Week 8

Project Cost Estimating (2)

Engineering Economics

457.307 Construction Planning and Management

Department of Civil and Environmental Engineering

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A Sea of Problems

- **Simple Problems: Worked in one's head**
  - Should I pay cash for an item or use my credit card?
  - Shall we replace a burned-out motor?
  - Do I take a bus or a subway?
- **Intermediate Problems: Organized and analyzed, Economic aspects are significant**
  - Shall I buy or lease my next car?
  - Which equipment should be selected for a new assembly line?
  - Which materials should be used as roofing, siding, and structural support for a new building?
  - Do I buy a semester parking pass or use the parking meters?
  - Which printing press should be purchased? A low cost press requiring three operators or a more expensive one needing only two operators?

A Sea of Problems

- **Complex Problems: Economic, political and humanistic**
  - The selection of a girlfriend or a boyfriend (who may later become a spouse): economic analysis can be of little or no help.
  - Manufacturing site: Texas or California

Texas	**California**
Permit time: 9-12 months	Permit time: 12-18 months
No seismic sensitivity	Seismic sensitive location
No dock Facilities (major market: Asia)	Coast with dock facilities
Lower labor/construction cost	Higher construction cost
Closer to raw materials	More environmental restrictions
Lower taxes	CEO’ preference

Role of Engineering Economic Analysis

- **Suitable for Intermediate Problems & Economic Aspects of Complex Problems**
  - The decision is sufficiently important that serious thought and effort is required.
  - That careful analysis requires that the decision variables be carefully organized and the consequences be understood.
  - A significant component of the analysis leading to a decision are ECONOMIC ISSUES.
  - Engineering economic analysis focuses on: costs, revenues and benefits that occur at different times
  - When a civil engineer designs a road, a dam, or a building: construction costs occur in the near future and benefits to users only begin when construction is finished but then the benefits continue for a long time.

Decision Making Process

1. Recognize problem
2. Define the goal or objective
3. Assemble relevant data
4. Identify feasible alternatives
5. Select criterion to determine the best alternative
6. Construct a model
7. Predict each alternative's outcomes or consequences
8. Choose the best alternative
9. Audit the result

Example

- A machine part is manufactured at a unit cost of 40¢ for material and 15¢ for direct labor (other costs = 2.5 x direct labor cost). An investment of $500,000 in tooling is required. The order calls for 3,000,000 pieces. Half-way through the order, a new method of manufacture can be put into effect which will reduce the unit costs to 34¢ for material and 10¢ for direct labor, but it will require $100,000 for additional tooling. What, if anything, should be done?
- Alternative 1: Continue with present method
  - Direct cost: 1,500,000 pieces x 0.40 = $600,000
  - Direct labor cost: 1,500,000 pieces x 0.15 = $225,000 | Other costs = $562,500
  - Total = $1,387,500
- Alternative 2: Change the manufacturing method
  - Material cost: 1,500,000 pieces x 0.34 = $510,000
  - Direct labor cost: 1,500,000 pieces x 0.10 = $150,000 | Other costs = $375,000
  - Additional tooling cost: $100,000
  - Total = $1,135,000

Engineering Costs

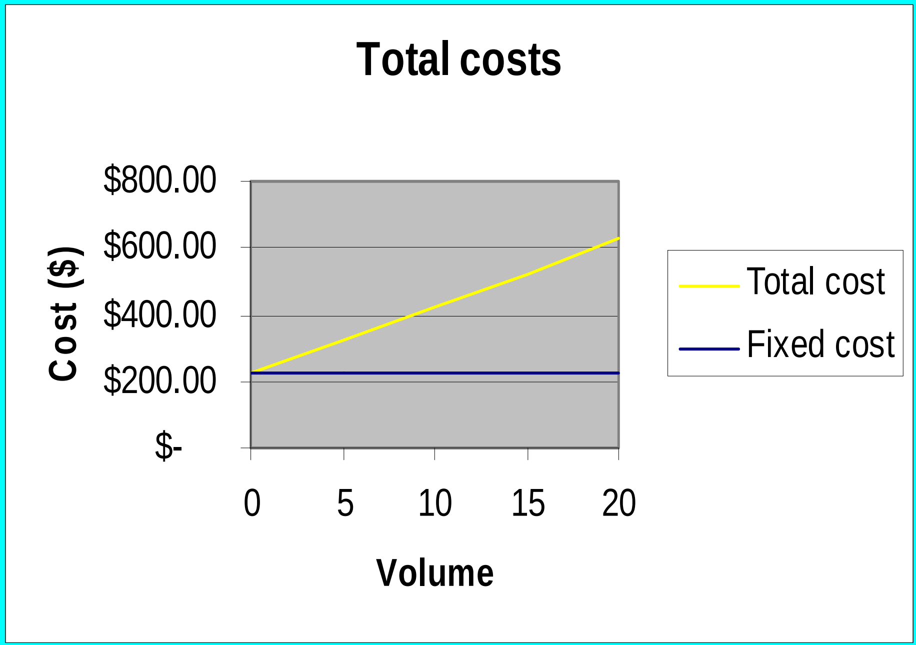
- **Classifications of Costs**
  - Fixed: constant, unchanging (e.g. "crane" costs, 12-18학점 등록금)
  - Variable: depend on activity level (e.g. "placing concrete" cost depends on the quantity, 18학점 이상 등록 시 추가 학점에 비례하여 등록금 산정)
  - Marginal: variable cost for one more unit (e.g. 17학점을 등록한 학생에게 18학점째 등록은 공짜이지만 18학점을 등록한 경우 19학점째는 추가비용 발생)
  - Average: total cost/number of units (e.g. 18학점 총 등록금 $3,600이면 학점당 등록금은 $200)

Engineering Costs

- An entrepreneur named JYP was considering the money-making potential of chartering a bus to take people from his hometown to an event in a larger city. JYP planned to provide transportation, tickets to the event, and refreshments on the bus for those who signed up. He gathered data and categorized these expenses as either fixed or variable.

Fixed Costs		Variable Costs	
Bus Rental	$ 80.00	Event Tickets	$ 12.50
Gas Expense	$ 75.00	Refreshments	$ 7.50
Other Fuels	$ 20.00		
Bus Driver	$ 50.00		
Total FC	$ 225.00	Total VC	$ 20.00

People	Fixed cost	Variable cost	Total cost
0	$ 225.00	$ -	$ 225.00
5	$ 225.00	$ 100.00	$ 325.00
10	$ 225.00	$ 200.00	$ 425.00
15	$ 225.00	$ 300.00	$ 525.00
20	$ 225.00	$ 400.00	$ 625.00

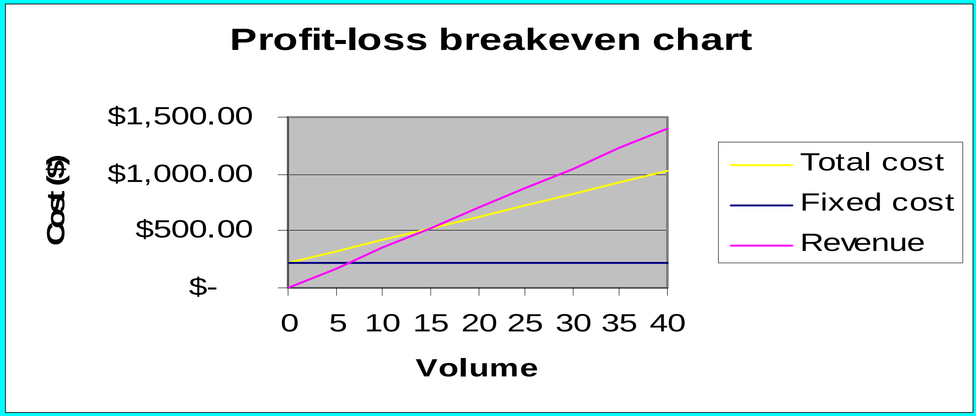


Engineering Costs

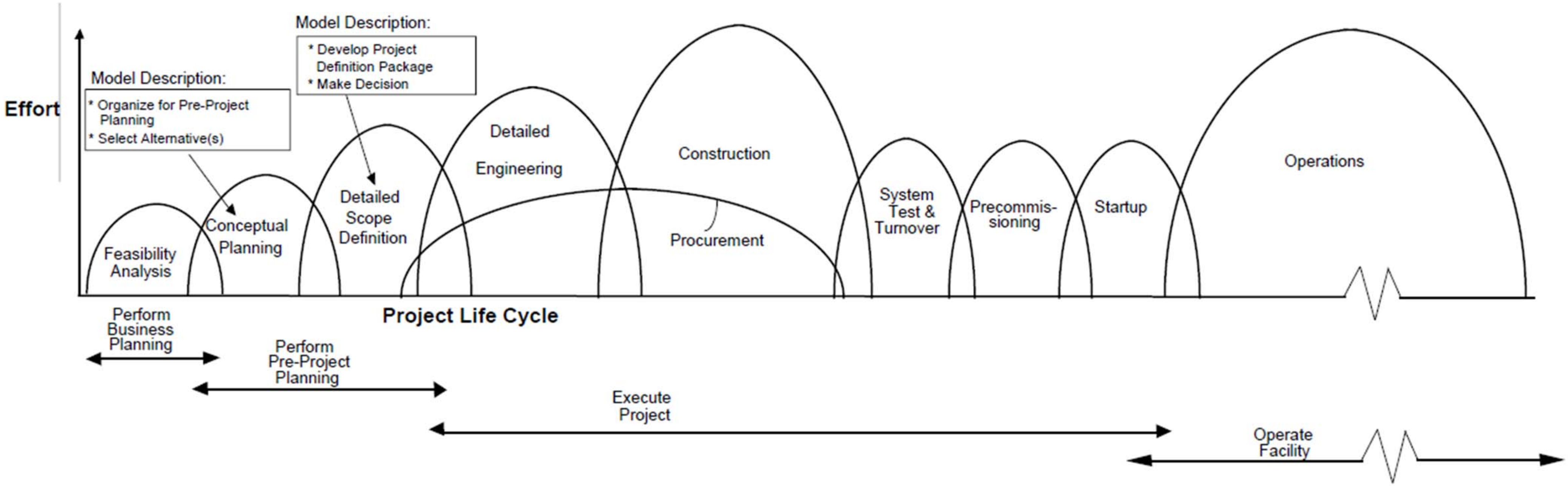
- **Profit and Loss Terms**

Fixed Costs		Variable Costs		Ticket price
Bus Rental	$ 80.00	Event Tickets	$ 12.50	$ 35.00
Gas Expense	$ 75.00	Refreshments	$ 7.50	
Other Fuels	$ 20.00			
Bus Driver	$ 50.00			
Total FC	$ 225.00	Total VC	$ 20.00	

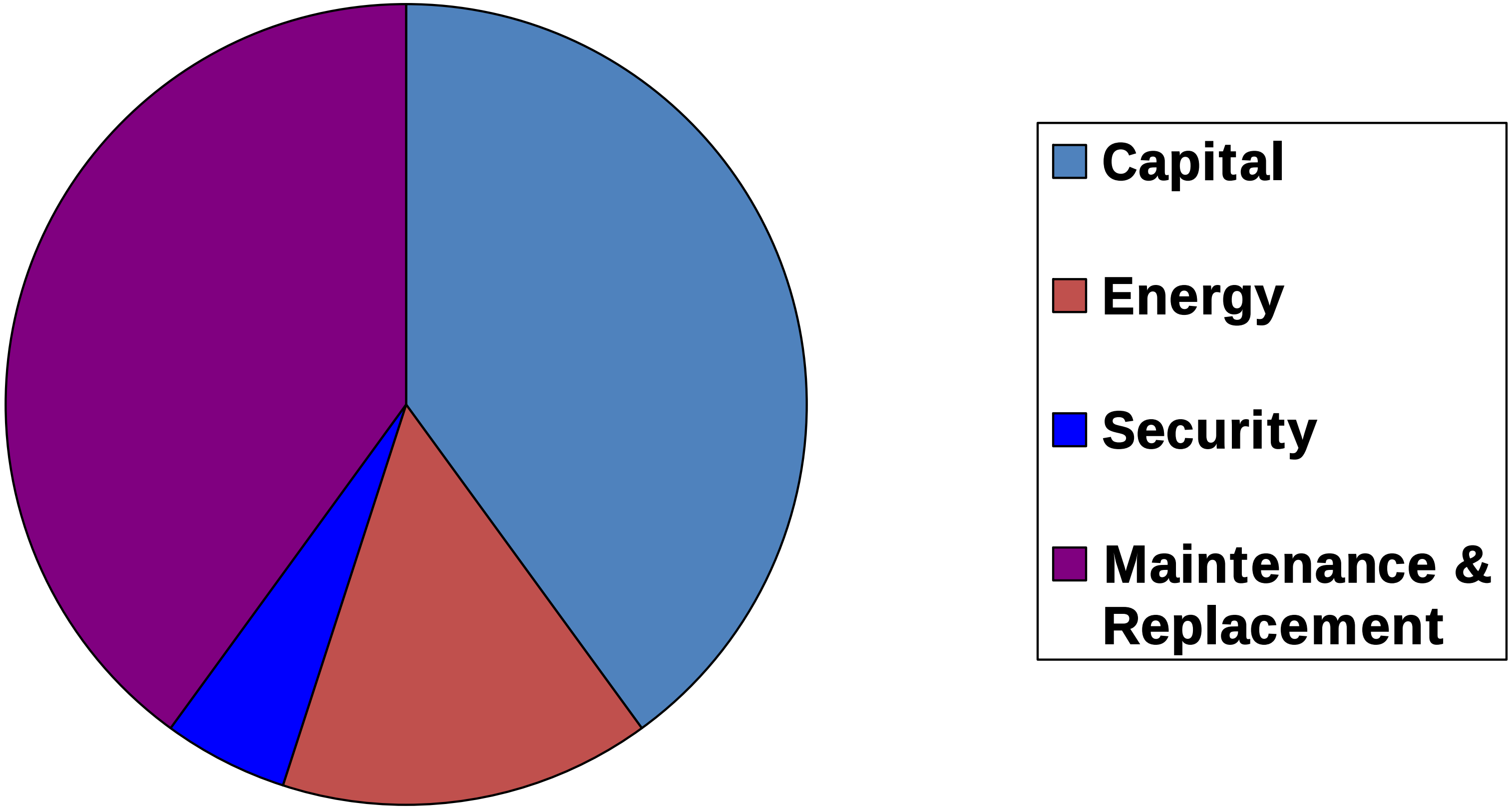
People	Fixed cost	Variable cost	Total cost	Revenue	Profit	Region
0	$ 225.00	$ -	$ 225.00	$ -	$ (225.00)	Loss
5	$ 225.00	$ 100.00	$ 325.00	$ 175.00	$ (150.00)	Loss
10	$ 225.00	$ 200.00	$ 425.00	$ 350.00	$ (75.00)	Loss
15	$ 225.00	$ 300.00	$ 525.00	$ 525.00	$ -	Breakeven
20	$ 225.00	$ 400.00	$ 625.00	$ 700.00	$ 75.00	Profit
25	$ 225.00	$ 500.00	$ 725.00	$ 875.00	$ 150.00	Profit
30	$ 225.00	$ 600.00	$ 825.00	$ 1,050.00	$ 225.00	Profit
35	$ 225.00	$ 700.00	$ 925.00	$ 1,225.00	$ 300.00	Profit
40	$ 225.00	$ 800.00	$ 1,025.00	$ 1,400.00	$ 375.00	Profit



Project Lifecycle



Life Cycle Cost (LCC)



Adapted from *Life Cycle Assessment – A Primer*, Paladino Consulting LCC, July 2000, Seattle, WA, www.palcon.com

LCC Practice

- **LCC methodology encompasses:**
  - Capital costs
  - O&M costs
    - Energy in particular
  - Salvage costs

- Economic analysis is future based.
- Costs and benefits in the future require estimating.
- Estimated costs are not known with certainty: Power Sizing(Segmenting + Interests), Cost Indexes, Learning Curve, etc.
- The more accurate the estimate, the more reliable the decision.

LCC Practice

국가 요소	한국	미국	영국	일본
주관기관	국토교통부, 개별기관	OMB / NIST, 개별기관	산업성, 표준협회	건설성
적용대상 공사금액	의무			권고사항
	100억 원 이상	$10,000,000 ~ $25,000,000	£150,000 (설계VE 용역비)	
법령 종류	법령/지침 등	OMB Circular 등	BS(British Standard) 등	권고사항
주요 목표	Maintenance, Finance	Energy	Environment, Energy	Maintenance, Finance
적용시점	기본설계, 실시설계, 시공과정	설계단계, 시공단계, (기관별 상이)	초기설계단계 (권장)	초기/개발단계

**OMB: Office of Management and Budget*

LCC Practice

요소 \ 국가	한국	미국	영국	일본
LCC 분석 주체	DBB방식일 경우 발주기관이 의무적으로 직접 또는 전문가를 고용하여 LCC 분석, 입찰자가 LCC 개선방안 제시 DB나 제안입찰인 경우 입찰자가 가이드라인에 따른 LCC 제시	발주기관이 제시하는 기준에 따라 LCC 분석이 요구되므로 입찰자가 분석함 정부공인 LCC 분석가가 있음.	BTO방식을 주로 사용하며 운영 시 발생되는 비용을 운영자가 부담하므로 시공/관리업체(민간 SPC)에서 정부 제공 분석 가이드라인에 따라 LCC 분석	

구분	내용
한국	관계규정없음
미국	최초비용+유지보수비용+에너지비용+물비용+교체비용-회수가치
영국	설계비용+건설비용+장기운영유지비용+처분비용-회수가치
호주	자본비용+운영비용+유지관리비용+처분비용-회수가치
일본	기획설계비용+건설비용+유지관리비용+해체비용-재이용비용

별지 제2호서식

생애주기비용절감 · 가치향상 제안서

제안서번호 :

사 업 명		발주청담당자	
제안자명			
제 안 명			

제안내용	
개 선 전(개략도면 포함)	개 선 후(개략도면 포함)

<table>
<tr><td rowspan="4">경제성 평가결과</td><td rowspan="2"></td><td colspan="5">생애주기비용(LCC)절감효과</td><td colspan="3">가치향상효과</td></tr>
<tr><td>① 건설사업비용</td><td>② 유지관리비용</td><td>③ 계(LCC) (=①+②)</td><td>④ 절감액 (=L_1-L_2)</td><td>절감율 (④/L_1×100%)</td><td>⑤ 성능점수 [P](점)</td><td>⑥ 가치점수 [V](점)</td><td>가치향상도 {(V_2-V_1)/V_1}×100%)</td></tr>
<tr><td>개선전</td><td></td><td></td><td>L_1=</td><td rowspan="2"></td><td rowspan="2"></td><td>P_1=</td><td>V_1=</td><td rowspan="2"></td></tr>
<tr><td>개선후</td><td></td><td></td><td>L_2=</td><td>P_2=</td><td>V_2=</td></tr>
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제안의 특징			
	장 점	단 점	시공시 주의할점

효 과 (기술성)	

※유지관리비용은 현재가치를 기입함

※성능점수 및 가치점수는 공종 및 구성요소가 아닌 전체 프로젝트 기준으로 평가함

※생애주기비용으로 설계의 경제성 검토가 불가능한 경우 「건설사업비용절감 제안서」로 대체

- **LEED (Leadership in Energy and Environmental Design) Green Building Rating System**

  – **인증기준**

    - <u>지속 가능한 토지의 사용</u> (친환경 부지선택 및 관리)

      미개발 토지의 개발에서 생태계와 수로에 대한 신규 건물이 미치는 영향을 최소화하고 그 지역의 적절한 조경을 장려하고, 교통수단의 선택, 우수관리, 오염의 감소, 침식 감소, 열섬 현상 및 건설관련 환경오염 방지

    - <u>수자원 효율</u>

      효율적 건축 자재 사용 및 외부 조경을 통한 현명한 물 사용 및 사용의 감축

    - <u>에너지와 대기환경</u>

      에너지 사용량 감시, 효율적인 설계 및 건설, 효율적 가전제품, 시스템, 조면 사용, 재생 에너지 사용

    - <u>자재와 자원</u>

      효율적 자재 생산 및 유통, 재사용 및 재활용을 통한 폐기물 감소

    - <u>실내 환경</u>

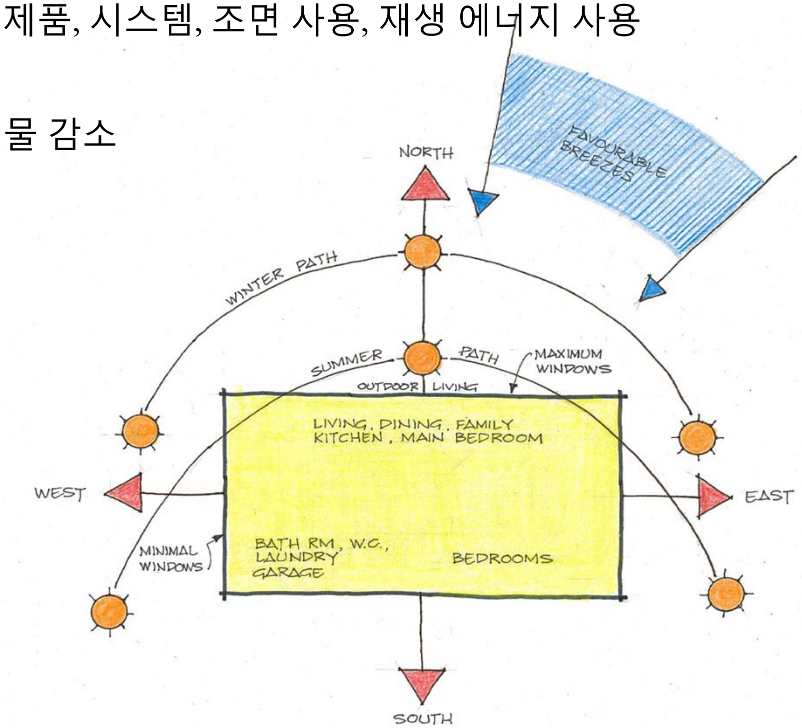
      실내공기 및 자연광, 전망 및 소음 개선

    - <u>기타</u>

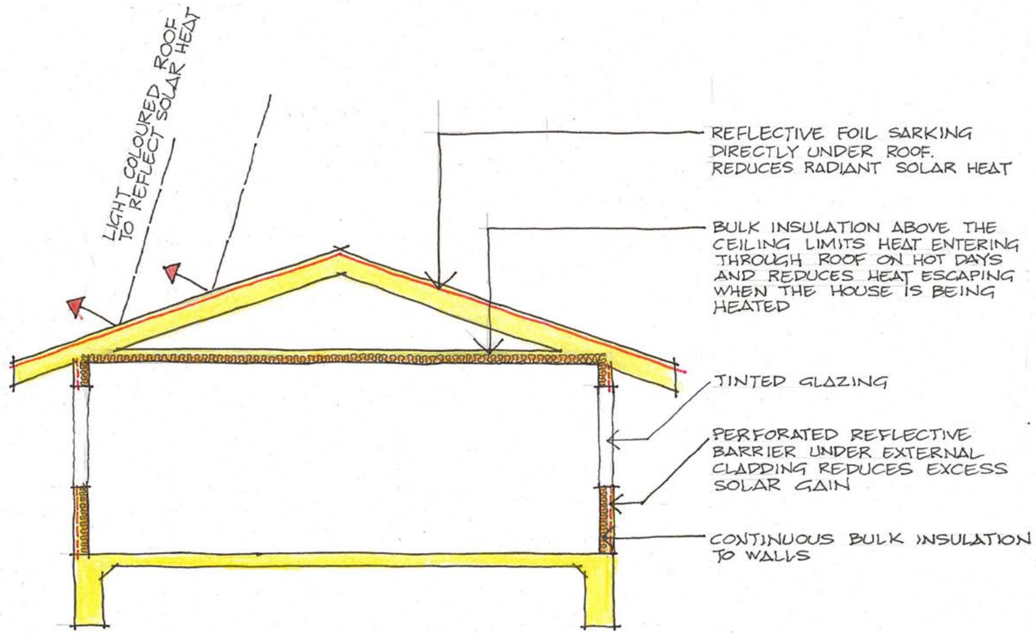
      지역과의 연계 (기존 인프라 환경, 교통 체계, 주변 환경, 산책공간 등)

      창의적 디자인 및 혁신 기술 (additional 6 points)

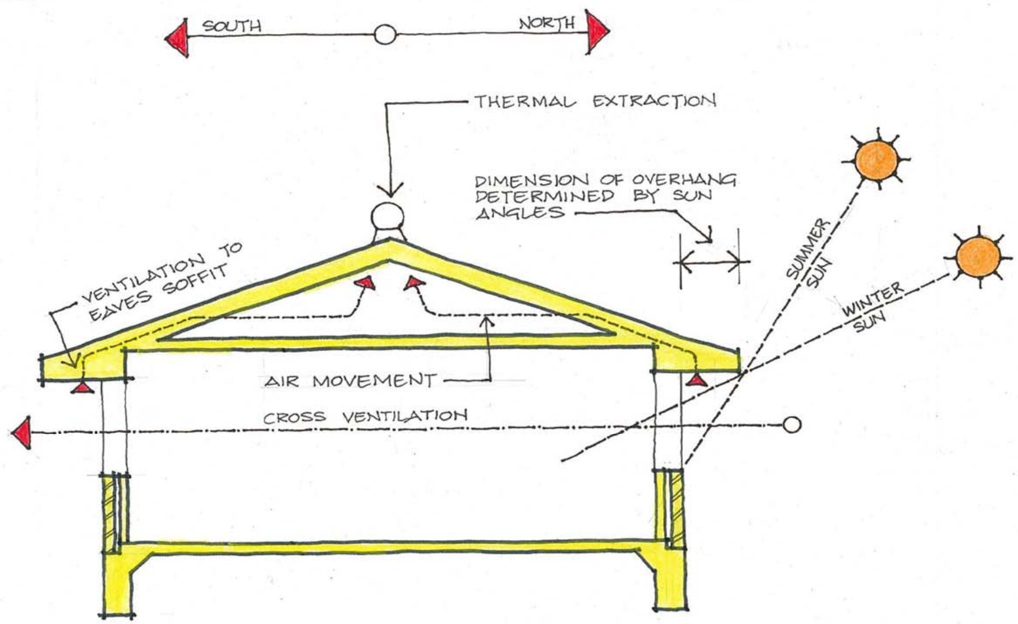
      지역적 특성 (additional 4 points)



Korea: 친환경 건축물 인증 by 국토해양부, 환경부 since 2005 (greenbuilding.re.kr)



ROOF AND WALL INSULATION



AIR MOVEMENT / SHADING

1 CHOOSE

Determine which rating system

어떤 종류의 LEED인증을 받을 지 결정합니다. 빌딩 종류와 LEED 등급에 따라 선택할 수 있습니다.

2 REGISTER

Register your project

프로젝트를 등록합니다. 프로젝트에 대한 등록 수수료는 USGBC Silver, Gold, Platinum 회원의 경우 US$ 900, 기타 일반의 경우 US$ 1,200입니다.

3 SUBMIT

Submit your certification application

인증 신청서를 제출하고 인증 심사 비용을 지불합니다. 수수료는 건물 유형과 면적에 따라 지불합니다.

4 REVIEW

Await the application review

문서 검토를 기다립니다. 검토 프로세스는 건물의 유형에 따라 차이가 있습니다.

5 CERTIFY

Receive the certification decision

검토 단계를 거친 후 결과를 수락하거나 이의를 제기 할 수 있습니다. 긍정적인 결정이란 LEED 인증을 받은 것을 의미합니다.

Greenroads 인증은 Green, Silver, Gold, Evergreen 의 4단계로 구성

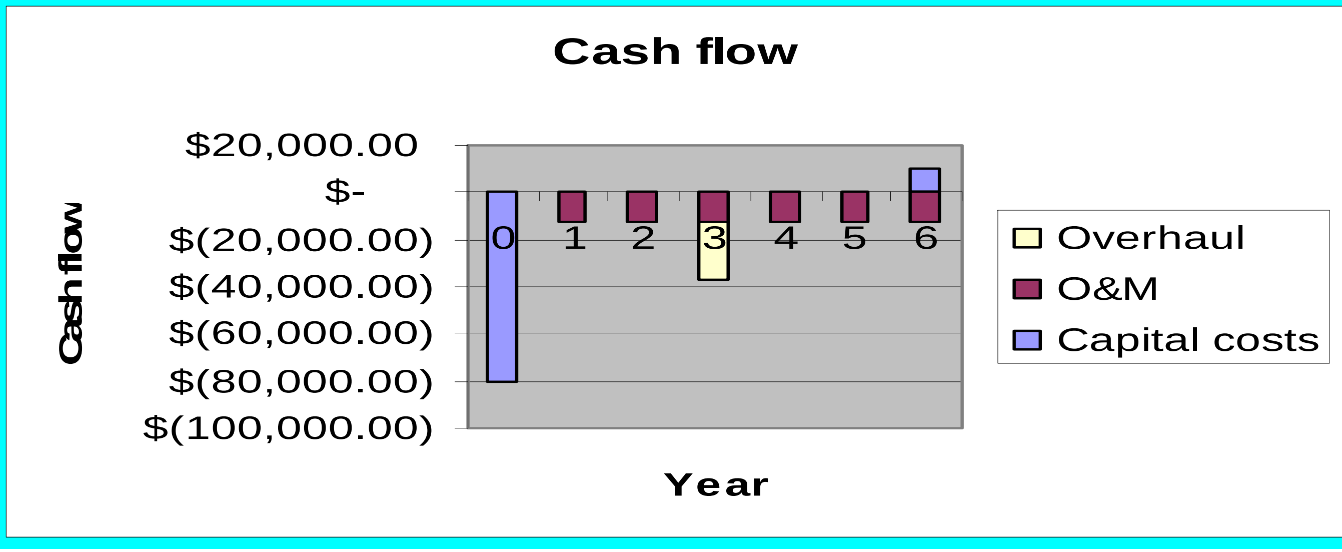
Greenroads certified	Greenroads certified SILVER	Greenroads certified GOLD	Greenroads certified EVERGREEN
32-42 points	43-54 points	55-63 points	64+ points
PR + 30% VC	PR + 40% VC	PR + 50% VC	PR + 60% VC

Category	Description	Points
Project Requirements	Minimum requirements for a Greenroad	Req
Environment & Water	Stormwater, habitat, vegetation	21
Access & Equity	Modal access, culture, aesthetics, safety	30
Construction Activities	Construction equipment, quality, use	14
Materials & Resources	Material extraction, processing, transport	23
Pavement Technology	Pavement design, material use, function	20
	Total Voluntary Credit Points	**108**
Custom Credits	Write your own credit for approval	10
	Grand Total	**118**

Cash Flow Diagrams

- Summarizes the flow of money overtime
- Can be represented using a spreadsheet

Year	Capital costs	O&M	Overhaul	Total
0	$ (80,000.00)			$ (80,000.00)
1		$ (12,000.00)		$ (12,000.00)
2		$ (12,000.00)		$ (12,000.00)
3		$ (12,000.00)	$ (25,000.00)	$ (37,000.00)
4		$ (12,000.00)		$ (12,000.00)
5		$ (12,000.00)		$ (12,000.00)
6	$ 10,000.00	$ (12,000.00)		$ (2,000.00)



*Overhaul: 기계시스템 정비

Net Present Value (NPV) Analysis

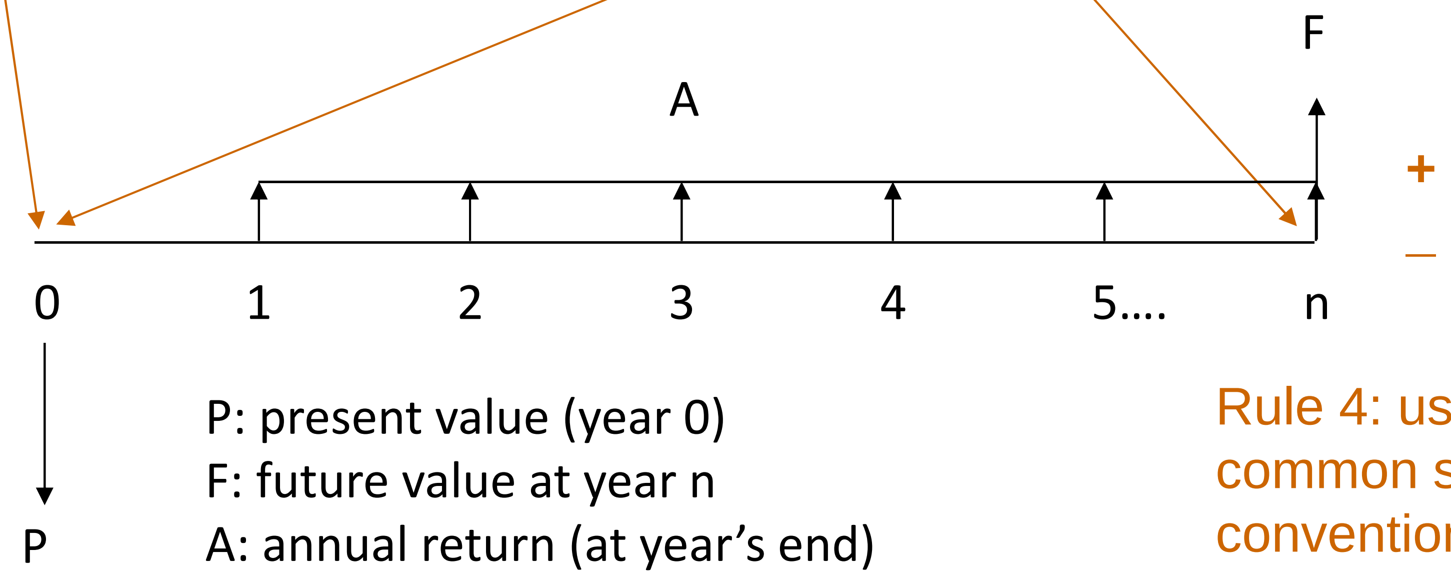
- **Today's $100 OR Tomorrow's $100?**

Cash Flow Mapping

Rule 1: Always start at year 0!
(present time or start of study period)

Rule 3: always compare alternatives using the same study period

Rule 2:
Ignore expenses before study period (sunk costs).



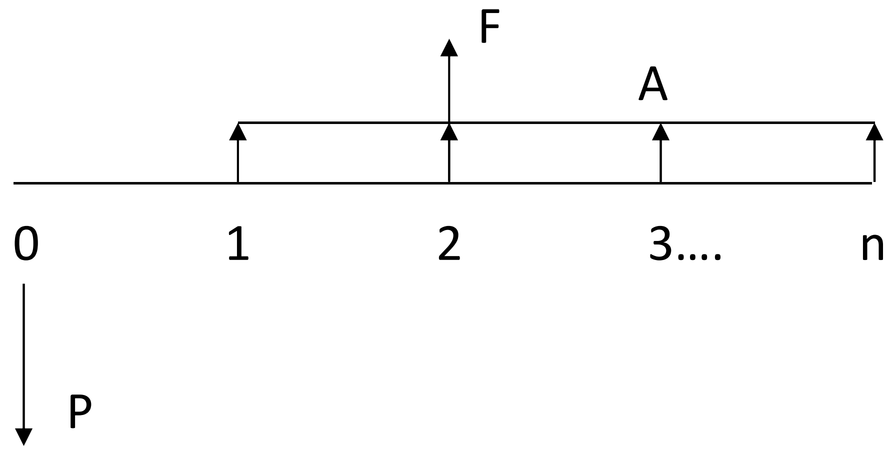
P: present value (year 0)
F: future value at year n
A: annual return (at year's end)
i: interest rate per period
n: number of years/periods

Rule 4: use a common sign convention

If you can get the cash flow diagram straight, you have the problem mostly solved!

Discounting or NPV Formulas

NPV = Net Present Value



F|P (P to F) $F = P(1+i)^n$

P|F $P = 1/(F|P)$

F|A (A to F) $F = A[((1+i)^n)-1)/i]$

A|F $A = 1/(F|A)$

P|A (A to P) $P = A\ [((1+i)^n)-1)/(i(1+i)^n)]$

A|P $A = 1/(P|A)$

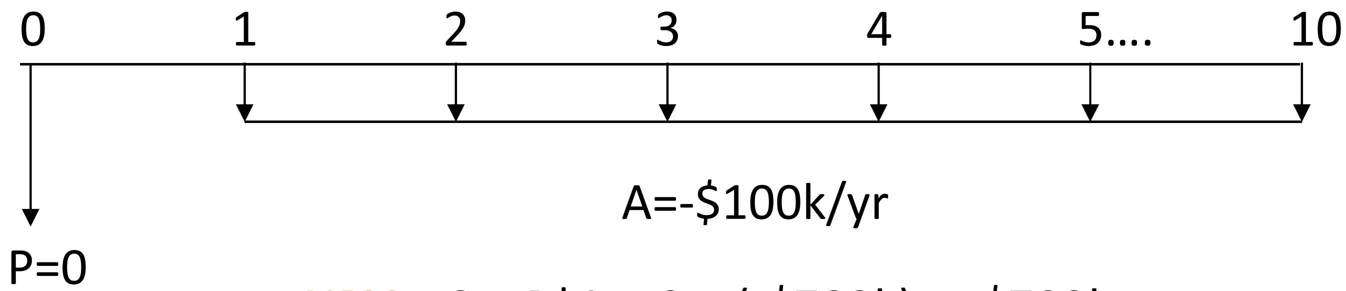
NPV Example

- **Repair vs Replace HVAC system**
  - If ***repair*** current HVAC,
    - no upfront costs (P=0), but O&M costs are $100k/yr
  - If ***replace*** with new HVAC,
    - upfront costs are $300k   and O&M costs are $50k/yr
  - Assume 10 year lifespan, i = 7%

NPV Example (Cont'd)

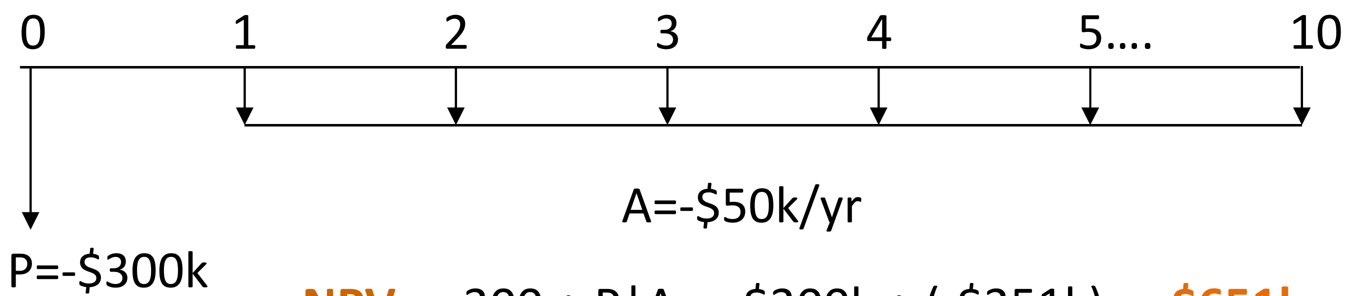
$P|A = A\,[((1+i)^n)-1)/(i(1+i)^n)]$

- **Repair**



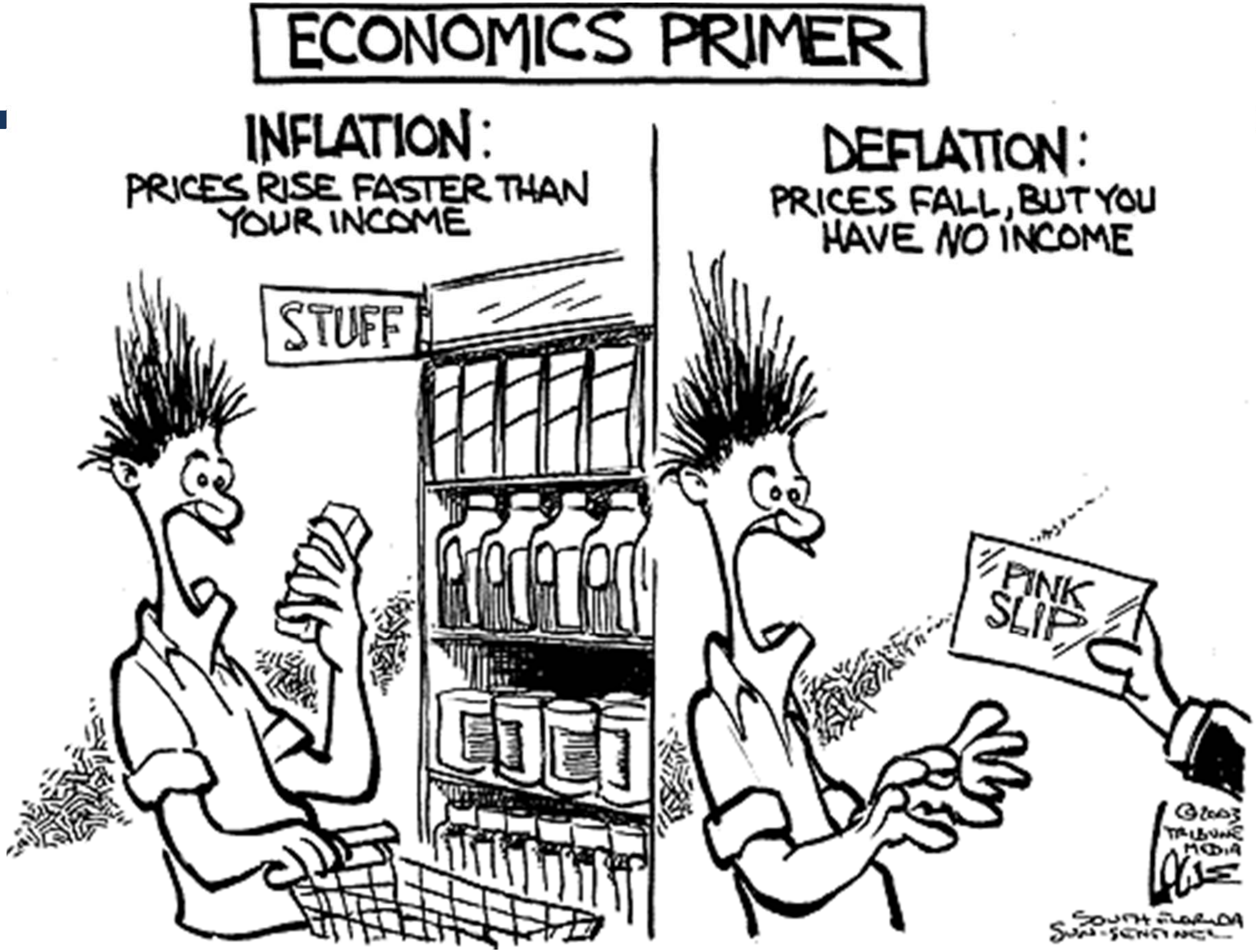
NPV = 0 + P|A = 0 + (-$702k) = -$702k

- **Replace**

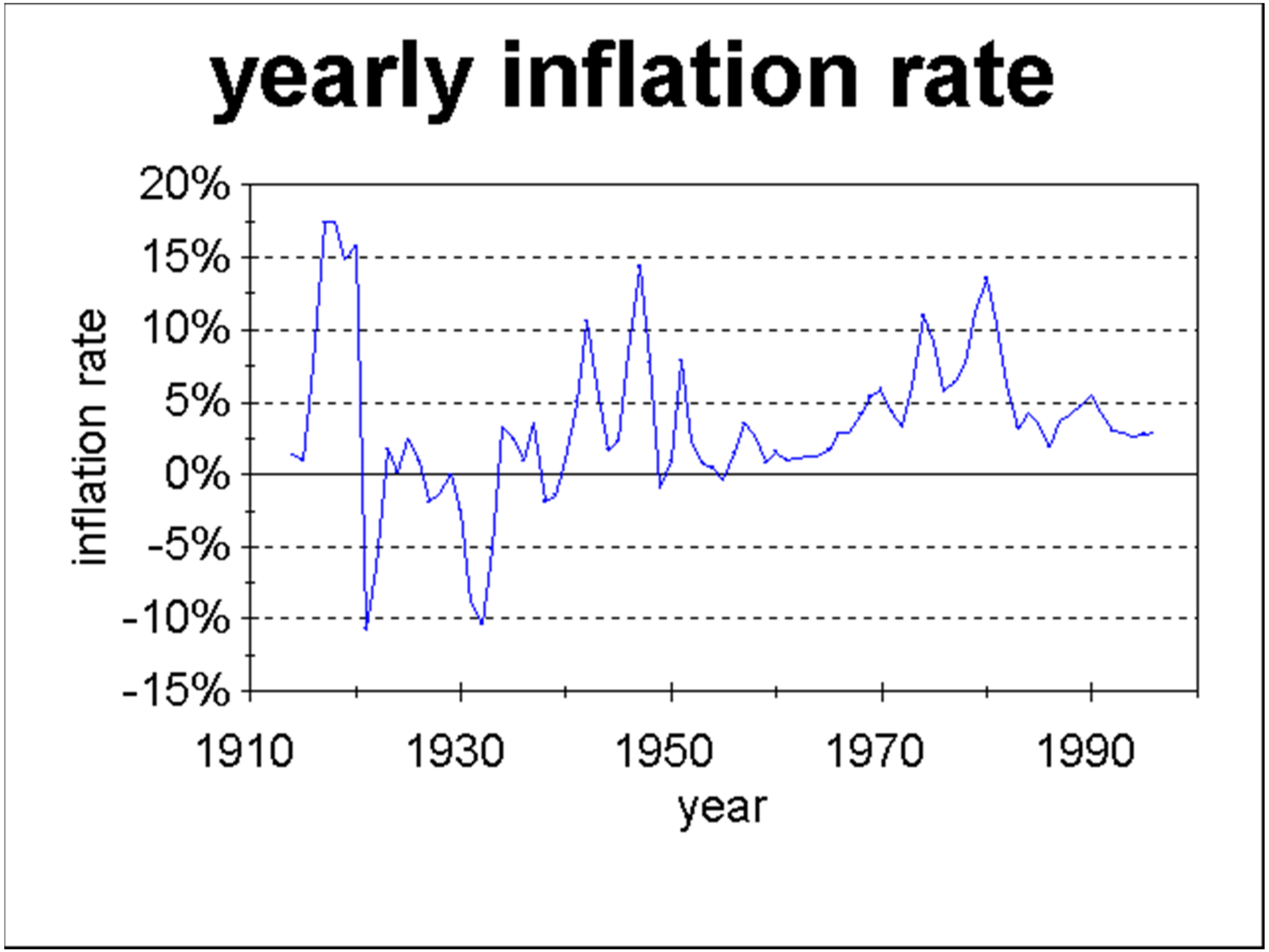


NPV = -300 + P|A = -$300k + (-$351k) = **-$651k**

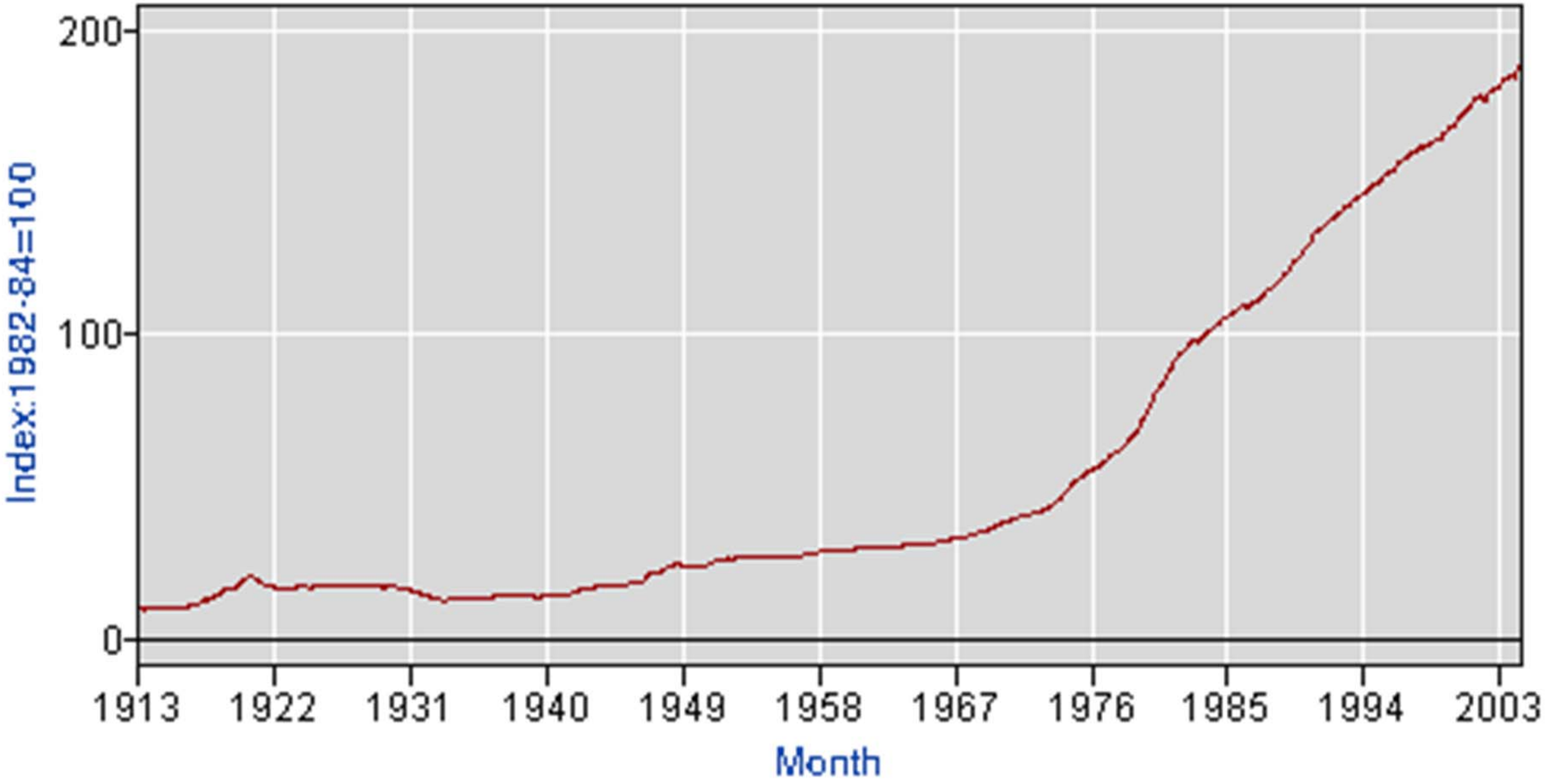
Makes sense to invest in the new system!


ECONOMICS PRIMER
INFLATION:
PRICES RISE FASTER THAN YOUR INCOME
STUFF
DEFLATION:
PRICES FALL, BUT YOU HAVE NO INCOME
PINK SLIP
©2003 TRIBUNE MEDIA
SOUTH FLORIDA SUN-SENTINEL

Inflation Happens



…and it adds up

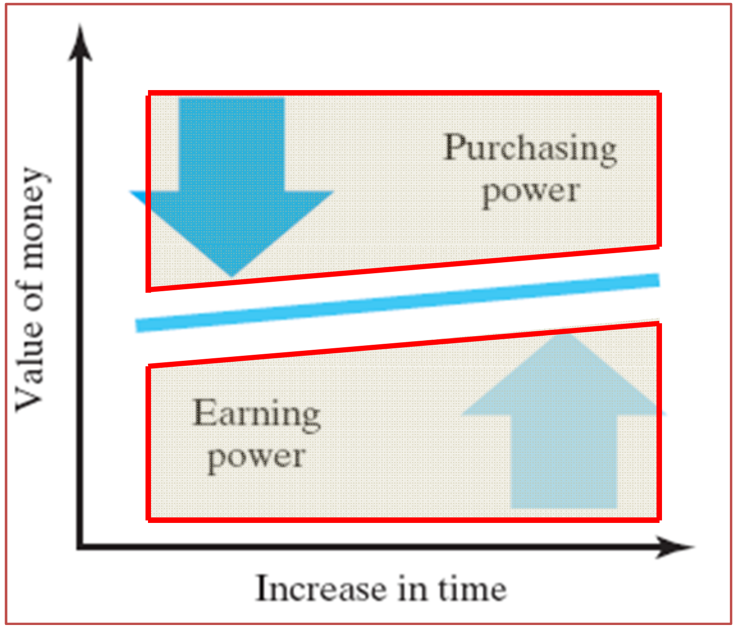


CPI (Consumer Price Index)
All items/Urban: 1913-2004

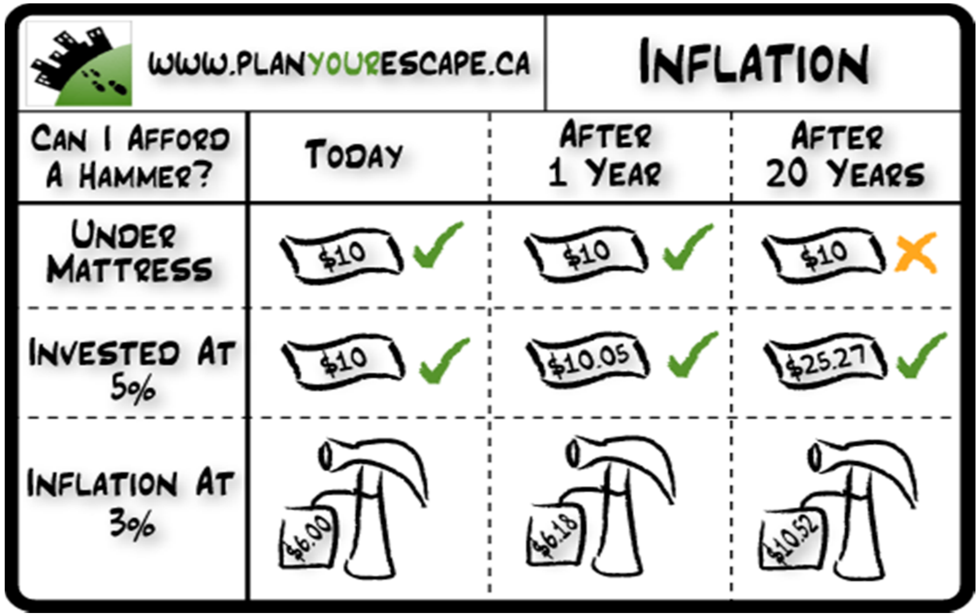
Source: US Dept of Labor
Bureau of Labor Statistics
www.bls.gov

Time Value of Money

- Money has a time value because it can earn more money over time. (interest: earning power)
- Money has a time value because its purchasing power change over time. (inflation)



Contemporary Engineering Economics, 5th edition © 2010



http://www.planyourescape.ca/understanding-inflation-24

The Corrosive Effect of Inflation

- **Suppose 3% inflation for 30 years**
  - $1 purchasing power today →
    F|P, 3%, 30 yrs → Need $2.43 tomorrow

- **Suppose 4% inflation for 30 years**
  - $1 today → Need $3.24 tomorrow

What does this do to your estimate for retirement savings?

Discount Rates and Inflation

- **Cash flows**
  - Constant dollars(불변가): No inflation. Thinking from present. Dollars expected to be same as base date

    e.g., $100 O&M costs: In 2030, actually pay $100+α
  - Current dollars(경상가): Account for inflation in each period

    e.g., $1,000 home mortgage: In 2030, actually still pay $1,000

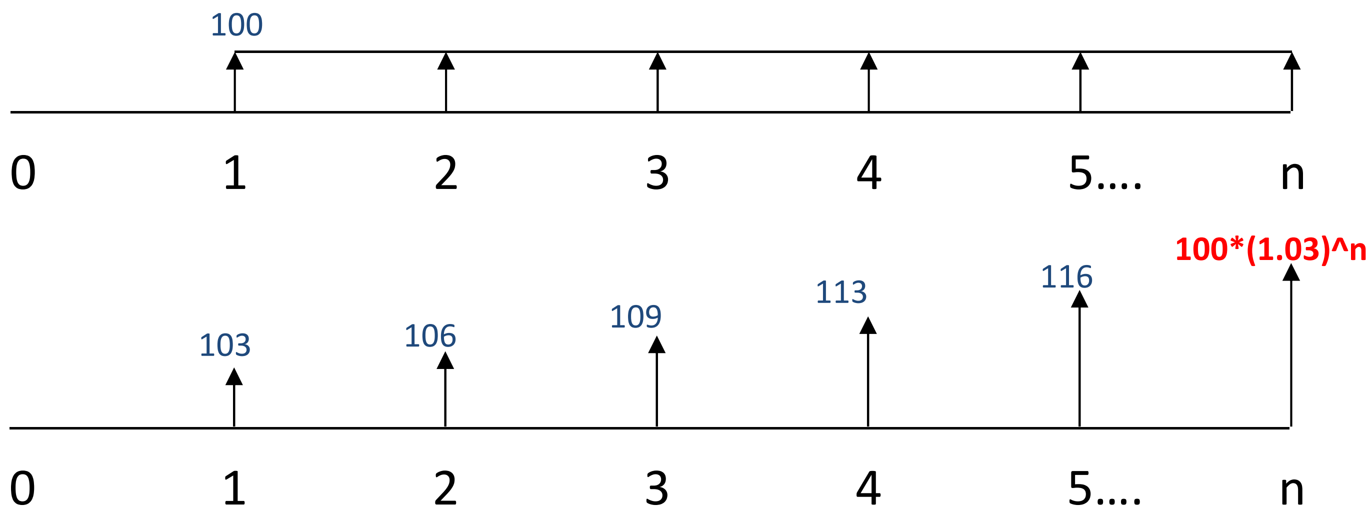
**O&M Cost of $400: 현재로 봤을 때 400불이란 얘기이지 실제로 그때가 되면 더 낼 수가 있다.*
Home Mortgage of $400: 그때가 되도 400불을 낸다. (인플레이션을 이미 고려)

- **Discount rate accounts for time value of money**
  - Real interest(불변할인율): Rate after inflation
  - Nominal interest(경상할인율): Rate inclusive of inflation
  - Nominal ≈ Real + Inflation rate (approximate)

**Real interest rate 4%: inflation은 생각하지 않고 4%의 이자*

Discount Rates and Inflation

- Use
  - Real interest rate with constant dollars
  - Nominal interest rate with current dollars
  - Example: real rate = 4%, inflation rate = 3%, annual income of $100k/yr in constant dollars



constant,
real = 4%

If n = 10,
NPV ≈ $810

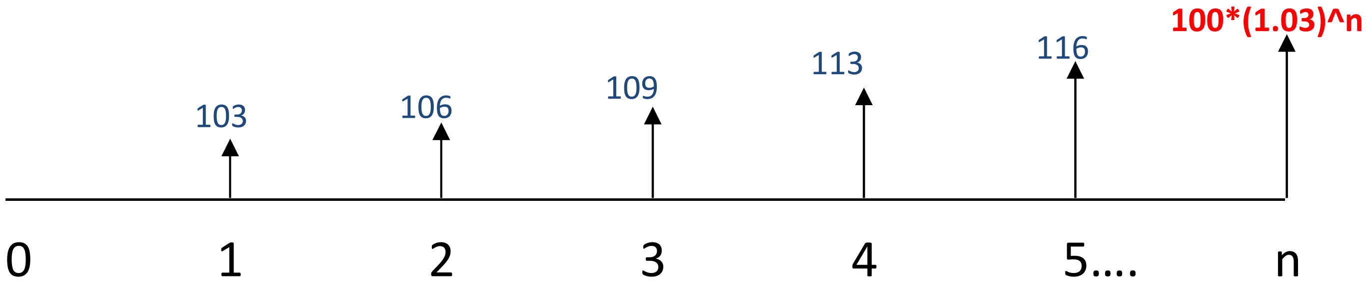
current,
nominal ≈ 7%

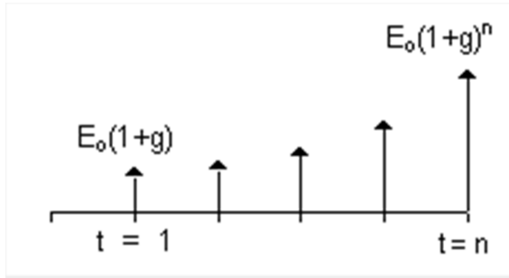
If n = 10,
NPV ≈ $810

PV's are Same!

Exponential Gradient Series Cash Flow

P|EG (EG to P) $P = EG[(z^n-1)/(z^n(z-1))], z=(1+i)/(1+g)$

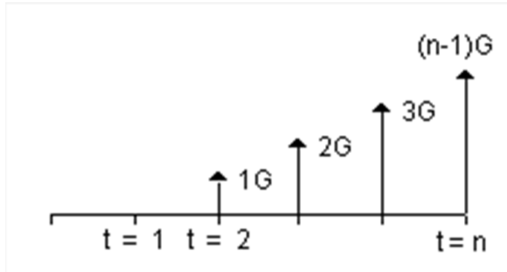




cf. Uniform Gradient Series Cash Flow

P|G (G to P)

$P = G[((1+i)^n-1)/(i^2\times(1+i)^n)-n/(i\times(1+i)^n)]$



Cool about Real Interest

- **You can ignore inflation!**
  - Make estimates in constant dollars
  - Everything is scaled to today's prices
  - Is more accurate: inflation varies, but real returns more stable

    *Real return: Real interest provides increase in money in the future after taking account of inflation increase

    e.g., $100 O&M costs: In 2030, actually pay $100+α

Exercise (1)

The SH 230 highway project east of Austin was awarded based on a life cycle cost analysis. Proposals were made by two consortiums; Lonestar and Four Rivers. **Lonestar** proposed to build the four lane divided highway east of Austin using **continuously reinforced concrete pavement** for a ***construction cost of $226,666,000/year for six years***, and for ***a maintenance cost of $4,300,000/year for the following 29 years***. **Four Rivers** proposed to build the highway using **asphalt concrete pavement for** ***$262,000,000/year for five years*** and for ***a maintenance cost of $10,600,000/year for the following 30 years***. TxDOT added ***a cost of $1,733,000/year in the last 15 years*** onto the **Four Rivers** proposal for a more realistic estimate that included milling and overlay expenses. At a **6% interest**, which proposal should TxDOT have chosen? Use NPV analysis and a **35 year analysis period**.

Exercise (1)

- **Lonestar**

Exercise (1)

- **Four River**

Exercise (2)

Apartment HVAC System Renovation?

Current Window-based System VS New Centralized System

System LCC = Initial Cost + Maintenance Cost + Replacement Cost + Residual Values + Energy Cost

Cost	Window-Unit Systems	Centralized Systems
Initial cost	-	$22,771
Maintenance cost	$90 per year	$90 per year
Window unit replacement cost	$1,300	-
Baseboard heater replacement cost	$130	-
Residual values	$138	-
Energy cost	$859 per year	$531 per year

***Analysis period: 30 years | Constant value analysis | Discount rate: 4%**

Window unit replacement: 4^{th}, 13^{th}, 22^{nd} year

Based board heater replacement: 6^{th}, 18^{th} year

Exercise (2)

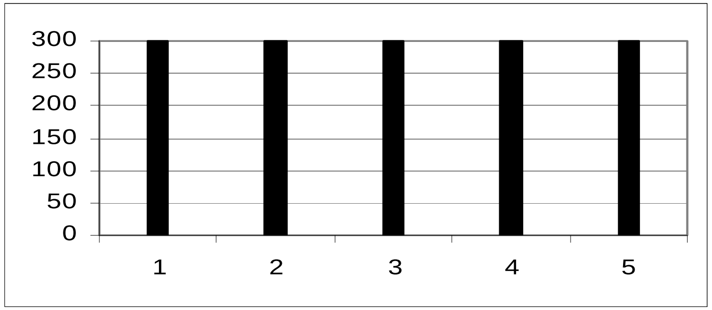
Current Window-based System

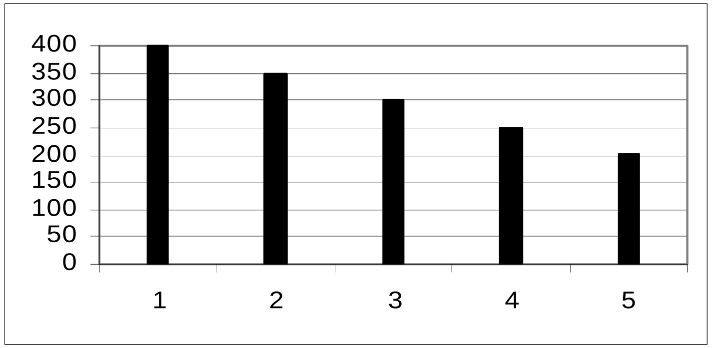
Exercise (2)

New Centralized System

Useful Lives = Analysis Period

Ex. 5.1: Consider 2 options costing $1000 each, but savings from the first will be $300 per year ending at 5 years, while the savings from the second start at $400 and decline $50 per year, ending at 5 years. At 7% interest, which would you recommend?





Analysis period: Assume 5 years

PW of A = -1000 + 300(P/A,7%,5)

= -1000 + 300 (4.100) = $230

PW of B = -1000 + 400(P/A,7%,5) – 50(P/G,7%,5)

= -1000 + 400(4.100) – 50(7.647) = $258

Alternative B has a higher Present Worth.

Comparing Alternatives

Ex. 5.8: You can buy some land for \$50k. You have 3 choices:

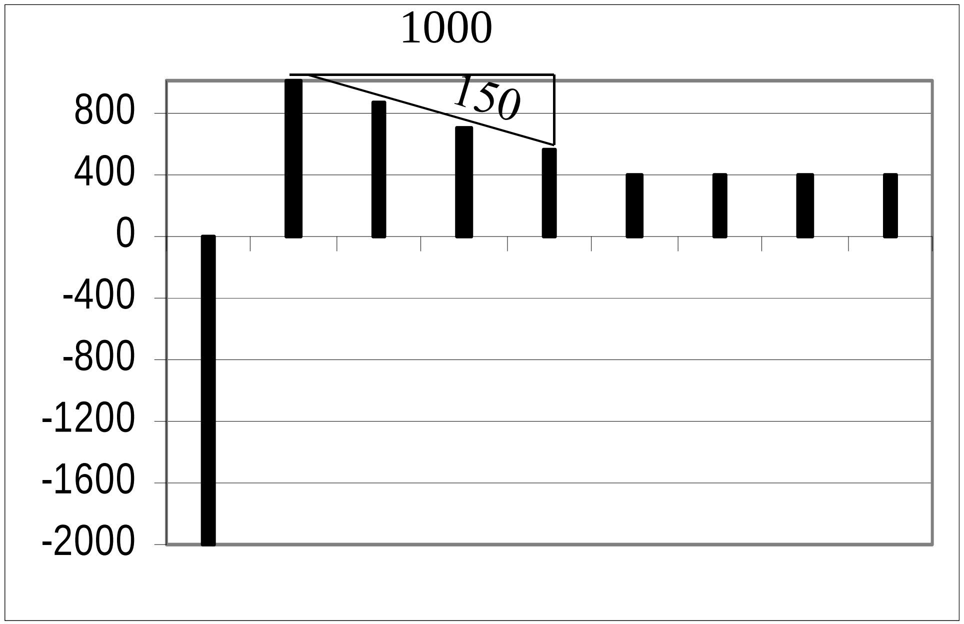
1. **Operate a market to earn \$5,100 p.a. Sell for \$30k in 20 yrs.**
2. **Build a gas station for \$45k. It will earn \$10,500 p.a., and will sell for \$30k in 20 yrs.**
3. **Build a motel for \$300k. It will earn \$36k p.a, and will sell for \$150k in 20 yrs.**

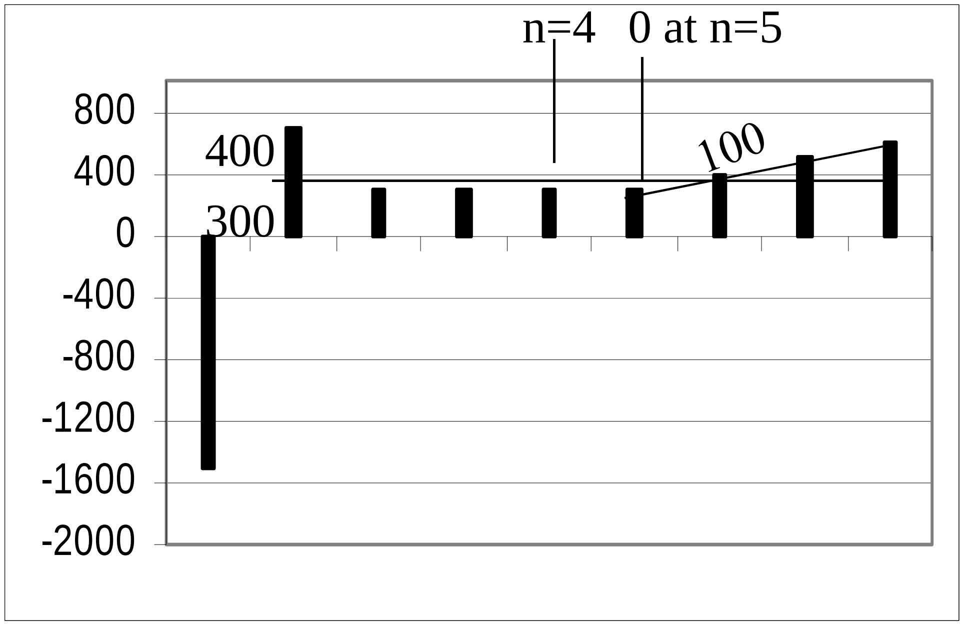
Which alternative would you choose at 10% interest?

PW of Alt 1 = -50k + 5100(P/A,10%,20) +30k(P/F,10%,20)
= -50k + 5100(8.514) + 30k(0.1486) = -\$2120
PW of Alt 2 = -95k + 10.5k(8.514) + 30k(0.1486) = -\$1140
PW of Alt 3 = -350k + 36k(8.514) + 150k(0.14)86 = -\$21,210

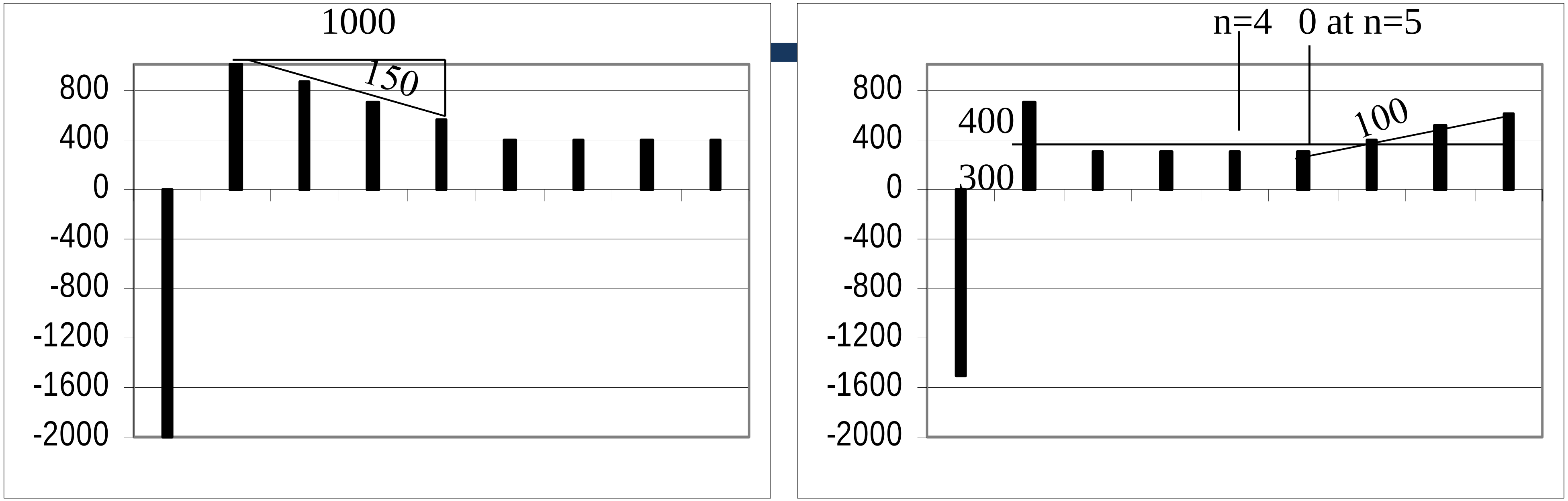
Alternatives with Complex Cash Flows

Ex. 5.10: Machine A costs $2000, income starts at $1000 in Year 1, declines $150 per yr, and settles at $400 per yr for Years 5-8. Machine B costs $1500, income is $700 in yr 1, then $300 in Years 2-5, then grows by $100 per yr to end at $600 in Year 8. Which is preferable at 8%?





Comparing Two Alternatives (cont'd)



PW of A = - 2000 + 400(P/A,8%,8)

+ 600(P/A,8%,4) – 150 (P/G,8%,4)

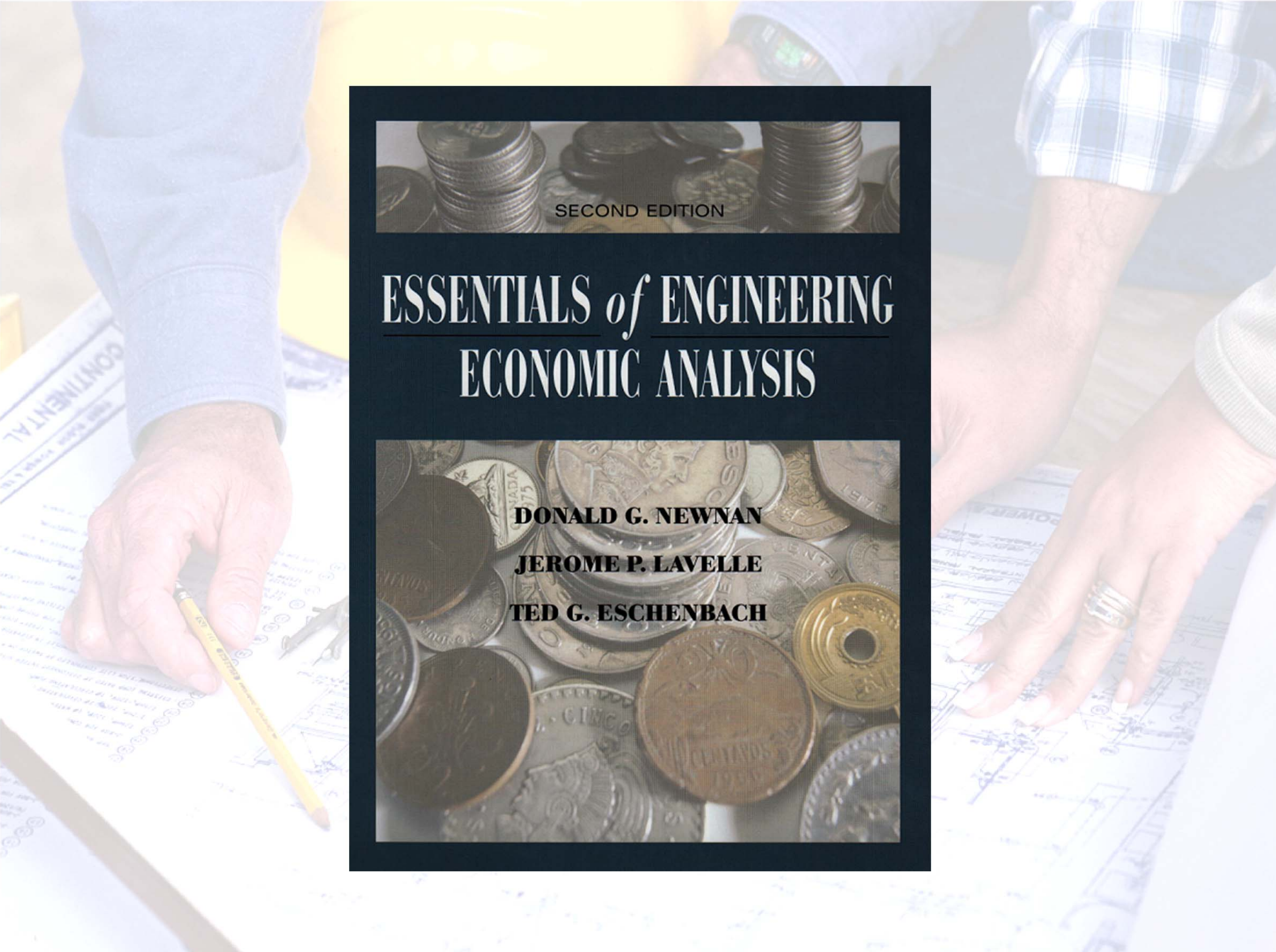
= - 2000 + 400(5.747) + 600(3.312) – 150(4.650) = $1589

PW of B = - 1500 + 400(P/F,8%,1) + 300(P/A,8%,8)

+100(P/G,8%,4)(P/F,8%,4)

= - 1500 + 400(0.9259) + 300(5.747) + 100(4.650)(0.7350) = $936

Machine A has greater Present Worth.


SECOND EDITION
ESSENTIALS of ENGINEERING
ECONOMIC ANALYSIS
DONALD G. NEWNAN
JEROME P. LAVELLE
TED G. ESCHENBACH

Uncertainty Assessment

- **Future predictions are uncertain by nature**
  - Interest rates, costs, timing of replacements, etc.
- **Need to make an assessment of how variation in costs makes a difference to NPV**
  - In general, the further out in time, the less important something is (discounting at work)
  - Most important assessment is uncertainty in costs in near term and annual costs
  - Change in NPV due to variation in interest rates also important

Uncertainty Assessment

- **Sensitivity Analysis:**
  - Vary key costs, re-compute NPV
    - Generally "High-Expected-Low" is good to get a range
    - Vary costs one at a time to build picture of most influential
    - Cost that have great influence on NPV bear further study to increase certainty

Uncertainty Assessment

- **Breakeven analysis:**
  - Compute min/max values
    - Minimum value of a savings for project to breakeven
    - Maximum value of initial investment for project to breakeven
  - Useful to determine at what threshold value(s) project becomes uneconomic
    - Compare min/max to expectations about costs

Assess Non-Monetary Value

- **Some costs/benefits cannot easily be quantified**
  - Value of a quieter HVAC system
  - Value of north facing windows with a view
- **These should be identified and presented to decision makers along with cost assessment**
  - e.g., energy efficient HVAC has LCC savings of $235,000, but is significantly noisier (>3db)

Assess Non-Monetary Value

- **Generally, multiple considerations attach to multiple alternatives**

Ambient temp
Acoustic privacy
Lighting
View

↔

Base (do nothing)
Alternative 1
Alternative 2

- **Difficult to make a fair, collective comparison**
- **Several structured, matrix approaches exist to help rank, value non-monetary considerations**
  - Attach benefit value and importance for each consideration to each alternative
  - Make a weighted comparison

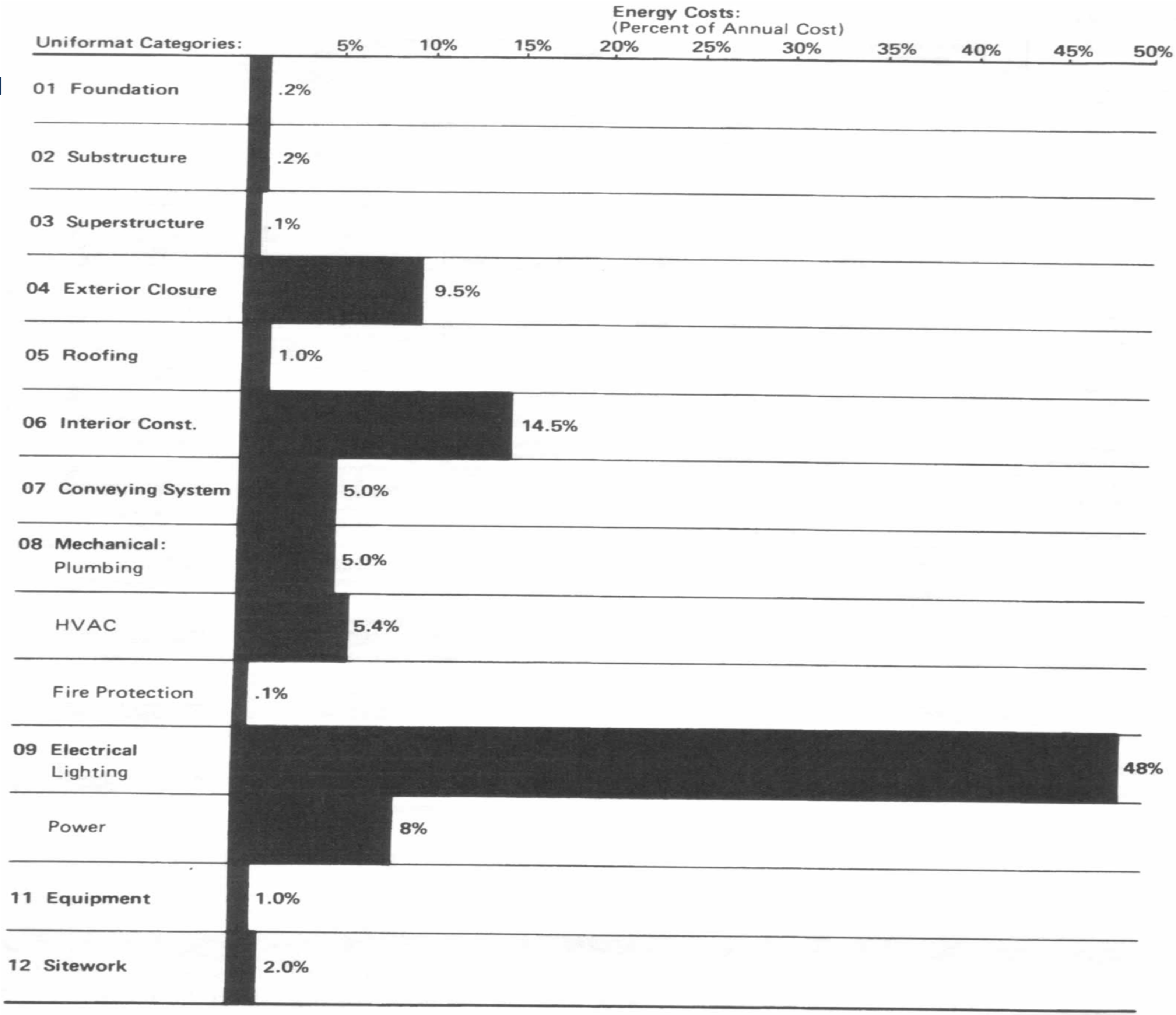
Make Recommendations

- **Present**
  - Alternatives
  - LCC of each alternative with non-monetary benefits/costs
  - Ranking of independent projects (SIRs) (as needed by decision)
- **Make a recommendation**
  - Alternative 2 costs $10k more than Alternative 1 but saves $25k over the base (do-nothing) scenario. Alternative 2 provides a better working environment than Alternative 1 and the base scenario (non-monetary benefits), which we believe outweighs the $10k difference in cost.

Energy Prices

- **Energy savings are a key area of LCC practice**
  - Annual savings/expenditures
  - Energy costs can be large share of operating costs
    - 15% of total lifecycle cost, higher portion of operating costs
- **Lighting/electrical, HVAC, & water most common replacements and upgrades**
  - Direct users of energy (e.g., air handling units)
  - Indirect energy wasters (e.g., windows)

Building Energy Costs



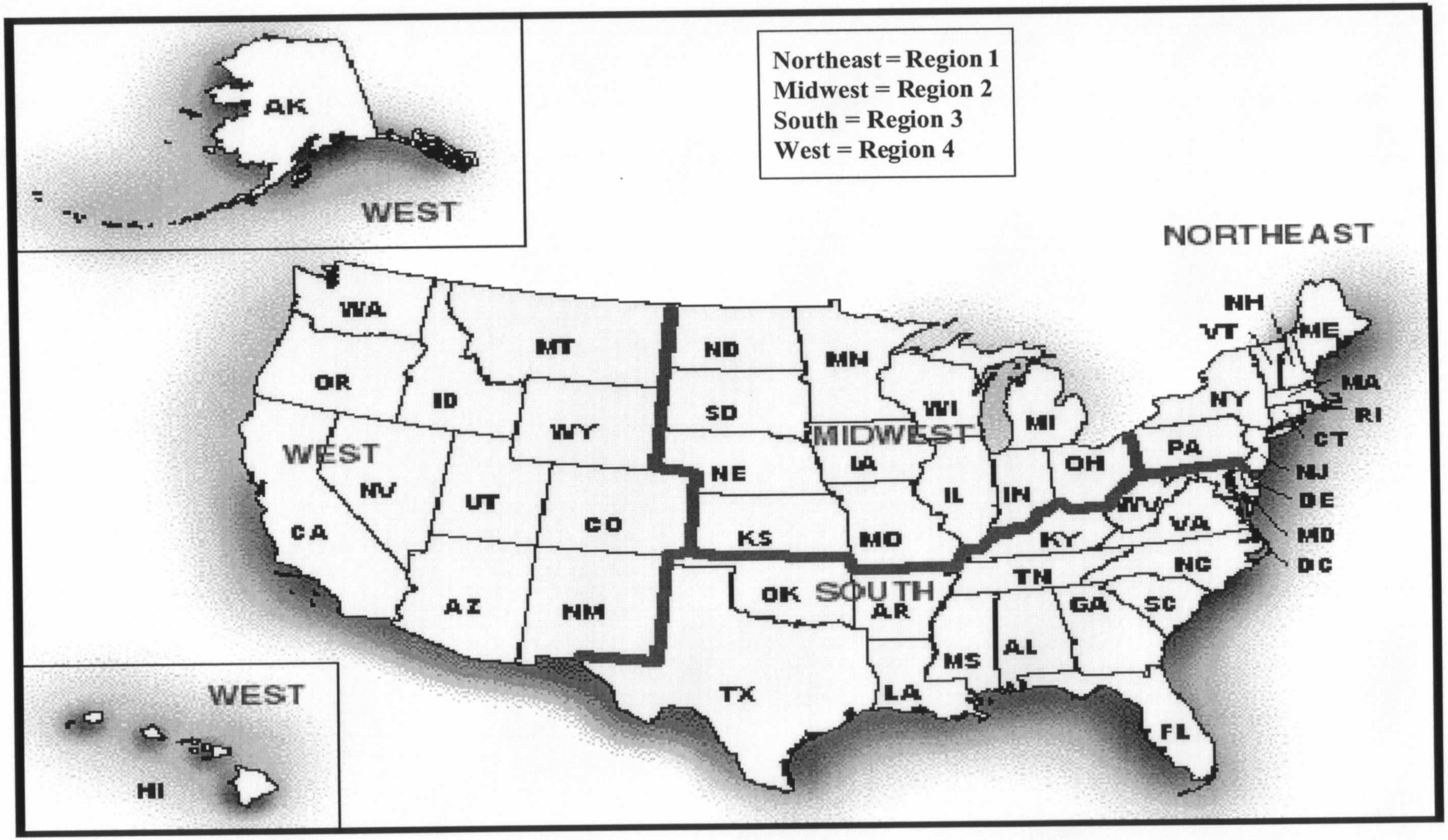
Energy Price Changes

- **Energy costs may have changes in real rates aside from inflation**
  - Contradicts constant dollar assumptions
- **Accounting for energy price changes**
  - Use current dollar valuations
  - Use a discount factor

Energy Price Indices/Factors

- **US Government publishes energy price indices and discount factor tables**
  - NISTIR 85-3273 (DOE rates)
  - Lookup FEMP UPV* factor
    - Federal Energy Management Program Uniform Present Value Factor
  - Multiply FEMP UPV* by present annual expenditure rate to get discounted NPV (this NPV includes real price adjustments)
  - FEMP UPV* determined by:
    - Region, fuel type, rate type, discount rate, study period

DOE Energy Regions



FEMP UPV* Example

- **$20,000/yr annual energy cost**
  - Get costs from current data, utilities, manufacturers…
- **Data for analysis using Table**
  - Federal commercial office building
  - 20 year span
  - Natural gas
  - Connecticut building: Region=1
  - Discount: std DOE value
  - **FEMP UPV* = 17.09**
- **NPV = $20,000 × 17.09 = $341,800**

FEMP UPV* Table

Table Ba-1. FEMP UPV* Discount Factors adjusted for fuel price escalation, by end-use sector and fuel type.

Discount rate = 3.0 % (DOE)

Census Region 1 (Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont)

	RESIDENTIAL				COMMERCIAL					INDUSTRIAL					TRANSPORT	
N	Elec	Dist	LPG	NtGas	Elec	Dist	Resid	NtGas	Coal	Elec	Dist	Resid	NtGas	Coal	Gasln	N
1	0.91	0.97	0.96	1.01	0.87	0.98	0.97	1.04	0.95	0.83	1.00	0.98	1.12	0.96	1.01	1
2	1.83	1.96	1.92	2.03	1.74	1.99	2.01	2.10	1.88	1.65	2.03	2.02	2.32	1.89	2.04	2
3	2.76	2.98	2.90	2.99	2.60	3.03	3.14	3.14	2.77	2.48	3.09	3.14	3.49	2.78	3.11	3
4	3.66	4.00	3.87	3.92	3.42	4.09	4.31	4.12	3.64	3.25	4.18	4.30	4.61	3.65	4.20	4
5	4.53	5.02	4.85	4.82	4.21	5.15	5.50	5.09	4.48	4.00	5.27	5.47	5.70	4.49	5.28	5
6	5.38	6.05	5.81	5.69	4.99	6.23	6.70	6.02	5.30	4.74	6.37	6.65	6.75	5.29	6.36	6
7	6.22	7.09	6.76	6.54	5.76	7.31	7.90	6.93	6.08	5.47	7.48	7.84	7.78	6.08	7.42	7
8	7.04	8.12	7.70	7.37	6.52	8.39	9.12	7.81	6.84	6.18	8.59	9.03	8.77	6.84	8.47	8
9	7.83	9.14	8.62	8.18	7.25	9.47	10.35	8.68	7.57	6.88	9.69	10.23	9.74	7.57	9.51	9
10	8.60	10.15	9.52	8.97	7.97	10.53	11.57	9.52	8.28	7.56	10.78	11.42	10.69	8.28	10.53	10
11	9.35	11.14	10.40	9.74	8.68	11.57	12.77	10.34	8.96	8.23	11.85	12.59	11.62	8.96	11.53	11
12	10.09	12.11	11.26	10.50	9.37	12.60	13.95	11.15	9.62	8.89	12.91	13.74	12.54	9.63	12.51	12
13	10.81	13.06	12.10	11.25	10.05	13.60	15.11	11.95	10.27	9.54	13.94	14.87	13.44	10.28	13.48	13
14	11.51	13.98	12.93	11.97	10.72	14.58	16.25	12.73	10.90	10.18	14.95	15.99	14.32	10.91	14.42	14
15	12.19	14.90	13.73	12.68	11.37	15.55	17.38	13.48	11.51	10.80	15.94	17.09	15.18	11.51	15.34	15
16	12.85	15.79	14.52	13.37	11.99	16.50	18.48	14.22	12.10	11.41	16.91	18.16	16.03	12.11	16.24	16
17	13.49	16.67	15.29	14.05	12.61	17.43	19.56	14.95	12.68	12.00	17.87	19.21	16.86	12.68	17.13	17
18	14.12	17.53	16.04	14.72	13.21	18.34	20.62	15.67	13.24	12.59	18.80	20.24	17.69	13.24	18.00	18
19	14.74	18.37	16.78	15.38	13.81	19.24	21.67	16.38	13.78	13.17	19.73	21.25	18.51	13.79	18.85	19
20	15.34	19.20	17.50	16.04	14.40	20.12	22.69	17.09	14.32	13.75	20.63	22.25	19.33	14.32	19.69	20
21	15.94	20.02	18.20	16.69	14.98	20.99	23.71	17.79	14.84	14.32	21.53	23.24	20.16	14.83	20.51	21
22	16.52	20.82	18.89	17.33	15.56	21.85	24.72	18.48	15.34	14.89	22.41	24.21	20.97	15.34	21.31	22
23	17.09	21.62	19.57	17.96	16.13	22.70	25.70	19.16	15.83	15.44	23.27	25.16	21.77	15.82	22.10	23
24	17.64	22.40	20.24	18.57	16.68	23.53	26.67	19.82	16.31	15.99	24.13	26.11	22.56	16.30	22.88	24
25	18.19	23.16	20.89	19.17	17.22	24.35	27.62	20.48	16.78	16.53	24.97	27.03	23.33	16.77	23.64	25
26	18.72	23.92	21.53	19.76	17.76	25.16	28.56	21.11	17.23	17.05	25.80	27.94	24.09	17.22	24.39	26
27	19.23	24.66	22.16	20.34	18.28	25.96	29.49	21.74	17.67	17.57	26.61	28.84	24.84	17.66	25.13	27
28	19.74	25.39	22.77	20.91	18.78	26.74	30.41	22.36	18.11	18.07	27.41	29.72	25.58	18.09	25.85	28
29	20.23	26.10	23.37	21.47	19.28	27.50	31.32	22.97	18.52	18.56	28.20	30.60	26.31	18.50	26.55	29
30	20.71	26.80	23.96	22.01	19.76	28.26	32.21	23.56	18.93	19.04	28.97	31.46	27.03	18.91	27.25	30

LCC: Optimal Efficiency Level

- **Definition: Most cost effective *Performance Level* for a facility**
  - Differs from other LCC analysis
    - Not LCC for alternative with potentially different performance
    - Rather, least costly parameter for a given level of performance
  - Examples (energy efficiency):
    - Level of insulation in roof and walls (R-values)
    - Efficiency of a furnace
    - Collector area for a solar heating system

**R-value: Measure of thermal resistance (insulation)*

Calculating Efficiency Level

- **General assumption: increasing efficiency increases initial investment**
  - If not, no tradeoffs
- **Steps:**
  - Define parameters and range of possible alternatives
  - Estimate energy usage (or relevant parameter) for each alternative
  - Calculate LCC for each alternative
  - Select lowest LCC
  - Interpolate as needed

Efficiency Example

- **Find R-Value on House Attic Insulation**
  - Service date: Jan 13
  - Life: 25 yrs
  - Replacement schedule: N/A
  - Residual value: None
  - Electricity price: $0.08/kWh
  - Location: Ohio (DOE Region 2)
  - Rate type: Residential
  - **FEMP UPV* = 17.57**

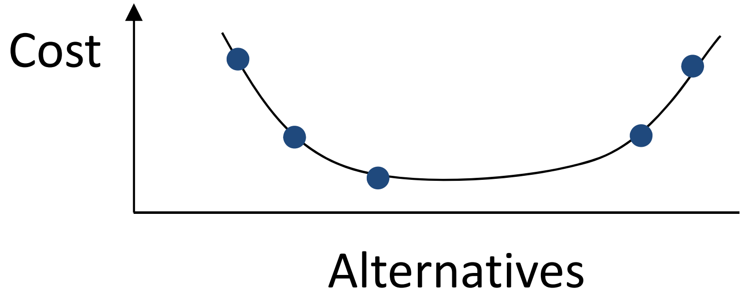
Efficiency Example

Table Ba-2. FEMP UPV* Discount Factors adjusted for fuel price escalation, by end-use sector and fuel type.

Discount Rate = 3.0 % (DOE)

Census Region 2 (Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota,
Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin)

	RESIDENTIAL				COMMERCIAL					INDUSTRIAL					TRANSPORT	
N	Elec	Dist	LPG	NtGas	Elec	Dist	Resid	NtGas	Coal	Elec	Dist	Resid	NtGas	Coal	Gasln	N
1	0.93	0.95	0.97	1.02	0.91	0.97	1.06	1.05	0.98	0.87	0.98	1.08	1.17	0.96	1.00	1
2	1.84	1.93	1.95	2.03	1.79	1.96	2.15	2.12	1.94	1.70	2.00	2.17	2.42	1.90	2.02	2
3	2.74	2.93	2.96	3.00	2.64	3.00	3.26	3.17	2.87	2.51	3.06	3.30	3.65	2.81	3.08	3
4	3.62	3.95	3.98	3.92	3.48	4.05	4.40	4.17	3.78	3.29	4.13	4.46	4.84	3.70	4.18	4
5	4.48	4.96	4.99	4.82	4.29	5.10	5.53	5.16	4.66	4.04	5.21	5.60	6.00	4.58	5.26	5
6	5.32	5.99	6.01	5.71	5.09	6.18	6.66	6.12	5.52	4.79	6.31	6.75	7.15	5.44	6.33	6
7	6.14	7.03	7.02	6.57	5.87	7.26	7.78	7.07	6.36	5.52	7.41	7.88	8.26	6.28	7.39	7
8	6.93	8.07	8.01	7.42	6.62	8.34	8.89	7.98	7.16	6.23	8.51	9.01	9.35	7.09	8.44	8
9	7.70	9.09	9.00	8.24	7.36	9.42	9.98	8.88	7.94	6.92	9.61	10.12	10.41	7.88	9.48	9
10	8.45	10.11	9.96	9.05	8.08	10.48	11.04	9.76	8.69	7.60	10.69	11.19	11.45	8.64	10.49	10
11	9.18	11.10	10.90	9.84	8.79	11.52	12.09	10.62	9.41	8.26	11.75	12.25	12.47	9.38	11.49	11
12	9.89	12.08	11.83	10.62	9.48	12.55	13.11	11.48	10.11	8.91	12.80	13.29	13.49	10.09	12.47	12
13	10.58	13.03	12.73	11.39	10.16	13.55	14.11	12.31	10.79	9.55	13.82	14.31	14.48	10.78	13.43	13
14	11.26	13.97	13.62	12.13	10.82	14.54	15.09	13.12	11.45	10.17	14.82	15.31	15.43	11.44	14.37	14
15	11.91	14.89	14.49	12.85	11.47	15.50	16.06	13.91	12.09	10.78	15.80	16.29	16.36	12.09	15.29	15
16	12.55	15.79	15.34	13.56	12.10	16.45	17.00	14.68	12.71	11.38	16.77	17.24	17.28	12.72	16.19	16
17	13.16	16.68	16.17	14.26	12.71	17.38	17.92	15.44	13.31	11.95	17.71	18.18	18.19	13.32	17.08	17
18	13.76	17.55	16.98	14.95	13.31	18.30	18.82	16.20	13.89	12.52	18.64	19.09	19.09	13.92	17.95	18
19	14.34	18.40	17.78	15.64	13.89	19.20	19.71	16.95	14.46	13.08	19.56	19.99	20.00	14.50	18.81	19
20	14.92	19.24	18.57	16.32	14.47	20.09	20.58	17.70	15.02	13.62	20.46	20.88	20.90	15.06	19.64	20
21	15.47	20.07	19.34	17.00	15.03	20.96	21.45	18.45	15.56	14.16	21.35	21.76	21.81	15.61	20.46	21
22	16.02	20.89	20.09	17.67	15.58	21.82	22.29	19.19	16.08	14.69	22.22	22.62	22.71	16.14	21.27	22
23	16.55	21.69	20.83	18.33	16.12	22.67	23.13	19.91	16.59	15.21	23.08	23.47	23.59	16.66	22.06	23
24	17.07	22.48	21.56	18.98	16.65	23.51	23.95	20.62	17.09	15.72	23.93	24.30	24.46	17.17	22.84	24
25	17.57	23.26	22.28	19.61	17.16	24.34	24.76	21.32	17.58	16.22	24.77	25.13	25.32	17.66	23.60	25
26	18.07	24.03	22.99	20.24	17.67	25.15	25.55	22.01	18.05	16.71	25.60	25.93	26.17	18.15	24.36	26
27	18.55	24.78	23.68	20.85	18.16	25.95	26.34	22.69	18.52	17.19	26.41	26.73	27.01	18.62	25.09	27
28	19.02	25.52	24.35	21.45	18.65	26.74	27.11	23.36	18.96	17.66	27.21	27.52	27.83	19.07	25.82	28
29	19.47	26.25	25.02	22.05	19.12	27.51	27.87	24.01	19.40	18.12	27.99	28.29	28.65	19.52	26.53	29
30	19.92	26.97	25.67	22.63	19.59	28.27	28.62	24.66	19.83	18.57	28.76	29.05	29.46	19.96	27.22	30



Efficiency Example

R-value	(1) Initial Cost	(2) Annual kWh	(3) Annual Energy Cost (2)×$0.08/kWh	(4) NPV Energy Cost (3)×17.57	(5) LCC (1)+(4)	(6) Net Savings $13,497-x
R-0	$0	9,602	768	$13,497	$13,497	$0
R-11	300	7,455	596	10,479	10,779	2,718
R-19	450	7,055	564	9,917	10,367	3,130
R-30	650	6,804	544	9,564	10,214	3,283
R-38	800	6,703	536	9,422	10,222	3,275
R-49	1,000	6,628	530	9,316	10,316	3,181

R-30 is best option (lowest LCC-using positive number convention)

Project Financing

- **Many projects are financed**
- **Need to include NPV of financing in LCC**
- **Why is this tricky?**
  - Value of annual payments in CURRENT, not constant dollars
  - EX: Mortgage payment of $12,000/yr, 30yr period. The payment does not grow with inflation!!!

Financing Example

- **Project Financing Data**
  - Annual O&M costs $2,000/yr
  - Loan payment: $12,000/yr
  - 30 years
  - Nominal rate: 7%
  - Real rate: 4%