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· August 15-18, 2010 · Dallas, Texas ·
· Dallas Convention Center ·

Building Life Cycle Costing

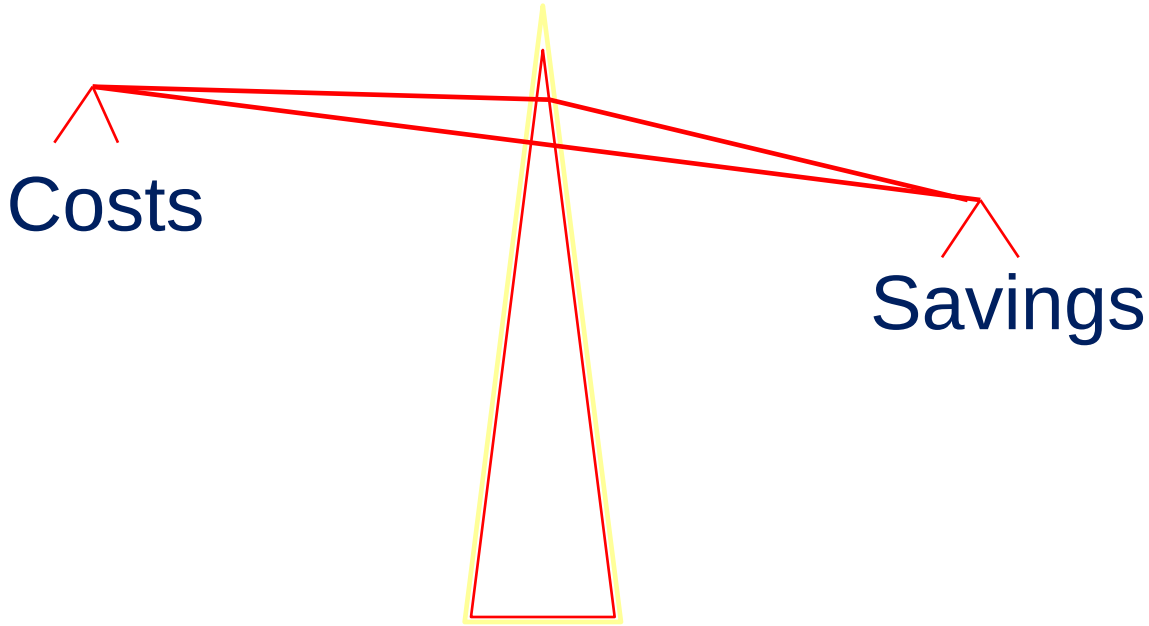
Life Cycle Costing

- Objectives:
  - Rationale for Life-Cycle Cost Analysis
  - Basic LCC methodology
  - Interpretation of analysis results
  - BLCC software

LCCA – Legislation References

- 2005 Energy Policy Act
- EO 13423
- 2007 EISA

Basic Economic Criterion for Capital Investments that Reduce Future Operating Costs



Savings must be greater than costs!

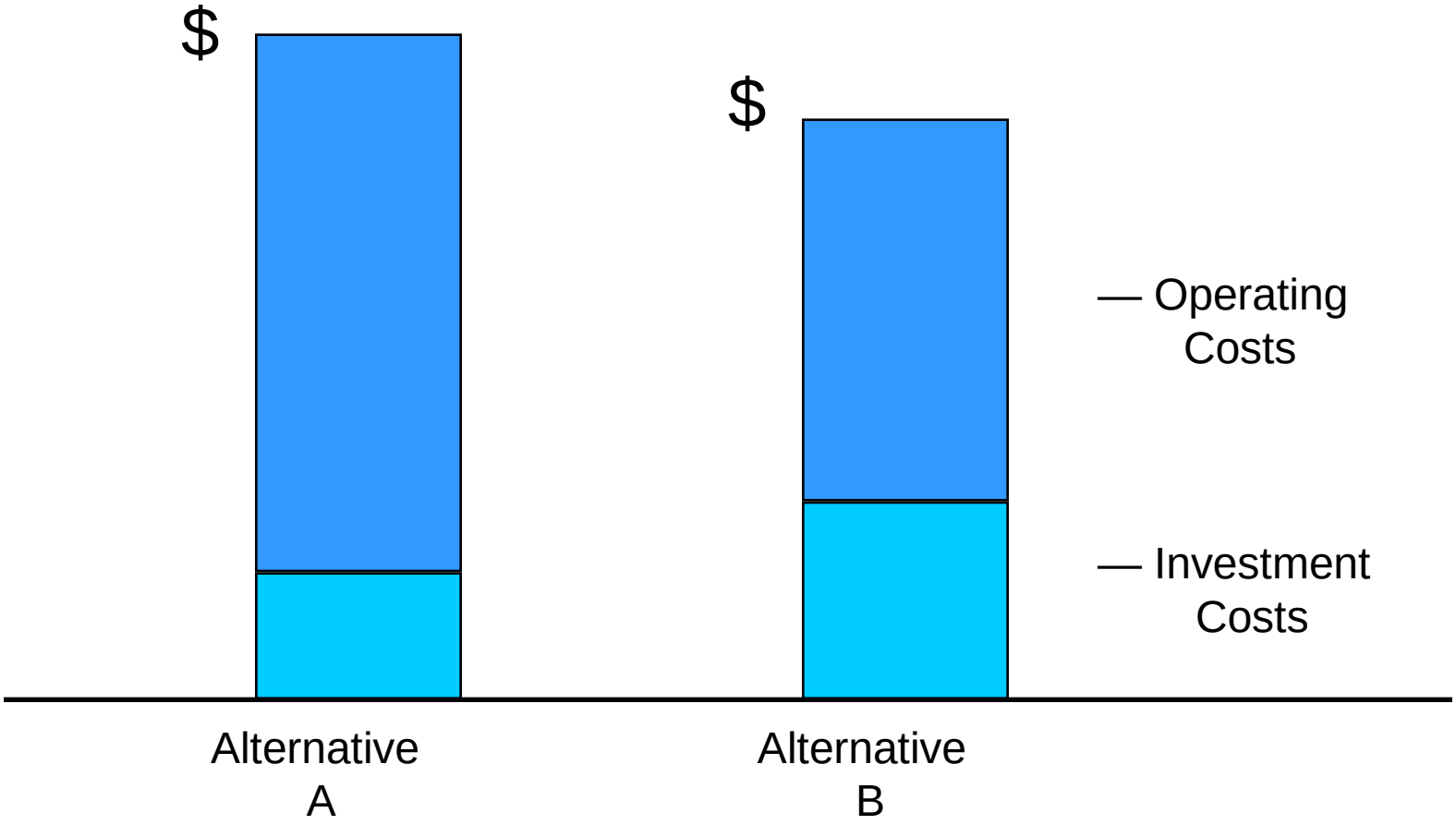
Why its more than a simple of sum costs and savings?

- Cost of capital
  - like renting a car!
- Why does the capital cost?
  - Time value of money
    - Costs & Savings occurring at different points in time
- Return on investments
  - Minimum attractive rate of returns
    - Private sector

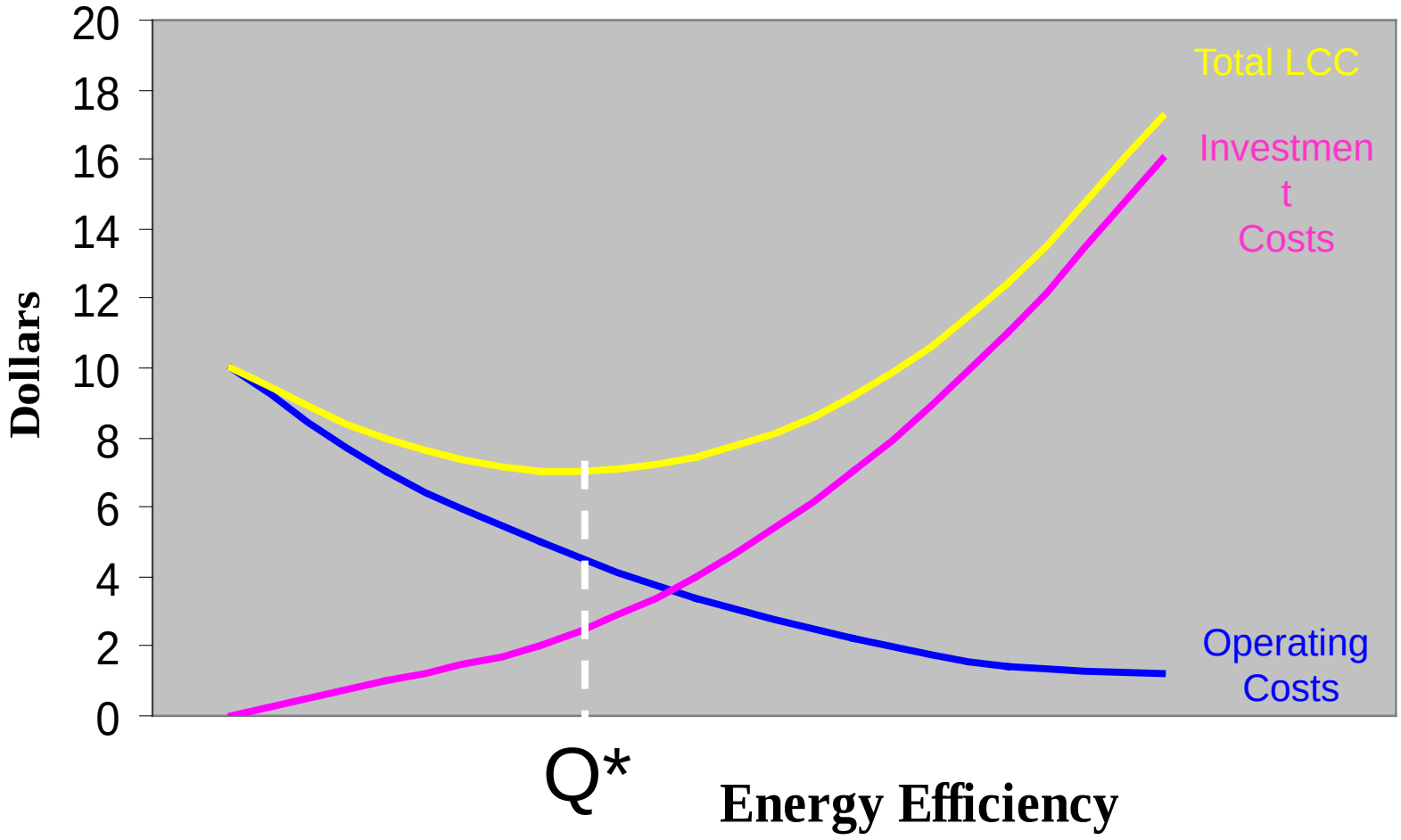
Why Alternates?

- Mutually exclusive design choices
- Technologies
  - Air-cooled chiller vs. water cooled chiller
- Performance
  - 1.1 kW/ton Vs. 0.65 kW/ton
- Fuel Prices
- O&M costs
- Life Expectancies
- Do nothing options
  - Should be included in the analysis – Most of the time

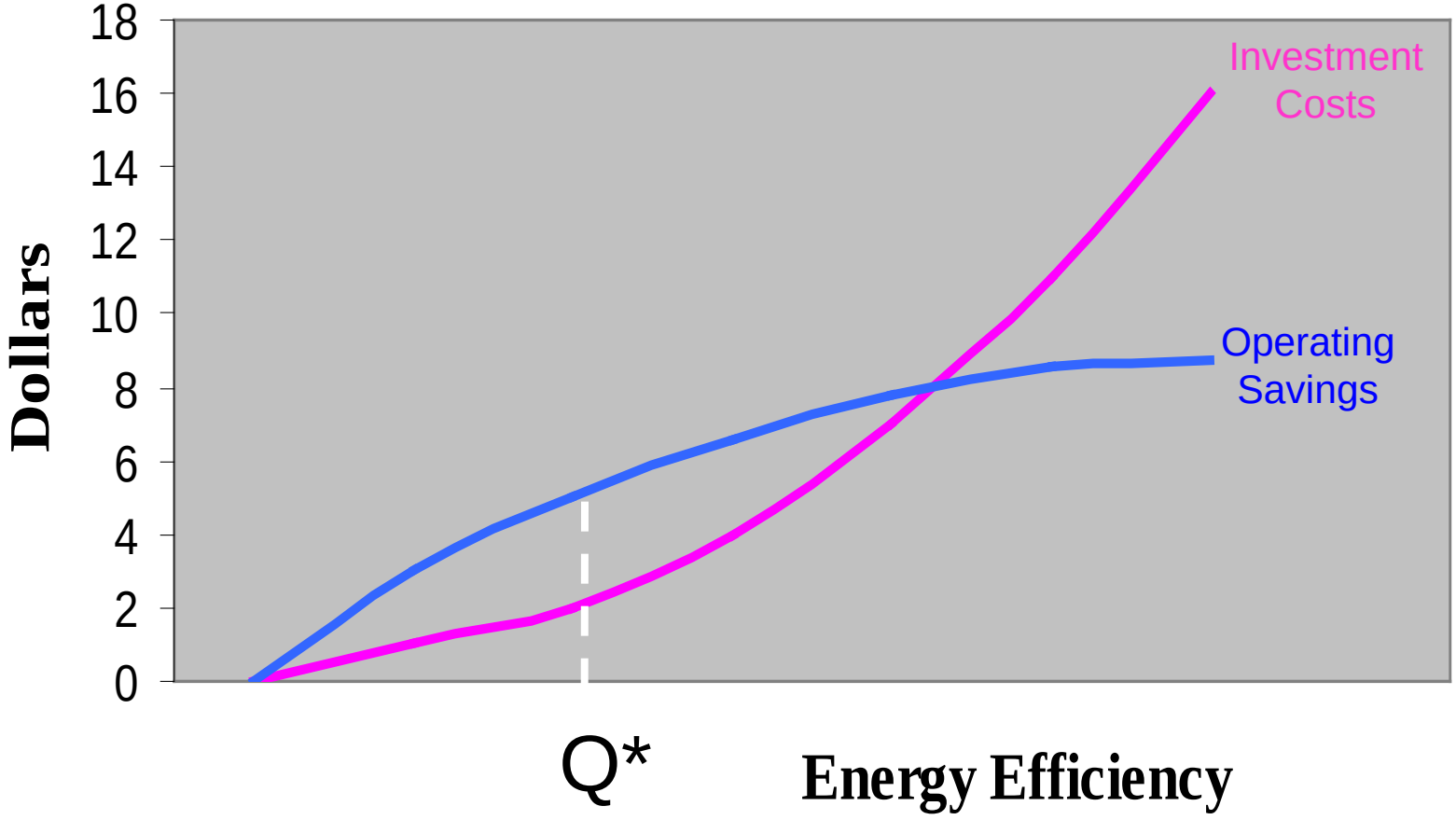
Life-Cycle Costs of Two Alternatives



Total Life-Cycle Cost is Minimized



Net Savings are Maximized



Types of Decisions

- Accept/reject projects
- Optimal energy efficiency level
- Optimal system selection or design
- Optimal combination of interdependent systems
- Prioritization of independent projects

Life-Cycle Cost Analysis

LCCA is

- a method of economic analysis that sums all *relevant* project cash flows (costs and savings) over a *given study period* in *present-value* terms.

- most relevant when selecting among *mutually exclusive project alternatives* that provide the same functional performance but have different initial costs, OM&R costs, and/or expected lives.

Typical Project Costs

- Investment-related:
  - Acquisition costs
  - Replacement costs
  - Residual value
    - in-place or salvage?
    - Disposal costs
- Operating-related:
  - Operation, maintenance, and repair costs
  - Energy and water costs
  - Contract-related costs (for financed projects)
- Sunk costs – need to be identified

The Study Period

The study period

- is the length of time over which an investment is analyzed based on
  - the expected life of the project and/or
  - the investor's time horizon.
- Base Date: analysis date to which all cash flows are discounted.
- Service Date: date when building or system is occupied or becomes operational.
- Study period must be the same for all alternatives.

Study Period

Base Date

Study Period

Service Date

Service Period

Year 01 02 03 04
n

Coinciding Study Period and Service Period

Base Date

Study Period

Service Date

Service Period

Year 01 02 03 04 05 06 07
n

Phased-in Planning/Construction/Implementation Period

Adjusting for Different System Lives

SYSTEM I: 15 YEARS

Residual

1 15 20

SYSTEM II: 20 YEARS

Replacement Residual

1 15 20
30

Length of study period

Present Value and Discounting

A present-value amount

- is the equivalent value to an investor, as of the base date, of a cash amount paid or received at a future date.

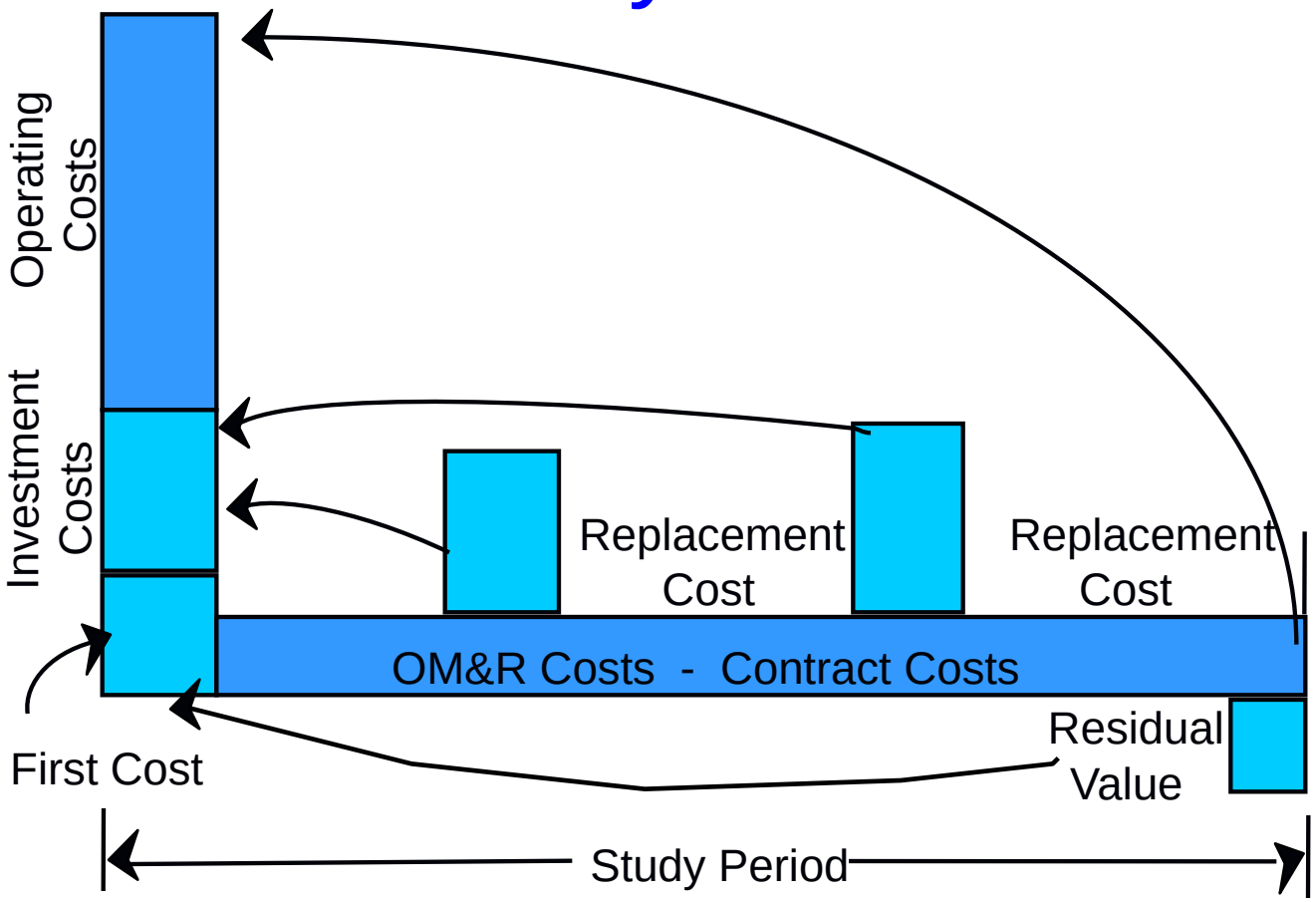
The present value of a future amount

- is found by discounting; discounting adjusts for the investor's time-value of money.

The discount rate

- is the interest rate that makes an investor indifferent between cash amounts received or paid at different points in time.

Life-Cycle Cost



Converting future amounts to present value:

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

$$LCC = \sum_{t=0}^{n} \frac{C_t}{(1+d)^t}$$

where n = length of study period.

Useful Discount Factors

(1) Single present value (SPV) factor for one-time amounts or non-annually recurring amounts:

$$PV = F_t \times SPV_{(t,d)}$$

(2) Uniform present value (UPV) factor for uniform annual amounts:

$$PV = A_0 \times UPV_{(n,d)}$$

where A_0 = annual amount at base-date prices

Useful Discount Factors (cont.)

(3) Modified uniform present value (UPV*) factor for changing annual amounts (uniform escalation)

$$PV = A_0 \times UPV^*_{(n,d,e)}$$

Where UPV* = (1+e)/(d-e)*[1-((1+e)/(1+d))^N]
e = escalation factor
d = discount factor

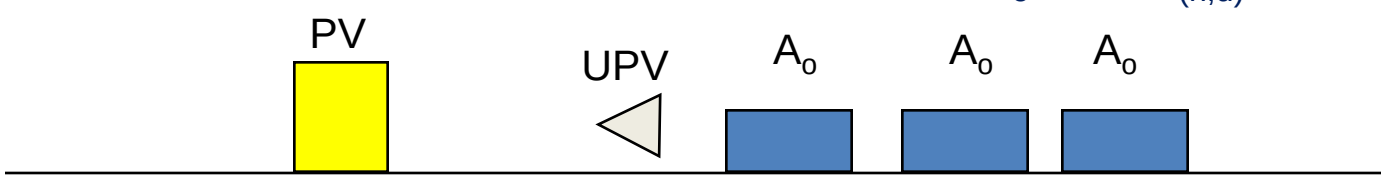
DOE Energy Price Projections

- DOE energy price escalation rates vary
  - by region (census region)
  - by fuel type (elec., oil, gas, LPG, coal)
  - by rate (residential, commercial, industrial)
  - by year

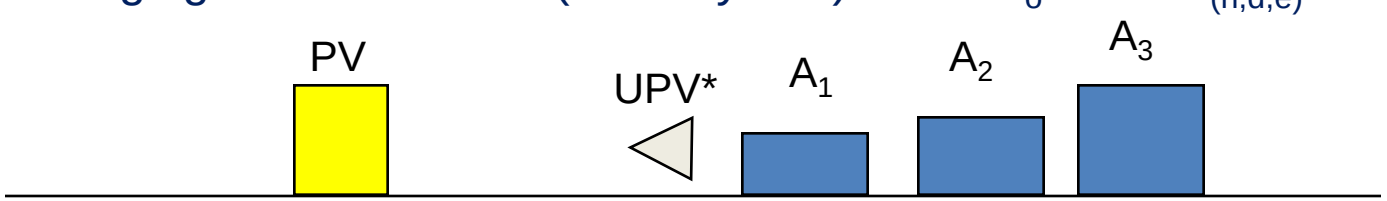
Summary of Present Value Factors

Single future amount (year t) $PV = F_t \times SPV_{(t,d)}$

Recurring annual amount (over n years) $PV = A_o \times UPV_{(n,d)}$



Changing annual amount (over n years) $PV = A_o \times UPV^*_{(n,d,e)}$



Single Present Value Factor

Example: Find the present value of $1,000 received at the end of year 10 when the discount rate is 3.0% (table A-1, Annual Supplement to HB135).

$$PV = F_t \times SPV$$

$$PV = \$1{,}000 \times SPV_{(d=3.0\%,\ t=10)}$$

$$= \$1{,}000 \times 0.744 = \$744$$

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Uniform Present Value (UPV) Factor

Find the present value of an annually recurring operating cost of $1,000 each year for 10 years when the discount rate is 3.0% (table A-2, Annual Supplement to HB135).

$$PV = A_0 \times UPV$$

$$PV = \$1{,}000 \times UPV_{(d=3.0\%,\ n=10)}$$

$$= \$1{,}000 \times 8.53 = \$8{,}530$$

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Modified Uniform Present Value (UPV*) Factor

Find the present value of an annually recurring operating cost of $1,000 over 10 years, when this cost is expected to escalate at 2%/yr and the discount rate is 3.0% (table A-3a, Annual Supplement to HB135).

$$PV = A_0 \times UPV^*$$

$$PV = \$1{,}000 \text{ (annual)} \times UPV^*_{(d=3.0\%,\ n=10,\ e=2\%)}$$

$$= \$1{,}000 \times 9.48 = \$9{,}480$$

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FEMP UPV* Factor for Energy Costs

Find the present value of an annually recurring electricity cost of $1,000 over 10 years, given current DOE energy price escalation rates (US Average, industrial rates) and the current DOE discount rate of 3.0% (table Ba-5, Annual Supplement to HB135).

$$PV = A_0 \times UPV^*$$

$$PV = \$1{,}000 \times UPV^*_{(d=3.0\%,\ n=10,\ electr.,\ industrial,\ US\ avg)}$$

$$= \$1{,}000 \times 7.78 = \$7{,}780$$

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Sources of Discount Factors

- Discount factors can be hand-calculated, computer-calculated, or looked up.
- Sources:
  - Annual Supplement to Handbook 135 (for federal projects)
  - NIST DISCOUNT computer program, NISTIR 85-3273-xx
  - Generic discount factor tables, NISTIR 89-4203
- Available from:
  - DOE HELP Desk at 1-800-DOE-EREC (363-3732) or
  - http://www1.eere.energy.gov/femp/program/lifecycle.html -- Technical Assistance – Life-Cycle Cost Analysis
  - Updated annually on April 1

Microsoft Excel

- Present Value - PV(rate,nper,pmt,fv,type)
  - “Type” - end of the period or beginning of the period cash flow
- Net Present Value - NPV(rate,value1,value2, ...)
  - Applicable for periodic cash flows only
- Uniform Payments - PMT(rate,nper,pv,fv,type)
- Refer to help sections for financial functions and formulae

Comparing LCCs of Alternative Systems Requires a Common Analytical Perspective

- Base date
- Service date
- Study period
- Discount rate
- Inflation assumption (or constant dollar analysis)
- Cost estimating method(s)
- Operational schedules
- Energy analysis method

Federal Criteria for LCC Analysis

- Energy and Water Conservation Projects—10 CFR 436A/HB135
  - DOE discount rate (updated annually), published in Annual Supplement to Handbook 135
  - Maximum 25-year service period
  - Local energy prices, metered energy quantities
  - DOE energy price escalation rates
  - Analysis usually in constant base-year dollars (i.e., excluding inflation), except for financed projects
- Other federal projects—OMB Circular A-94
  - OMB discount rates, varying with length of study period and type of project
  - No limit on study period

NIST Handbook 135
1995 edition

LIFE-CYCLE COSTING MANUAL
for the Federal Energy Management Program

Sieglinde K. Fuller
Stephen R. Petersen

U.S. DEPARTMENT OF COMMERCE
Technology Administration
National Institute of Standards
and Technology

NISTIR 85-3273-24
(Rev. 5/09)

Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis – 2009

Annual Supplement to
NIST Handbook 135 and
NBS Special Publication 709

Amy S. Rushing
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U.S. DEPARTMENT OF COMMERCE
Technology Administration
National Institute of Standards
and Technology

Prepared for
United States Department of Energy
Federal Energy Management Program

May 2009

Uses of Life-Cycle Cost

Types of Decisions	LCC	Criterion
Accept /Reject	yes	lowest LCC
Optimal Performance	yes	lowest LCC
Optimal System/Design	yes	lowest LCC
Project Priority	no	---

Supplementary Economic Measures

- Net Savings (NS)
- Savings-to-Investment Ratio (SIR)
- Adjusted Internal Rate of Return (AIRR)
- Discounted Payback (DPB)

Net Savings (NS)

NS = PV of operational savings minus PV of additional investment

Alternative with the highest NS is the economic choice.

Uses of Net Savings

Types of Decisions	LCC	Criterion
Accept /Reject	yes	> 0 / < 0
Optimal Performance	yes	maximize
Optimal System/Design	yes	maximize
Project Priority	no	---

Savings-to-Investment Ratio (SIR)

SIR = Ratio of PV of operational savings to PV of additional investment costs

Uses of Savings-to-Investment Ratio

Types of Decisions	LCC	Criterion
Accept /Reject	yes	> 1 / < 1
Optimal Performance	no	---
Optimal System/Design	no	---
Project Priority	yes	descending order

Adjusted IRR

$$AIRR = (1 + r)\ SIR\ \hat{}\ ^{(1/N)} - 1$$

r = discount rate

Uses of AIRR

Types of Decisions	LCC	Criterion
Accept /Reject	yes	> r / <r
Optimal Performance	no	---
Optimal System/Design	no	---
Project Priority	yes	descending order

Example

Type of Project:	Energy Conservation Project
Facility	24/7, high base cooling load, continuous base heating load
Relevant Systems:	Three (3) 175 ton air-cooled chillers Two steam boilers
Discount rate:	2009 DOE discount rate: 3.0%
Fuel type:	Electricity
Price per kWh:	$0.11 off peak & $0.17 on peak
Useful life:	20 years
Study period:	20 years

Example – Alternatives

- Do Nothing – Base case
- Replace chillers with water-cooled chiller plant – Option 1
- Install a co-gen plant combined with absorption cooling – Option 2
- Stipulation – Maximum 20 year simple payback

Option 1 – Water-Cooled Chillers

Initial cost:	$1,200,000
Annual Savings	1,900,000 kWh $277,000
O&M Costs:	$40,000
Expected Life	20 Years
Study period:	20 years
Discount Rate:	3%

Cash-Flow Diagram for Option 1

$1,200,000
Initial investment cost

$277,000 annually
Electricity

$40,000 annually
OM&R

Base Date

Year 01 02 03 04 05 06 07 08 09 10 11 12 20

-

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Option 2 – Co-Gen Plant

Initial cost:	$3,200,000
Annual Savings	$420,000 (savings incl. fuel costs)
O&M Costs:	$90,000
Expected Life	20 Years
Study period:	20 years
Discount Rate:	3%

Cash-Flow Diagram for Option 2

$3,200,000
Initial investment cost

$420,000 annually
Electricity

$90,000 annually
OM&R

Base Date

Year 01 02 03 04 05 06 07 08 09 10 11 12 20

-

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Economics – Option 1 (WCC)

Simple Payback:	5.1 Years
Savings to Investment Ratio:	2.9

Economics – Option 2 (Co-Gen)

Simple Payback:	9.7 Years
Savings to Investment Ratio:	1.5

Incremental Analysis

Analyze the incremental cash flows – changes in each cost & savings category - from Option 1 to Option 2

Incremental Cash-Flow Diagram

$2,000,000
Additional Initial investment cost

$143,000 annually incremental energy

$50,000 annually OM&R

Base Date

Year 01 02 03 04 05 06 07 08 09 10 11 12 20

-

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Economics – Incremental Cash Flows

Simple Payback:	38 Years
Savings to Investment Ratio:	0.39

BLCC 5.3

Office of Applied Economics
Building and Fire Research Laboratory
National Institute of Standards and Technology

BLCC 5.3-10
Building Life-Cycle Cost Program

for Energy and Water Conservation and Renewable Energy Projects

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Overview – BLCC5

- Economic analysis of capital investments that reduce future costs
- Focus on energy and water conservation in buildings
- Downloadable from DOE/FEMP web site

Current Modules – BLCC5

- FEMP Analysis, Energy Project
  - for energy and water conservation and renewable energy projects under the FEMP rules, agency-funded
- Federal Analysis, Financed Project
  - for federal projects financed through Energy Savings Performance Contracts (ESPC) or Utility Energy Services Contracts (UESC)
- MILCON Analysis, Energy Project
  - for energy and water conservation and renewable energy projects in military construction, agency-funded
- MILCON Analysis, ECIP Project
  - for energy and water conservation projects under the Energy Conservation Investment Program (ECIP)

Data Requirements

- Project Information
  - name, location, analyst, comment, discounting convention, constant or current dollars, discount rate, base date, service date, and length of study period
- Capital Investment Costs
  - investment costs
  - cost-phasing
  - escalation rates
  - replacement costs and timing
  - residual values

Data Requirements (cont.)

- Operating-Related Costs
  - annually recurring operating, maintenance, & repair costs
  - non-annually recurring operating, maintenance, & repair costs
  - energy consumption and cost data
  - water consumption and cost data
  - escalation rates
- Contract Costs
  - annually recurring (annual contract payment, debt service, performance period expense)
  - non-annually recurring (implementation cost, financing procurement cost)

Lowest Report

File

NIST BLCC 5.1-02: Lowest LCC

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A

General Information

File Name:	C:\Program Files\BLCC5\projects\FederalFinanced.xml
Date of Study:	Thu May 30 16:15:15 EDT 2002
Analysis Type:	Federal Analysis, Financed Project
Project Name:	Lighting/Daylighting
Project Location:	Arizona
Analyst:	Derek Filben
Comment:	Replace existing lighting system with new system financed through a utility contract.
Base Date:	April 1, 2002
Study Period:	15 years 0 months (April 1, 2002 through March 31, 2017)
Discount Rate:	5.6%
Discounting Convention:	End-of-Year

Lowest LCC

Comparative Present-Value Costs of Alternatives
(Shown in Ascending Order of Initial Cost, * = Lowest LCC)

Alternative	Initial Cost (PV)	Life Cycle Cost (PV)
Existing	$0	$848,189
Lighting Retrofit	$0	$578,010 *

ECIP Report

File

NIST BLCC 5.1-02: ECIP Report

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A

The LCC calculations are based on the FEMP discount rates and energy price escalation rates updated on April 1, 2002.

Location:	Virginia	Discount Rate:	3.2%
Project Title:	Project #342 - Install DX Split System AC	Analyst:	JGG
Base Date:	April 1, 2002	Preparation Date:	Thu May 30 16:16:08 EDT 2002
BOD:	April 1, 2003	Economic Life:	21 years 0 months

File Name: C:\Program Files\BLCC5\projects\MilconECIP.xml

1. Investment

Construction Cost	$142,800
SIOH	$10,200
Design Cost	$17,000
Total Cost	$170,000
Salvage Value of Existing Equipment	$0
Public Utility Company Rebate	$0
Total Investment	$170,000

2. Energy and Water Savings (+) or Cost (-)

Base Date Savings, unit costs, & discounted savings

Item	Unit Cost	Usage Savings	Annual Savings	Discount Factor	Discounted Savings
Electricity	$25.52943	734.6 MBtu	$18,755	14.353	$269,185
Energy Subtotal		734.6 MBtu	$18,755		$269,185
Water Subtotal		0.0 Mgal	$0		$0
Total			$18,755		$269,185

NIST DOS-Based LCC Support Software

- BLCC4
- ERATES: complex electricity rate schedules
- EMISS: air pollution emission factors
- DISCOUNT: present value factors and calculations

NIST LCC Programs

- Programs updated every April 1 with new energy price escalation and discount rates

- Downloadable from DOE/FEMP Web site:
  - www.eere.energy.gov/femp/information/access_tools.cfm BLCC Programs