
- Alternative Window Systems

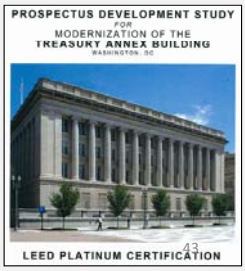
HVAC Airside System

- AHUs per Floor with VAVs and Diffusers
- Chilled Beams with 100% Outside Air AHUs on Roof

HVAC Central Plant Options

- Continued Use of the Existing
- New Cooling Tower
- New Chillers
- New Boilers

Case Study



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LCCA / CBA and Options for LEED Credits

Envelope Upgrades – Types of Insulation

The initial cost of the various insulations were compared based on the additional thickness required to achieve a specific R value in lieu of the original baseline insulation.

Two Scenarios of Insulation were Used

- ***Super Envelope*** = R-20 Wall & R-40 Roof
- ***Moderate Envelope*** = R-5 Wall & R-40 Roof

Types of Insulation

- Fiberglass Batt – R-3.4 per inch (Base)
- ***Semi-Rigid Fiberglass*** – R-5.5 per inch
  Super +$100,000 / Moderate +$0
- ***Aerogel*** – R-10 per inch
  Super +$868,000 / Moderate +$275,000

NOTE: Pricing based on 2009 cost without contingency or escalation

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LCCA / CBA and Options for LEED Credits

Envelope Upgrades – Alternative Window Systems

Upgrade of the window systems was complicated by the historic preservation requirements.

The original study included different scenarios.

- Clean / Paint / Reseal Existing Windows
- Refurbish Existing Windows
- Add New Interior Storm Window
- Replace with New Replica Window (Higher Thermal)

The LEED Platinum study used a casement window with improved thermal rating for the interior storm window to achieve the targeted U-Value of 0.30.

Cost Premium +$510,000

NOTE: Pricing based on 2009 cost without contingency or escalation

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LCCA / CBA and Options for LEED Credits

HVAC Airside System

The original study included the following:

- (8) Air Handling Units (AHU)
- ***VAV*** with Hot Water Coils
- Supply & Return Diffusers Throughout
- Complete Air Distribution Duct

The LEED Platinum study included the following:

- (2) Air Handling Units (AHU) 100% Outside Air
- ***Chilled Beams*** with Separate Chilled Water Distribution
- Radiators with Hot Water Distribution
- Supply & Return Diffusers in Only the Core Area
- Smaller Low Pressure Air Distribution Duct

Less Energy / Lower Maintenance / Longer Life

Cost Premium +$817,000

NOTE: Pricing based on 2009 cost without contingency or escalation

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LCCA / CBA and Options for LEED Credits

HVAC Central Plant Options

The LEED Platinum study included the following options:

- Continue using the existing central plant

- Add High Efficiency Chillers
  Cost Premium +$636,000

- Add a High Efficiency Cooling Tower
  Cost Premium +$288,000

- Replace the 80% efficient Steam Heat with a 90%+ Gas Fired Boiler system.
  Cost Premium +$202,000

NOTE: Pricing based on 2009 cost without contingency or escalation

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LCCA / CBA and Options for LEED Credits

Key Components and Systems Reviewed

Envelope Upgrades

• Types of Insulation	**Super F=$100,000 / A=$868,000** **Moderate F=$0 / A=$275,000**
• Alternative Window Systems	**$510,000**

HVAC Airside System

• AHUs per Floor with VAVs and Diffusers	**Base**
• Chilled Beams with 100% Outside Air AHUs on Roof	**$817,000**

HVAC Central Plant Options

• Continued Use of the Existing	**Base**
• New Chillers	**$636,000**
• New Cooling Tower	**$288,000**
• New Boilers	**$202,000**

NOTE: Pricing based on 2009 cost without contingency or escalation

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LCCA / CBA and Options for LEED Credits

Fundamental Analyses * & Energy Modeling**

Envelope Upgrades

- Types of Insulation — **Super F=$100,000 / A=$868,000**; **Moderate F=$0 / A=$275,000**
- Alternative Window Systems — **$510,000**

The additional cost of the Aerogel (A) insulation is substantial when compared to the equivalent R-Value Rigid Fiberglass (F) insulation.

***** Early in the feasibility study or design stage, only a fundamental analysis needs to be done. At this level the purpose of the LCC / CBA is not to determine the exact cost or benefit, but to determine the preferred components or systems.**

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LCCA / CBA and Options for LEED Credits

Fundamental Analyses & Energy Modeling

HVAC Airside System

- AHUs per Floor with VAVs and Diffusers — **Base**
- Chilled Beams with 100% Outside Air AHUs on Roof — **+$817,000**

The alternative Chilled Beams, AHUs replaced the AHUs and VAVs in the energy model. The central plant and envelope were not replaced.
The result was an energy savings of approx. $64,000 / year (21.8%).

In addition to the energy savings the Chilled Beams do not have moving parts and do not have regular maintenance cost like the VAVs.
VAV regular maintenance and repair 240 x $100 / yr = $24,000.

The quantity of AHUs reduced from (8) to (2).
AHU annual maintenance and repair 6 x $1000 / yr = $6,000.

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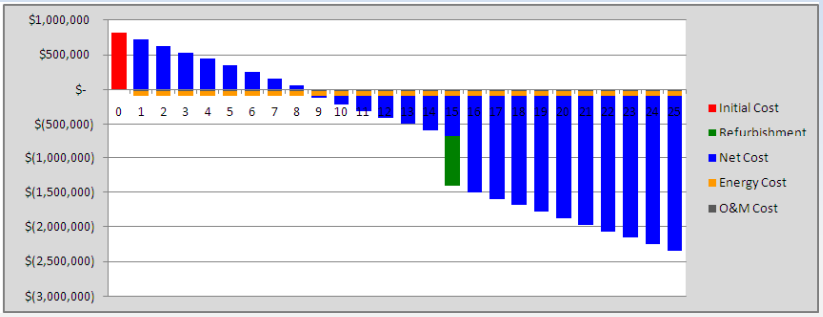
Chilled Beam Life Cycle Cost Analysis



The Comparison LCC Analysis Chilled Beams to VAVs.

- The **initial ADDITIONAL cost is $817,000**.
- The **reduction** in maintenance is **$30,000 / year**.
- The **reduction** in energy is **$64,000 / year**.
- The life expectancy of the Chilled Beam is 40 years.
- The **savings** to not replace VAVs in15 years is **$3,000 x 240 = $720,000.**
- The length of the study is **25 years**.

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Chilled Beam Life Cycle Cost Analysis

Calculating the Life Cycle Cost Savings of the Chilled Beams

The following will calculate the total 25 year life cycle cost, not including inflation, discount rates or salvage.

Initial Cost	1	x	$817,000	=	$ 817,000
O & M	25 Yrs	x	-$ 30,000	=	-$ 750,000
Energy	25 Yrs	x	-$ 64,000	=	-$1,600,000
Replace VAV	1	x	-$720,000	=	-$ 720,000

25 Year Savings TOTAL **($2,253,000)**

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Evaluation of Alternatives

Chilled Beams with Central Plant Alternatives

In addition to the Chilled Beams, Energy Models and LCC for the following combinations of HVAC Components were analyzed.

Opt. 1 - Chilled Beams (Existing Central Plant)
Opt. 2 - Chilled Beams + Chiller + Cooling Tower + Boiler
Opt. 3 - Chilled Beams + Chiller + Cooling Tower + Boiler + Super Envelope
Opt. 4 - Chilled Beams + Chiller + Boiler
Opt. 5 - Chilled Beams + Chiller + Boiler + Super Envelope





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Evaluation of Alternatives

Opt. 1 - Chilled Beams (Existing Central Plant)
Initial +$817,000 Life Cycle Cost ($2,253,000) Energy Red. 21.8%
LEED 2009 Pts +6 Environ 100% OA

Opt. 2 - Chilled Beams + Chiller + Cooling Tower + Boiler
Initial +$1,943,000 Life Cycle Cost ($2,027,000) Energy Red. 27.1%
LEED 2009 Pts +9 Environ 100% OA

Opt. 3 - Chilled Beams + Chiller + Cooling Tower + Boiler + Super Envelope
Initial +$2,553,000 Life Cycle Cost ($1,767,000) Energy Red. 29.4%
LEED 2009 Pts +10 Environ 100% OA

Opt. 4 - Chilled Beams + Chiller + Boiler
Initial +$1,655,000 Life Cycle Cost ($2,215,000) Energy Red. 26.5%
LEED 2009 Pts +9 Environ 100% OA

Opt. 5 - Chilled Beams + Chiller + Boiler + Super Envelope
Initial +$2,365,000 Life Cycle Cost ($1,805,000) Energy Red. 28.7%
LEED 2009 Pts +10 Environ 100% OA

Note: The Energy Reduction of the original study was 10.8%.

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Evaluation of Alternatives with CBA / ROI

Cost-Benefit Analysis / Return On Investment

CBA Return On Investment	Option 1	Option 2	Option 3	Option 4	Option 5
	Cost / Value	Cost / Value	Cost / Value	Cost / Value	Cost / Value
Initial Cost	$817,000	$1,943,000	$2,553,000	$1,655,000	$2,365,000
Life Cycle Cost	($2,253,000)	($2,027,000)	($1,767,000)	($2,215,000)	($1,805,000)
Return On Investment	**276%**	**104%**	**69%**	**134%**	**76%**
Energy Reduction	21.8%	27.1%	29.4%	26.5%	28.7%
LEED Credit Potential	6	9	10	9	10

Option 1 has very good Initial and Life Cycle Cost but the energy reduction and LEED potential are the lowest.

If the Return On Investment (ROI) is the only criteria, Option 1 will be selected.

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Evaluation of Alternatives

Weighted Criteria Cost-Benefit Analysis

CBA Score / Ranking	Option 1		Option 2		Option 3		Option 4		Option 5	
	Cost / Value	Score / Ranking	Cost / Value	Score / Ranking	Cost / Value	Score / Ranking	Cost / Value	Score / Ranking	Cost / Value	Score / Ranking
Initial Cost	$817,000	5	$1,943,000	2	$2,553,000	1	$1,655,000	4	$2,365,000	3
Life Cycle Cost	($2,253,000)	5	($2,027,000)	3	($1,767,000)	1	($2,215,000)	4	($1,805,000)	2
Energy Reduction	21.8%	1	27.1%	3	29.4%	5	26.5%	2	28.7%	4
LEED Credit Potential	6	1	9	3	10	4	9	3	10	4
Environmental Comfort OA	100%	5	100%	5	100%	5	100%	5	100%	5

To utilize this information in a Weighted Criteria CBA a score or ranking is assigned to each of the values.

The score or ranking of 1 is the lowest and 5 is the highest.

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Evaluation of Alternatives with CBA

Weighted Criteria Matrix	Weight Factor	Option 1		Option 2		Option 3		Option 4		Option 5	
		Base Score	Weighted Score	Base Score	Weighted Score	Base Score	Weighted Score	Base Score	Weighted Score	Base Score	Weighted Score
Initial Cost	4	5	20	2	8	1	4	4	16	3	12
Life Cycle Cost	7	5	35	3	21	1	7	4	28	2	14
Energy Reduction	10	1	10	3	30	5	50	2	20	4	40
LEED Credit Potential	7	1	7	3	21	4	28	3	21	4	28
Environmental Comfort	6	5	30	5	30	5	30	5	30	5	30
Totals		17	102	16	110	16	119	18	115	18	124

The scores from the previous sheet are entered in the Weighted Criteria Matrix.
The weight factors rate Energy Reduction as the most important factor followed by LEED credit potential and Life Cycle Cost.

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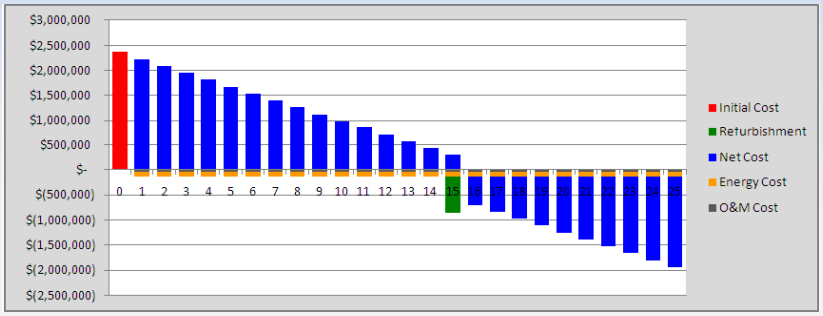
Preferred Option Life Cycle Cost Analysis



The LCC Analysis for the Preferred Option # 5.

- The **initial ADDITIONAL cost is $2,365,000**.
- The **reduction** in maintenance is **$33,000 / year**.
- The **reduction** in energy is **$105,000 / year**.
- The life expectancy of the Chilled Beam is 40 years.
- The **savings** to not replace VAVs in15 years is **$3,000 x 240 = $720,000.**
- The length of the study is **25 years**.

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Results of Case Study

	Points	Const. Cost	
Initial Study Overview	67	$67,009,000	
The initial study was a complete building renovation and modernization. With proper selection of materials and systems the additional hard costs to achieve the points for LEED Silver / Gold were minimal.			
EA/6 Green Power	2	0	
MR/1.2 Building Reuse *(95% will be retained)*	2	0	
SS/7.1 Heat Island Effect, Non-Roof *(Pavers & Landscaping)*	1	$60,000	
SS/8 Light Pollution Reduction *(alternate fixture type)* **	1	0	
EA/1 Optimize Energy *(see previous slides)*	9	$2,365,000	
MR/2 Construction Waste Management *(75% diverted)* **	1	0	
MR/4 Recycled Content *(20%)* **	1	0	
MR/5 Regional Materials *(20%)* **	1	0	
EQ/2 Increased Ventilation *(100% Outside Air)*	1	0	
Net Additional Points & Cost	19	$2,425,000	+3.6%
Total Life Cycle Cost Savings		($4,170,000)	
Net LCC Cost of Changes	86	($1,745,000)	

** Additional research found these credits could be achieved at no additional cost.

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Updating the LCCA with the Design Stages

Initial Study

As stated on a previous slide, early in the feasibility study or design stage, only a fundamental LCC analysis needs to be done. This study should include the initial cost, along with the operating, maintenance and energy costs of the major components.

Design Stage Updates

As the design progresses, the LCC should be updated and expanded to include the operating, maintenance and energy costs of all of the components. The updated LCC should also include the end of study residual value as well as the inflation, energy escalation and discount factors to provide the owner with an accurate analysis of the total life cycle cost.

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Questions & Comments

U.S. Green Building Council
National Capital Region Chapter

The Association for the
Advancement of Cost Engineering
National Capital Section

Analyzing the Cost of Building Green