Week 9

Project Cost Estimating (2)

457.657 Civil and Environmental Project Management

Department of Civil and Environmental Engineering
Seoul National University

Prof. Seokho Chi
shchi@snu.ac.kr
건설환경공학부 35동 304호

LCC Methodology - Overview

- **Major steps (1-10)**
- **Main discussion areas**
  - Types of decisions
  - Dates and Assumptions
  - Cost categories
  - NPV/LCC computation
  - Refinements
    - prioritization
    - uncertainty
    - non-monetary considerations

LCC Methodology – Major Steps

1. Define problem and state objectives
2. Identify feasible alternatives
3. Establish common assumptions and parameters
4. Estimate costs and times for each alternative
5. Project future costs to present value (NPV)
6. Compute and compare LCC for each alternative
7. Compute supplementary measures if necessary for project prioritization
8. Assess uncertainty of input data
9. Consider affects for which costs or benefits can't be estimated
10. Advise on the decision

From NIST Handbook 135

Major Steps 1 – 3

1. **Problem Description**
   – General info, type of decision, constraints
2. **Feasible Alternatives**
   – Technical description, rationale, non-monetary considerations
3. **Common Assumptions and Parameters**
   – Study period, base date, service date(s), discount rate, treatment of inflation, operational assumptions, energy and water price schedules

Types of Decisions for LCC

- **Accept/reject project**
  - Add storm windows to existing single pane windows
- **Select an optimal efficiency level for a building system**
  - Specify insulation value in an exterior wall
- **Select an optimal system from competing alternatives**
  - Select type of heating & cooling system

Types of Decisions for LCC (Cont'd)

- **Select an optimal combination of interdependent systems**
  - Specify type of lighting systems and efficiency of heating and cooling systems
  - Select building design among alternatives
- **Rank competing projects to allocate a limited budget**
  - Select among numerous energy efficiency projects

"Each of these uses similar investment criteria"

- Only complexity/range of calculations & inputs varies
- Methodology remains same (some execution differences)

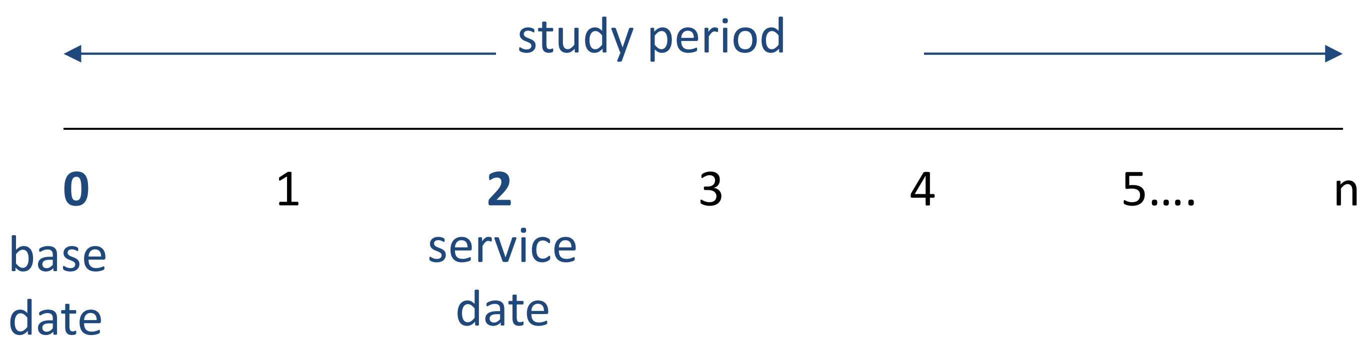
Study Period and Dates

- **LCC computes Present Value of alternatives over a period of time using discounting methods**

- **Hence, important to consider alternatives using same period of time or study.**
  - e.g., if want to compare over 10 years, need to compute costs for each alternative over a 10 year span
  - This implies alternatives with "lifespan < study" period must include replacement costs (if "lifespan > study", salvage)

Study Period and Dates (Cont'd)

- **Base date: common starting point for all alternatives**
  - Must be the same date for each alternative!!!!
  - Must project all cash flows to base date
- **Service date: time that construction is expected to be completed/start operation (occupancy date)**
  - Generally assume service date is same across alternatives



Discount Rates and Inflation

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

**Real interest rate 4%: inflation이 있어도 4%의 이자*

- **Cash flows**
  - Constant dollars: No inflation, dollars expected to be same as base date (time=0, thinking from Present)

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

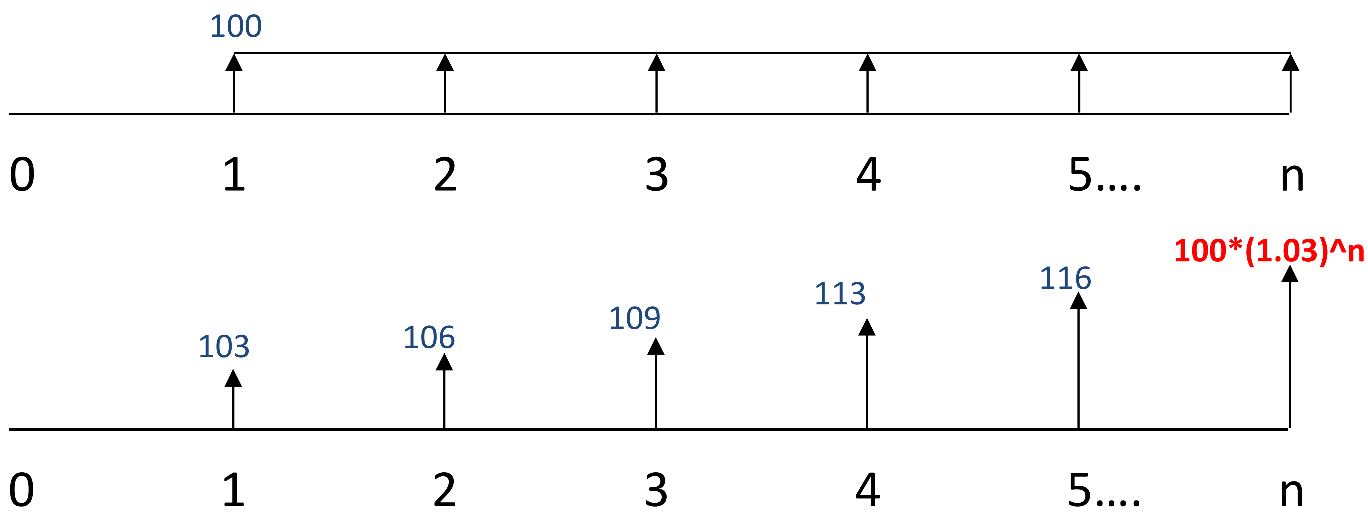
    e.g., \$1,000 home mortgage: In 2030, actually still pay \$1,000

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

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

PV's are Same!



constant,
real = 4%
If n = 10,
NPV ≈ $810

current,
nominal ≈ 7%
If n = 10,
NPV ≈ $810

Discount Rates and Inflation (Cont'd)

- **Federal Government has standard tables for accepted discount factors and inflation**
- **Discount rates for capital projects**
  - OMB Circular A-94
    - Includes nominal and real rates
- **Expected inflation rates for energy costs**
  - NISTIR 85-3273 (DOE energy indices/discount factors)
    - Includes regional adjustments

LCC Methodology – Major Steps

1. Define problem and state objectives
2. Identify feasible alternatives
3. Establish common assumptions and parameters
4. **Estimate costs and times for each alternative**
5. Project future costs to present value (NPV)
6. Compute and compare LCC for each alternative
7. Compute supplementary measures if necessary for project prioritization
8. Assess uncertainty of input data
9. Consider affects for which costs or benefits can't be estimated
10. Advise on the decision

From NIST Handbook 135

Step 4 – Estimate Cost and Time

- **Construction**
  - Estimates
- **Finance**
  - Need to include time value of payment flows if project is financed
- **O&M**
  - Annual O&M costs
  - History for current equipment
  - Special calculations for equipment to be replaced
  - Energy costs indices

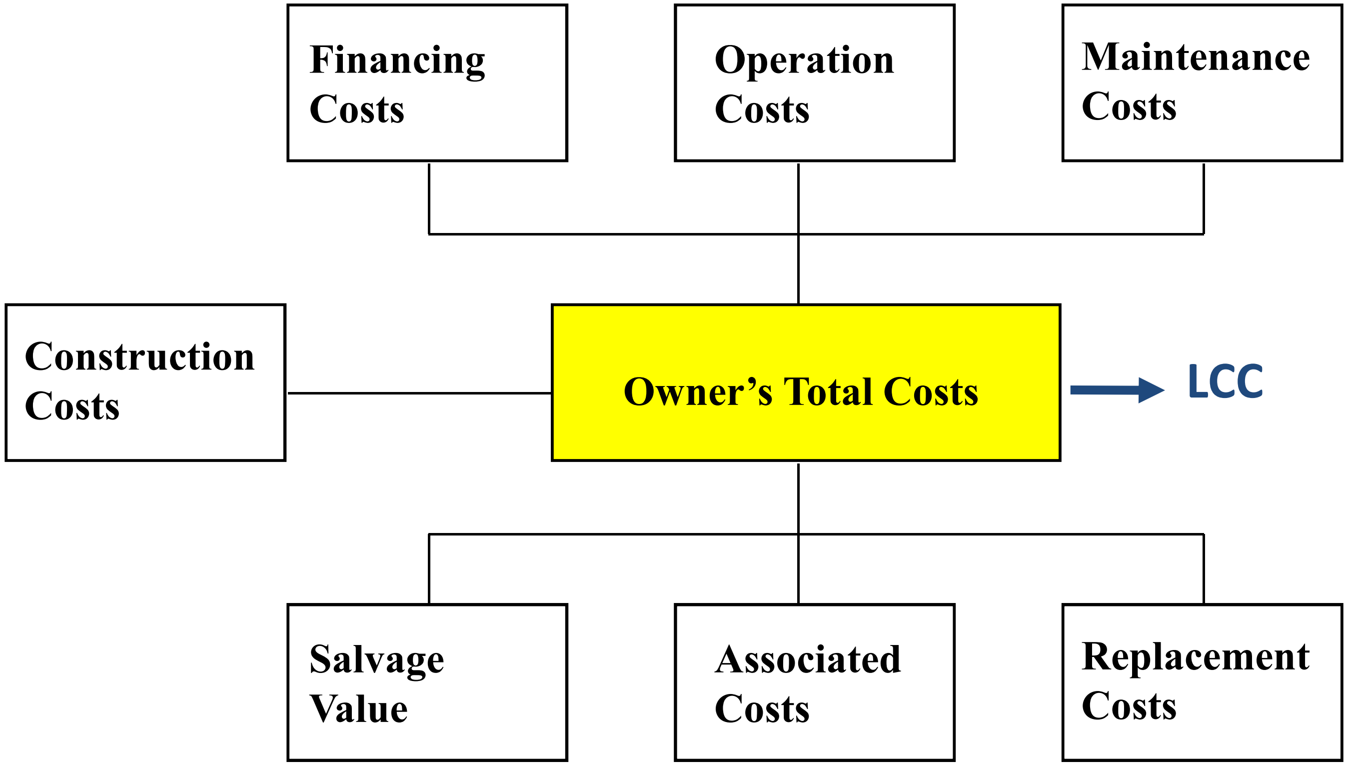
Step 4 – Estimate Cost and Time

- **Salvage value**
  - If end of life, what is disposition value: projected sale value or disposal expense
  - If life remains at end of study period, must compute residual value
    - Accepted rule: linearly pro-rate initial cost across lifespan

      Ex: \$500k initial cost, 50yr lifespan, residual=\$10k/yr

      If 30yr study period, residual value = \$10k/yr × (50-30yrs) = \$200k (note: this is constant dollars)

Step 4 – Estimate Cost and Time



1. All categories can be taken into consideration
2. Scope of decision can limit which categories are relevant (e.g., replace HVAC vs new building)

Typical life-cycle costs per GSF

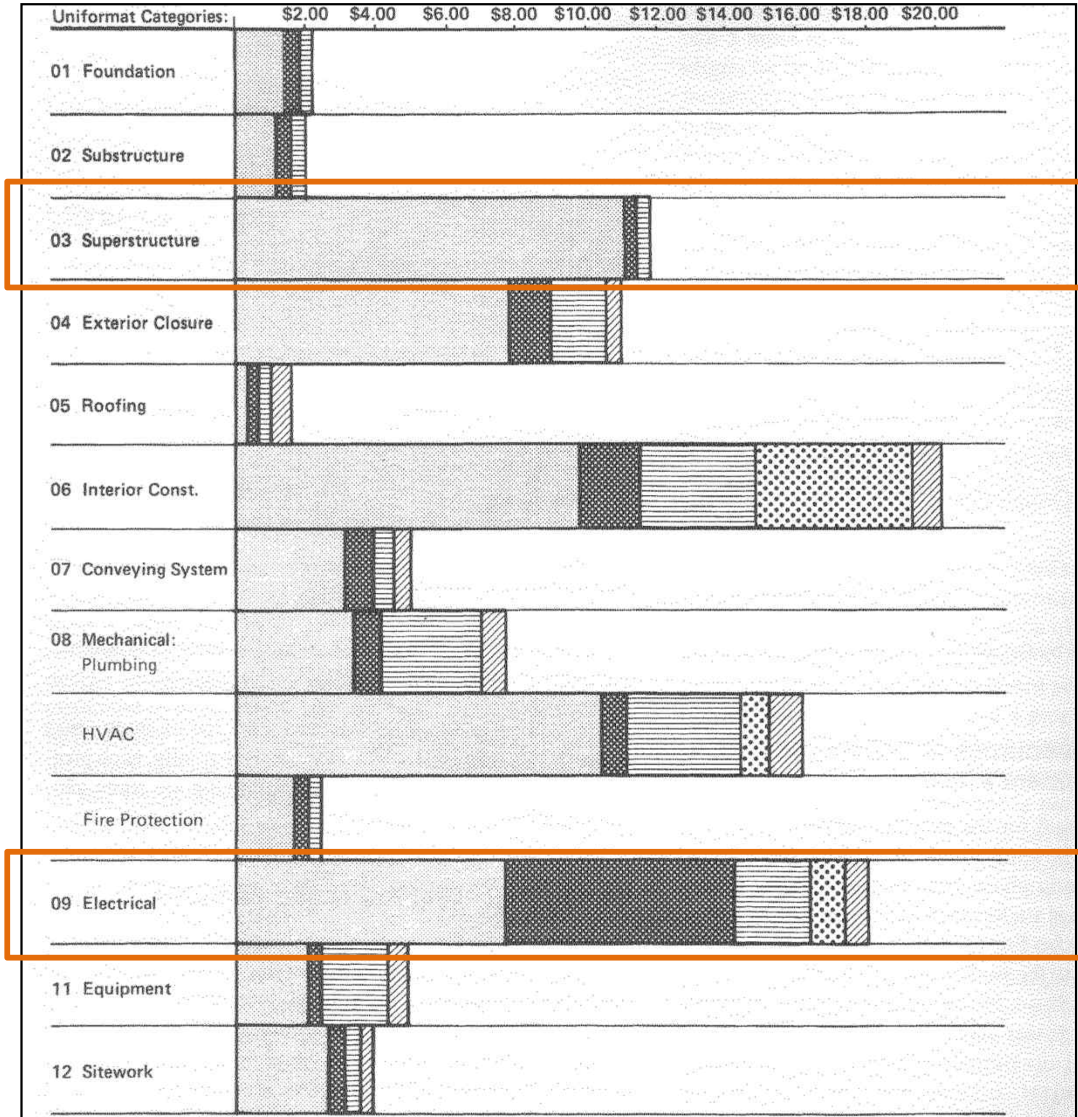
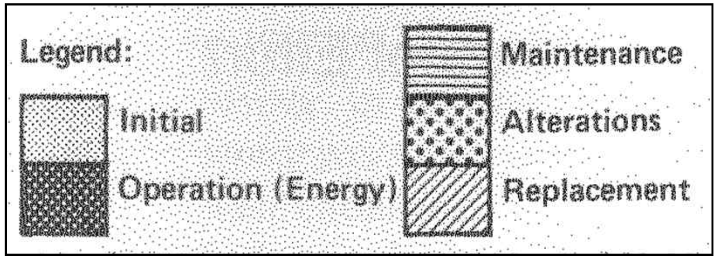


Figure 9-2

Life cycle cost distribution—typical office building.

**GSF: Gross Square Feet*



Step 4 – Estimate Cost and Time

- **Capital replacement: Future value of replacements required within study period**
  - Estimated by present dollar value of replacement cost at base date
- **Other costs**
  - Revenues, one-time expenses, rebates, etc.

Life Cycle Cost Analysis
General Purpose Work Sheet

Study Title: ______________________

Discount Rate: ________ **Date:** ______________

Life Cycle (Years): ________ **Present Time:** ______________

				Alternative 1 Describe:		*Alternative 2* Describe:		*Alternative 3* Describe:		*Alternative 4* Describe:	
				Estimated Costs	*Present Worth*	*Estimated Costs*	*Present Worth*	*Estimated Costs*	*Present Worth*	*Estimated Costs*	*Present Worth*
Initial/Collateral Costs	**Initial/Collateral Costs**										
	A.										
	B.										
	C.										
	D.										
	E.										
	F.										
	Total Initial/Collateral Costs										
	Initial Cost PW Difference										
Replacement/Salvage Costs	**Replacement/Salvage** (Single Expediture)	Year	PW Factor								
	A.										
	B.										
	C.										
	D.										
	E.										
	F.										
	Total Replacement/Salvage Costs										
Annual Costs	**Annual Costs**	Diff. Escal. Rate	PWA w/Escal.								
	A.										
	B.										
	C.										
	D.										
	E.										
	F.										
	Total Annual Costs										
LCC	**Total Life Cycle Costs (Present Worth)**										
	Life Cycle Cost PW Difference										
	Discounted Payback						Years		Years		Years
	Total Life Cycle Costs (Annualized)		PP Factor		Per Year		Per Year		Per Year		Per Year

PW=Present Worth PWA=Present Worth of Annuity PP=Periodic Payment

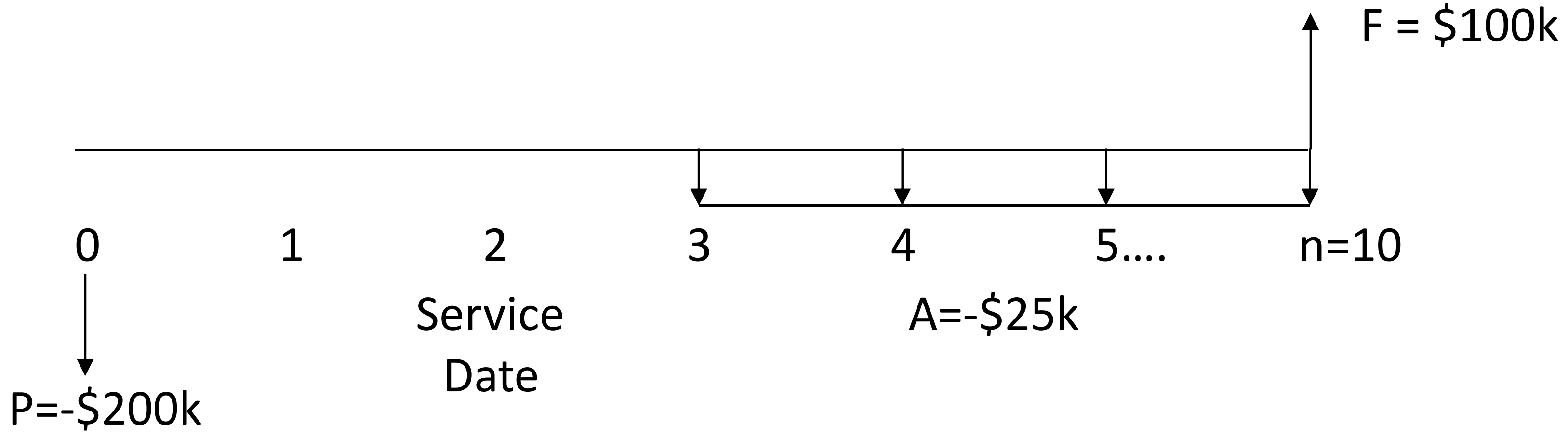
LCC Methodology – Major Steps

1. Define problem and state objectives
2. Identify feasible alternatives
3. Establish common assumptions and parameters
4. Estimate costs and times for each alternative
5. **Project future costs to present value (NPV)**
6. Compute and compare LCC for each alternative
7. Compute supplementary measures if necessary for project prioritization
8. Assess uncertainty of input data
9. Consider affects for which costs or benefits can't be estimated
10. Advise on the decision

From NIST Handbook 135

Step 5 – Compute NPV

- **Construct a cash flow diagram for each alternative**
  - Record annual costs, one-time expenses, etc.
  - Typically use constant dollars
  - Ex: pay $200k now, construction over 2 years (service date = 2), annual expenses from service date are $25k/yr, 10 year study, residual value=$100k, real rate = 5%

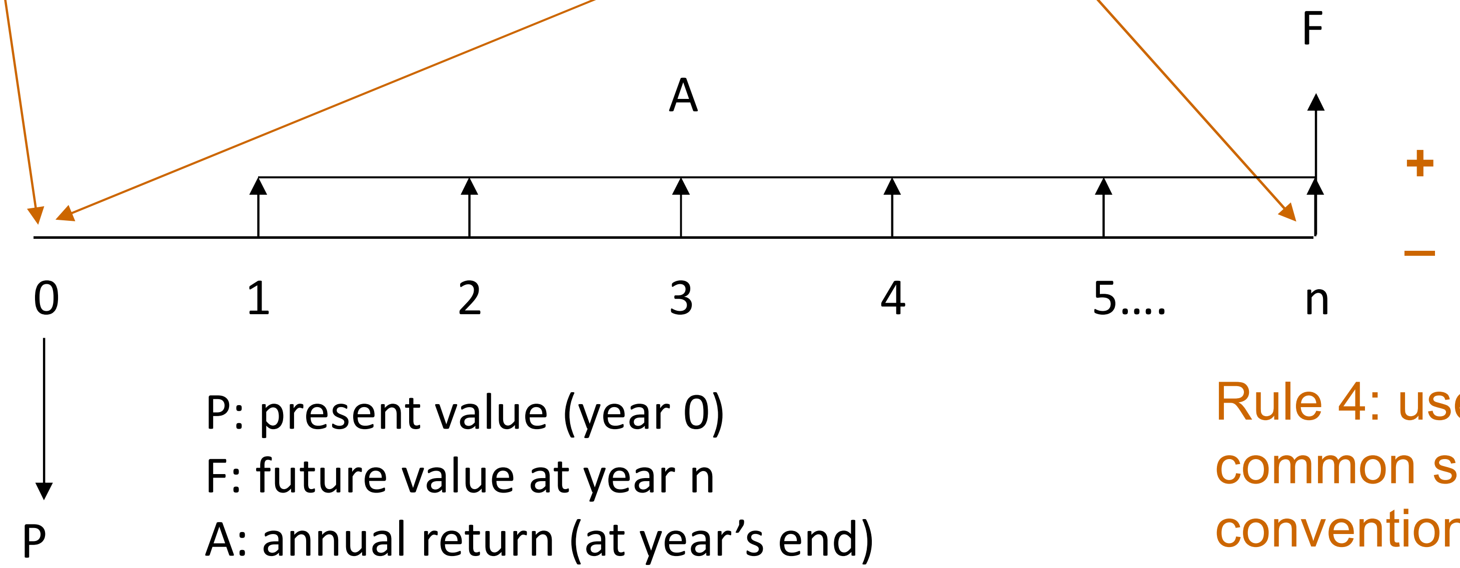


Reminder: Cash Flow Mapping

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).



Rule 4: use a common sign convention

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

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

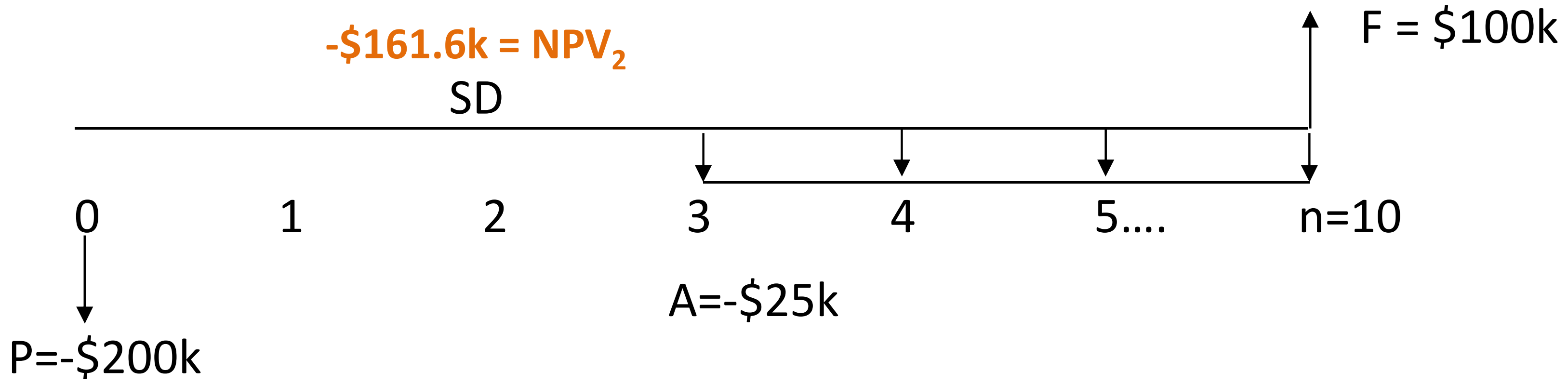
Step 5 - Computing NPV

- **Example (cont'd)**
  - Compute NPV for each aspect of cash flow
  - NPV of investment = -\$200k
  - NPV of Residual = \$100k × (P|F, n=10, i=5%) = \$61.4k
  - NPV of annual costs starting at Service date

    First, find NPV assuming Service Date is year 0:

    NPV_2 = -\$25k × (P|A, n=8, i=5%) = -\$161.6k

    Second, compute NPV of NPV_2 = -\$161.6k × (P|F, n=2, i=5) = **<u>-\$146.6k</u>**



LCC Methodology – Major Steps

6. Compute and compare LCC for each alternative
7. Compute supplementary measures if necessary for project prioritization
8. Assess uncertainty of input data
9. Consider affects for which costs or benefits can’t be estimated
10. Advise on the decision

From NIST Handbook 135

Step 6 – Compute LCC and Compare

- **From Step 5, sum NPV of individual cost elements for each alternative**
  - Sum of costs = LCC for alternative
- **For previous example:**
  - LCC = -$200k + -$146.6k + $61.4k = -$285.2k
  - Cash inflows positive
  - Cash outflows negative
  - Watch your signs and be consistent!!!!

Step 7 – Supplementary Measures

- **In general, LCC allows you to calculate the best choice among mutually exclusive alternatives for a single decision**
  - e.g., which HVAC system?
- **But what about a program of possible (independent) investments with a limited budget?**
  - Which to prioritize? How do I allocate the budget?

    Do projects having higher SIR (Savings/Investment ratio)

Step 8 – 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

Step 8 – 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

Step 8 – 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

Step 9 – 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)

Step 9 – 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

Step 10 – 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.

In Class Exercise

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**.

In Class Exercise

- Lonestar

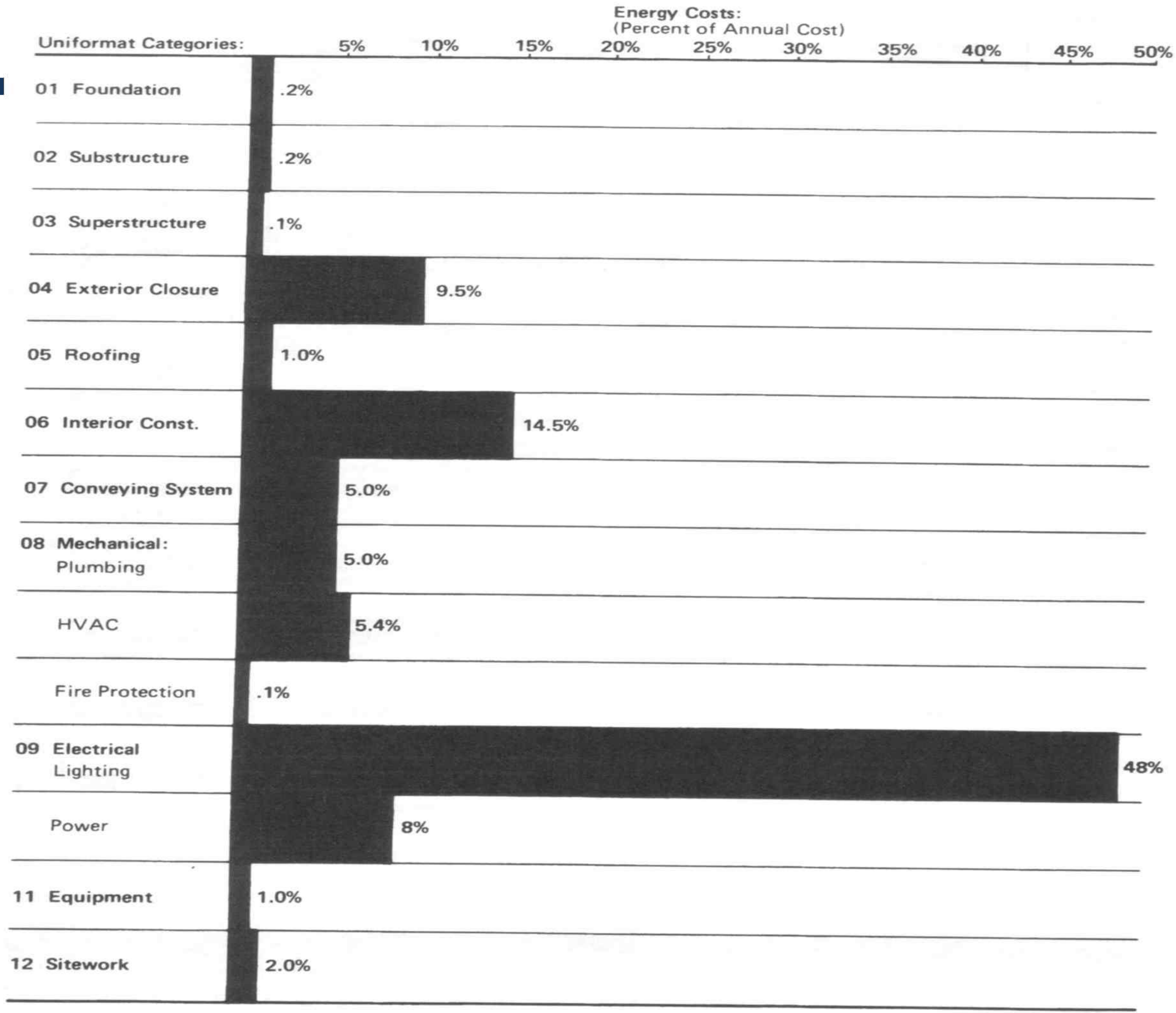
In Class Exercise

- **Four River**

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

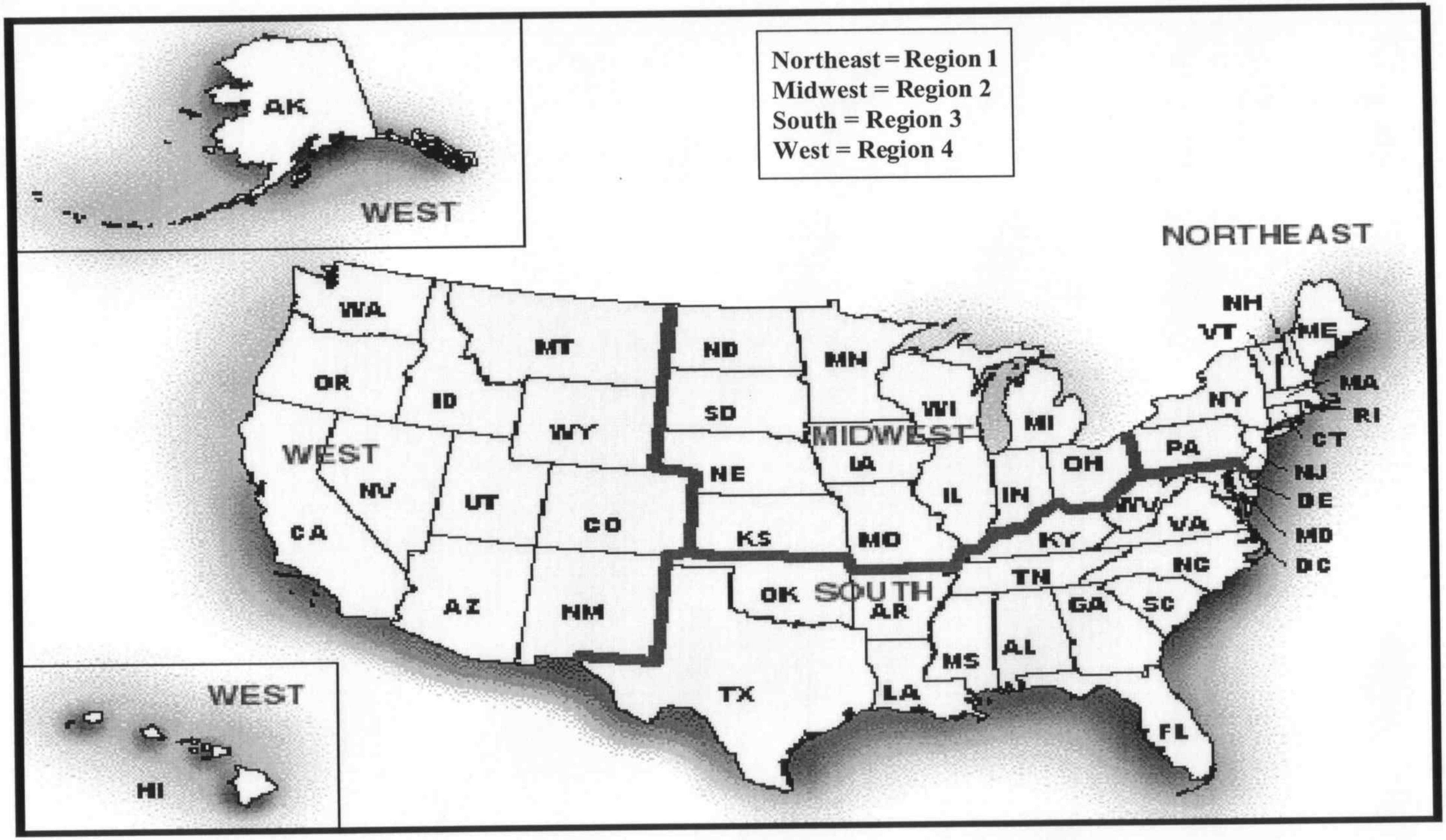
- **Energy costs may have changes in real rates aside from inflation**
  - Contradicts constant dollar assumptions

- **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

Note: **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

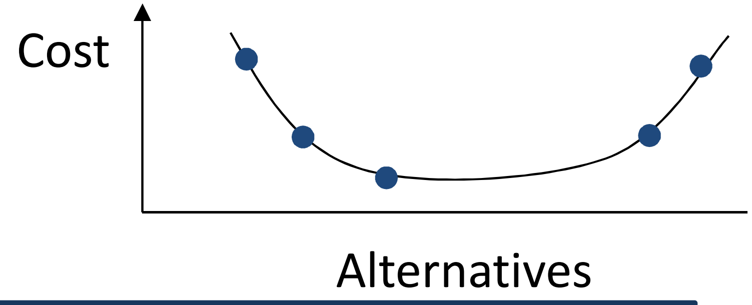
Table Ba-2. FEMP UPV* Discount Factors adjusted for fuel price escalation, by end-use sector and fuel type.

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**
  - Bonds, mortgages, etc.
- **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!!!

Reminder: Discount Rates and Inflation

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

**Real interest rate 4%: inflation이 있어도 4%의 이자*

- **Cash flows**
  - Constant dollars: No inflation, dollars expected to be same as base date (time=0, thinking from Present)

    e.g., \$100 O&M costs: In 2030, actually pay \$100+α
  - Current dollars: 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 얘기지 실제로 그때가 되면 더 낼 수가 있다.*
Home Mortgage of \$400: 그때가 되도 400불을 낸다. (inflation 이미 고려)

Financing Example

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