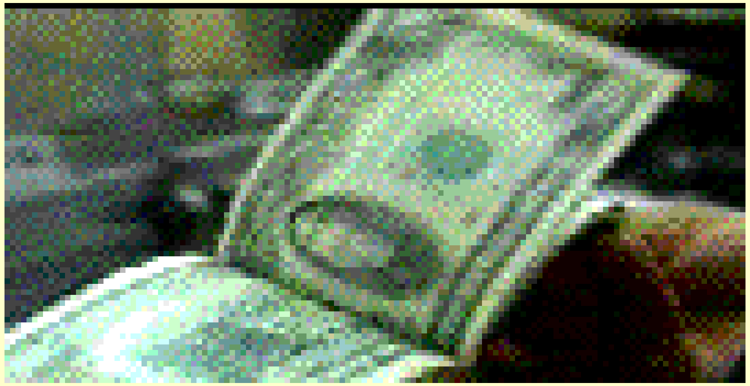


Economic and Financial Analysis

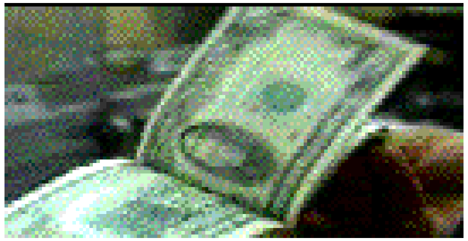
Dr. Sam C. M. Hui
Department of Mechanical Engineering
The University of Hong Kong
E-mail: cmhui@hku.hk

Jan 2015

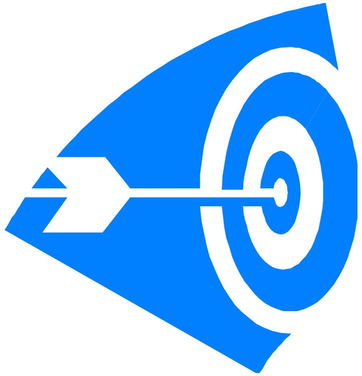
Contents

- Investment Appraisal
- Financing Options
- Building Economic Analysis
- Whole Life Costing

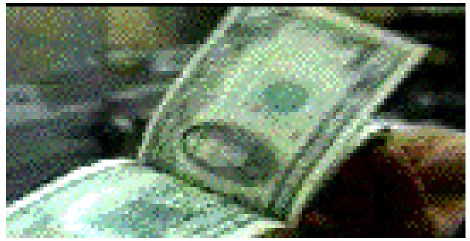
Investment Appraisal



- Purpose of financial appraisal
  - To determine which investments, among all the possibilities, make the best use of the money
  - To ensure *optimum benefits* from each investment
  - To minimise risk to the enterprise
  - To provide a basis for subsequent analysis of performance of the investment

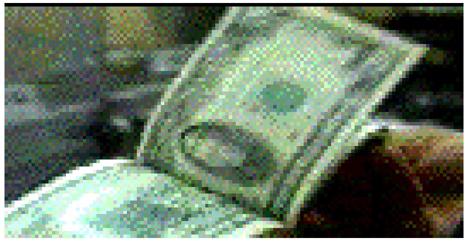


Investment Appraisal



- Six key steps of financial appraisal of energy efficiency investment in buildings
  - 1. Locate the buildings which have the potential
  - 2. Identify the area where a saving can be made & identify the measures required to release it
  - 3. Establish the costs & the savings for each measure & calculate the key financial indicators
  - 4. Optimise the financial return
  - 5. Establish how much investment capital is available & identify new sources of capital
  - 6. Decide which projects make best use of the capital

Investment Appraisal

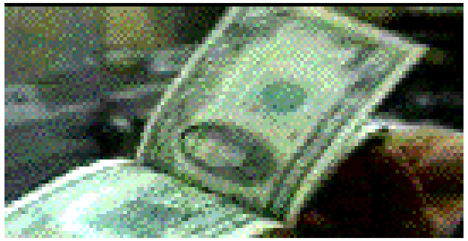


- Review using the financial energy management matrix (FEMM) (see diagram)
  - Identifying opportunities
  - Exploiting opportunities
  - Management information
  - Appraisal methods
  - Human resources
  - Project funding
- Mark on the levels & construct the profile

Financial Energy Management Matrix

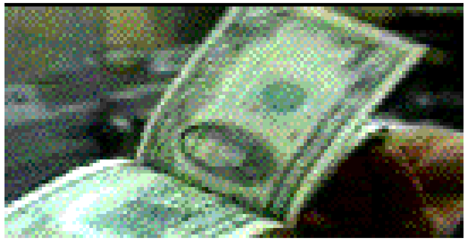
Level	Identifying Opportunities	Exploiting Opportunities	Management Information	Appraisal Methods	Human Resources	Project Funding
4	Detailed energy surveys are regularly updated. A list of high and low cost opportunities already fully costed and ready to proceed immediately.	Formal requirement to identify the most energy efficient option in all new build, refurbishment and plant replacement projects. Decisions made on basis of life-cycle costs.	Full management information system enabling identification of past savings and continuous opportunities for investment meeting organisation's financial parameters.	Full discounting methods using internal rates of return and ranking priority projects as part of an ongoing investment strategy.	Board take a proactive approach to a long-term investment programme as part of a detailed environmental strategy in full support of Energy Manager and team.	Projects compete equally for funding with other core business investment opportunities. Full account taken of benefits which do not have direct cost benefit, eg marketing opportunities, improved working conditions.
3	Energy surveys conducted by experienced staff or consultants in buildings likely to yield largest savings.	Energy staff are required to comment on all new build, refurbishment and plant replacement projects. Energy efficiency options often approved, but no account is taken of life-cycle costs.	Promising proposals get presented to decision makers, but insufficient information (eg for sensitivity analysis) results in delays and rejections.	Discounting methods using the organisation's specified discount rates.	Energy Manager working well with accounts/finance to present well argued cases to decision makers.	Projects compete for funding from capital budget along with other business opportunities, but have to meet more stringent requirements for return on investment.
2	Regular energy monitoring/analysis identifies possible areas for saving.	Energy staff are notified of project proposals which have obvious energy implications. Proposals for most energy efficient solutions vulnerable when capital costs need to be reduced.	Adequate management information available, but not in correct format or easily accessed in support of energy saving projects.	Undiscounted appraisal methods used, eg gross return on capital.	Occasional proposals to decision makers by Energy Manager with limited success and only marginal interest from decision makers.	Energy projects not normally considered for funding from capital budget, except when very short-term returns are evident.
1	Informal, ad hoc energy walkabouts conducted by staff with checklists in the hope of identifying energy saving measures.	Energy staff use informal contacts to identify projects where energy efficiency can be improved at marginal cost. Proposals routinely rejected to reduce capital cost.	Insufficient information to demonstrate whether previous investment in energy efficiency has been worthwhile.	Simple payback criteria is applied.	Responsibility unclear and those involved lack time, expertise and resources to identify projects and prepare proposals.	Funding only available from revenue on low risk projects with paybacks less than one year.
0	No mechanism/ resources to identify energy saving opportunities.	Energy efficiency not considered in new build, refurbishment and plant replacement decisions.	Little or no information available to develop a case for funding.	No method used irrespective of the attractiveness of project.	No one in organisation promoting investment in energy efficiency.	No funding available for energy projects. No funding in the past.

Investment Appraisal



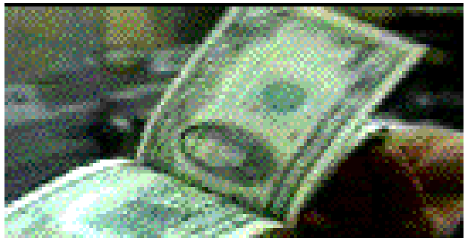
- From the profile of FEMM, assess how balanced your approach is
- Identify priority areas for action, such as
  - Least advanced
  - Easiest to implement
  - Cheapest to implement
  - Have most impact
  - Least contentious

Investment Appraisal

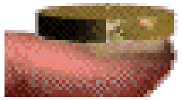


- Evaluate the strengths and weaknesses in managing energy efficiency investment
- Identify key opportunities for improving the performance
- Sensitivity analysis
  - Test (by varying key parameters) how assumptions made in costs & benefits affect the cash flow & financial parameters

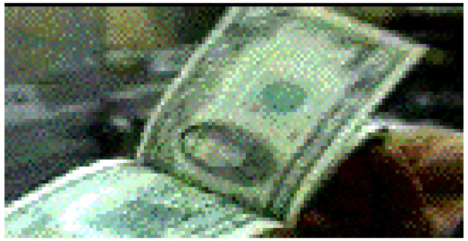
Investment Appraisal



- Benefits likely to arise
  - Reducing cooling/heating energy use
  - Reduced electricity use
  - Lower maintenance requirements
  - Reduced plant supervision
  - Improved comfort
  - Enhanced property value
  - Longer service life of remaining plant

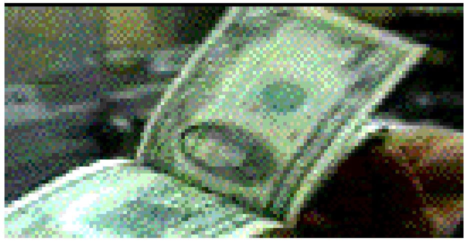


Investment Appraisal



- Appraisal methods
  - 1. Evaluate the cash flow (undiscounted)
  - 2. Determine the payback period (initial screening) & other parameters, e.g.
    - Gross return on capital
    - Net return on capital
    - Gross average rate of return
    - Net average rate of return (Internal Rate of Return, IRR)
  - 3. Net Present Value (NPV)
    - Apply a discount factor to future costs & earnings

Investment Appraisal



- Cash flow
  - Inflow (positive); outflow (negative)
  - Energy efficiency:
    - Reduce cash flowing out to pay for energy
    - May also produce non-energy cash benefits, e.g. maintenance savings
  - Initial outlay or first cost (a negative cash flow)
  - Energy cost savings (a positive cash flow)
  - For simplicity, assume one-year intervals

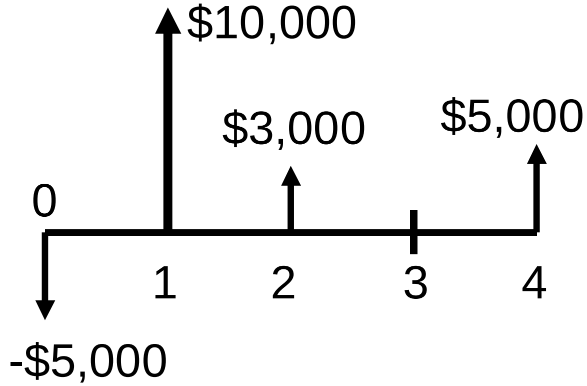


Table 1: Cash Flow Analysis For LED Exit Signs

Year	*Retrofit Cost*	*Energy & Demand Savings*	*Maintenance Savings*	*Omitted Savings*	*Risk Level*
0	$ 3,250	$ 0	$ 0	Neutral	Neutral
1	0	2,181	200		
2	0	2,181	200		
3	0	2,181	200		
4	0	2,181	200		
5	0	2,181	200		
6	0	2,181	200		
7	0	2,181	200		
8	0	2,181	200		
9	0	2,181	200		
10	0	2,181	200		

Key Assumptions:

1. Retrofit will be completed in 3 months.
2. LED exit signs have a 10-year life expectancy.
3. Energy savings are based on the current average energy rate of $0.078/kWh.
4. No changes in energy rates will occur during the 10-year period.
5. Maintenance savings are realized because lamps are changed less frequently.

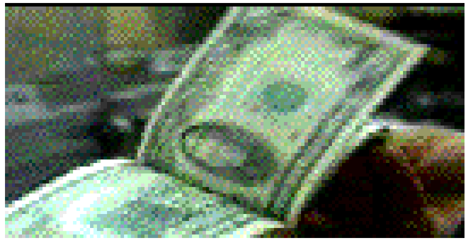
(Source: EnergyStar Building Manual, available at www.energystar.gov)

Cash flow analysis (example): simple payback = $20,000/$4,000 = 5 years

Year	Initial investment ($)	Energy savings ($)	Cumulative cash flow ($)
0	-20,000	---	-20,000
1	---	4,000	-16,000
2	---	4,000	-12,000
3	---	4,000	-8,000
4	---	4,000	-4,000
5	**---**	**4,000**	➔ **0 ***
6	---	4,000	4,000
7	---	4,000	8,000
8	---	4,000	12,000
9	---	4,000	16,000
10	---	4,000	20,000

* Payback is achieved when the cumulative cash flow reaches zero.

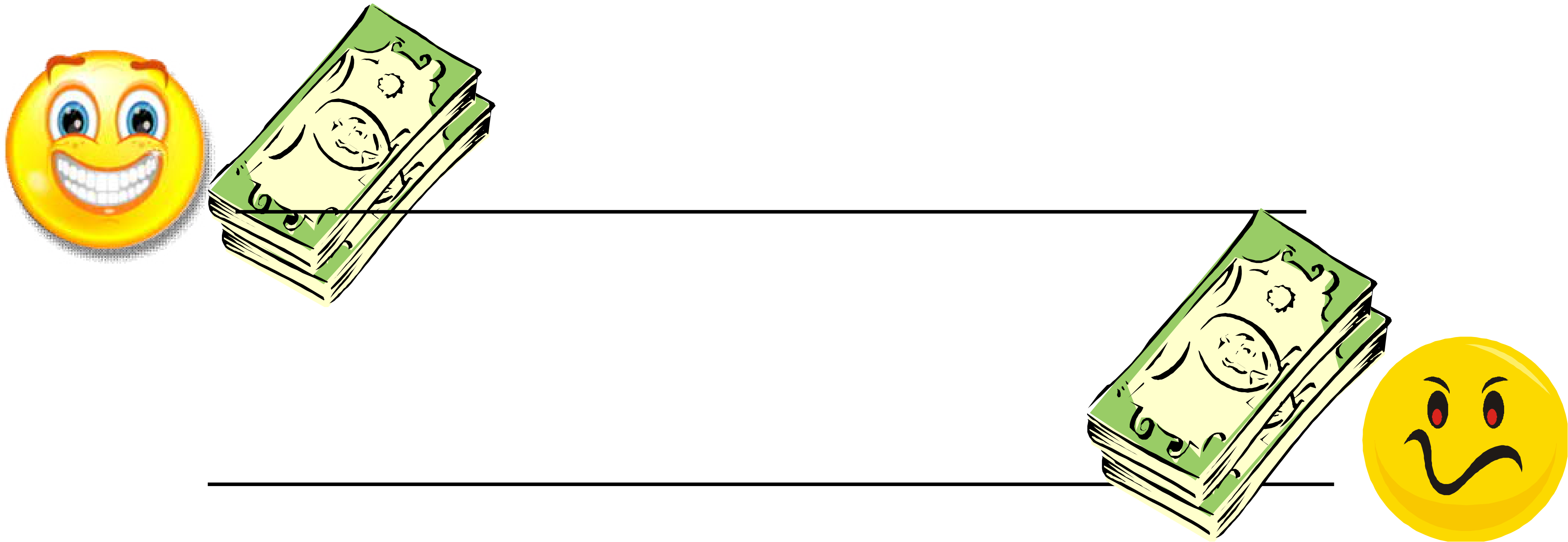
Investment Appraisal



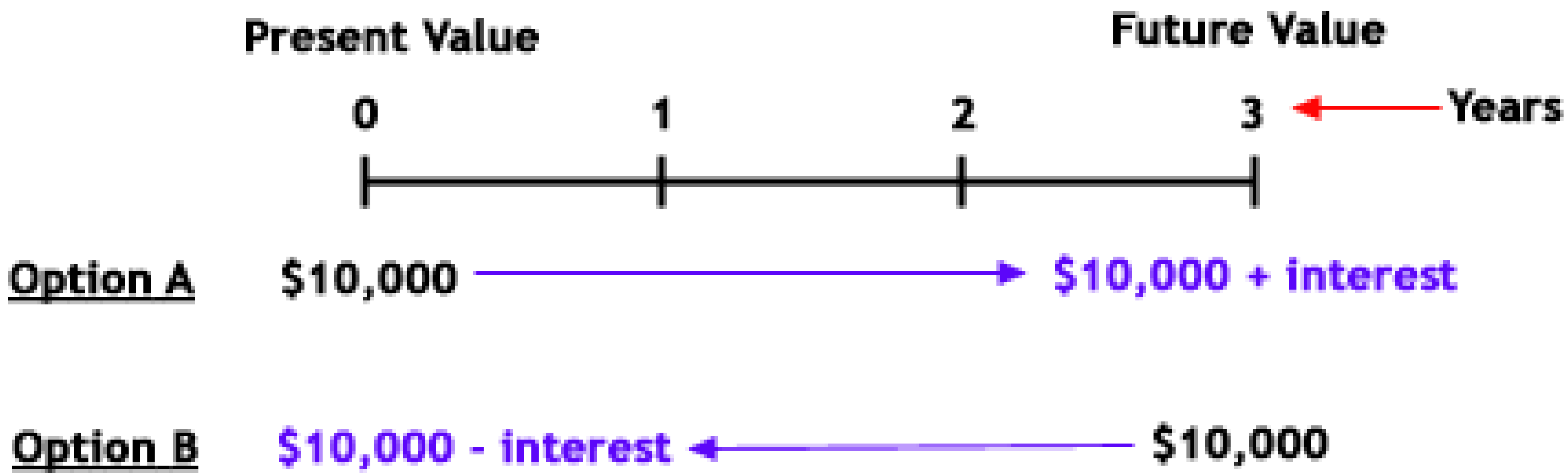
- Simple Payback (undiscounted)
  - Advantages:
    - Simple to calculate, easy to understand
    - Does not require any assumptions about the project lifetime or interest rates
  - Disadvantages:
    - Not consider savings achieved after the payback period
    - The *time value of money* is ignored
    - Does not consider any residual capital asset value at the end of the project life

Time Value of Money (TVM)

"An instant dollar is worth more than a distant dollar"



Today **3 years later**



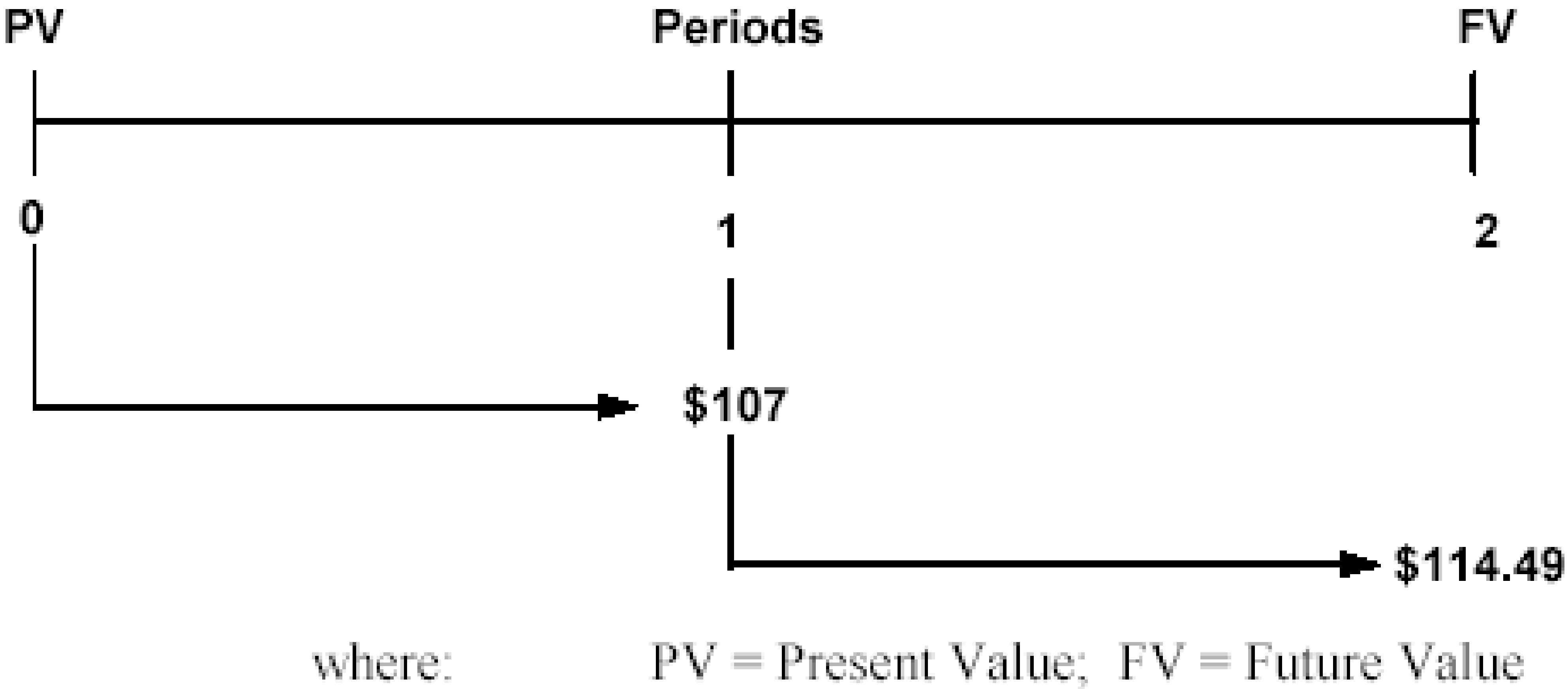
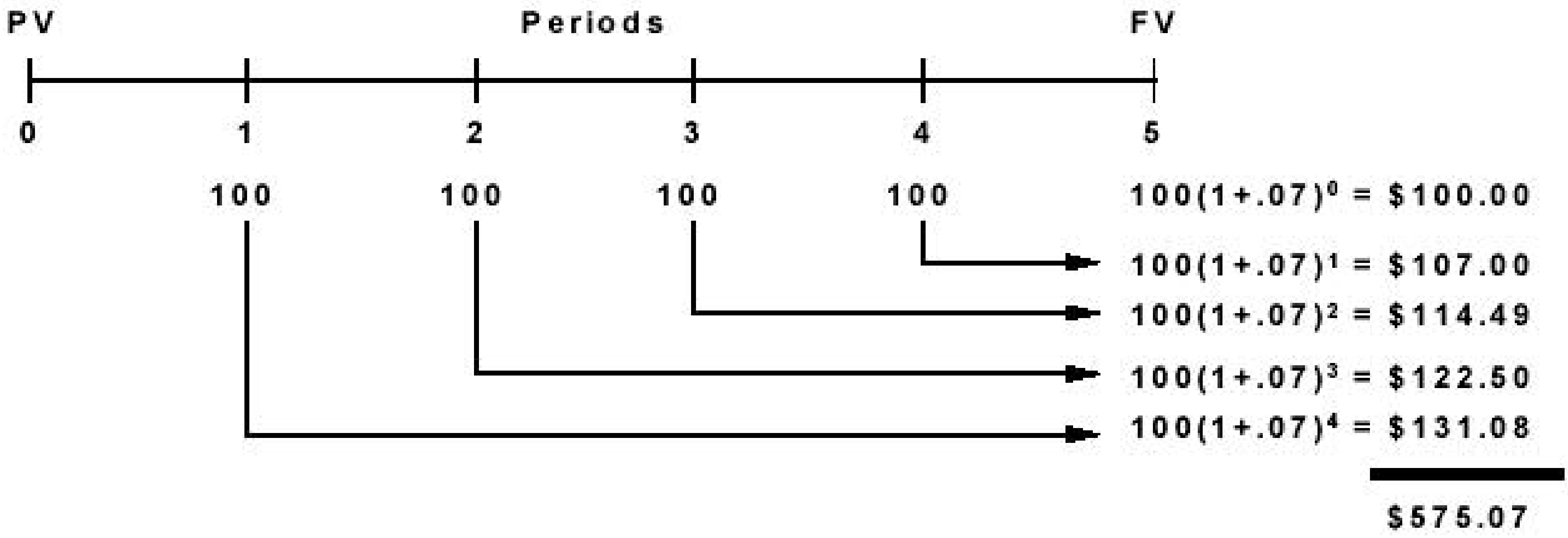


Figure 1. Future Value of a Single Payment

* Interest rate is assumed 7%.



$$FV = D \times \left(1 + \frac{IR}{100}\right)^{n}$$

$$PV = S \times \left(1 + \frac{IR}{100}\right)^{-n} = S \times DF$$

FV = future value
D = initial investment
IR = interest rate (%)
PV = present value
S = value of cash flow in n years time
DF = discount factor

Net present value PV analysis (example)

Year	Initial investment ($)	Energy savings ($)	Discount factor $(1 + IR/100)^{-n}$	Present worth of cash flow ($)
0	-20,000	---	1	-20,000
1	---	4,000	0.909	3,636
2	---	4,000	0.826	3,306
3	---	4,000	0.751	3,005
4	---	4,000	0.683	2,732
5	---	4,000	0.621	2,484
6	---	4,000	0.564	2,258
7	---	4,000	0.513	2,053
8	---	4,000	0.467	1,866
9	---	4,000	0.424	1,696
10	---	4,000	0.386	1,542
			NPV =	**4,578**

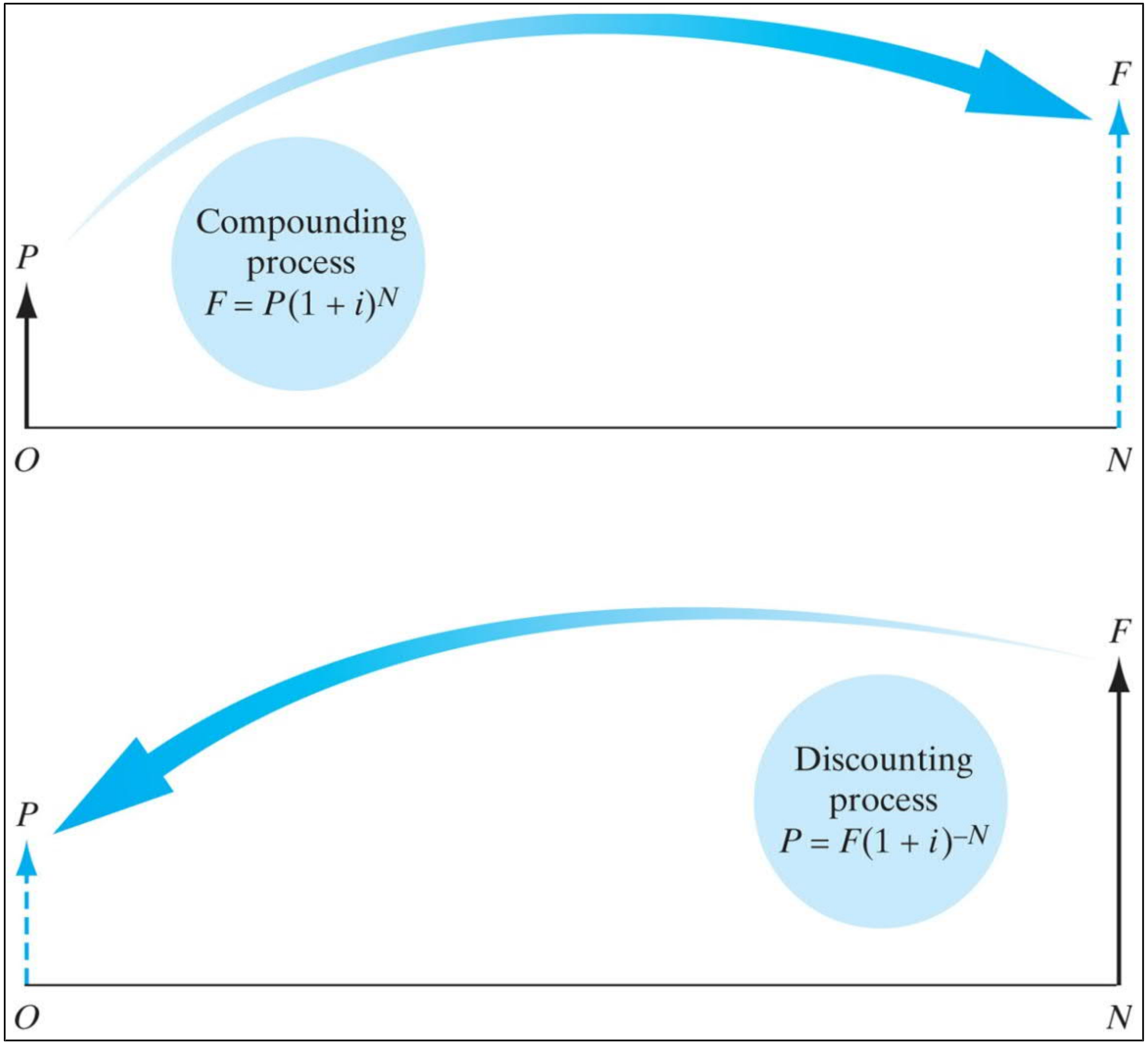
* Interest rate is assumed 10%.

Economic equivalence between present value (*P*) and future value (*F*)

* i = interest rate, N = number of years

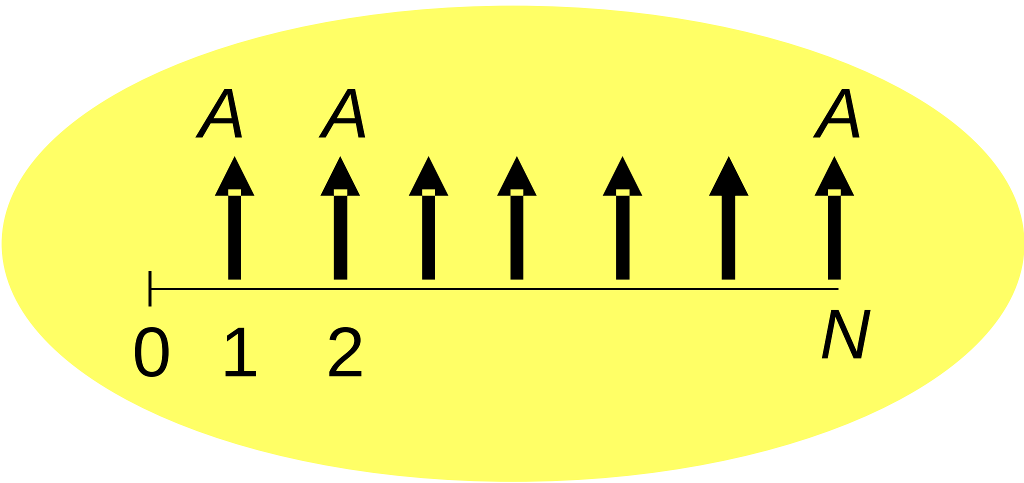
- Compounding Process – Finding an equivalent future value of current cash payment

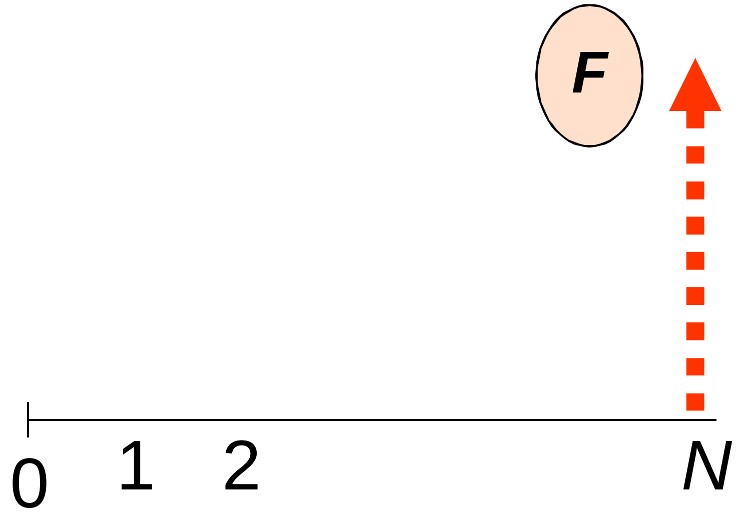
- Discounting Process – Finding an equivalent present value of a future cash payment

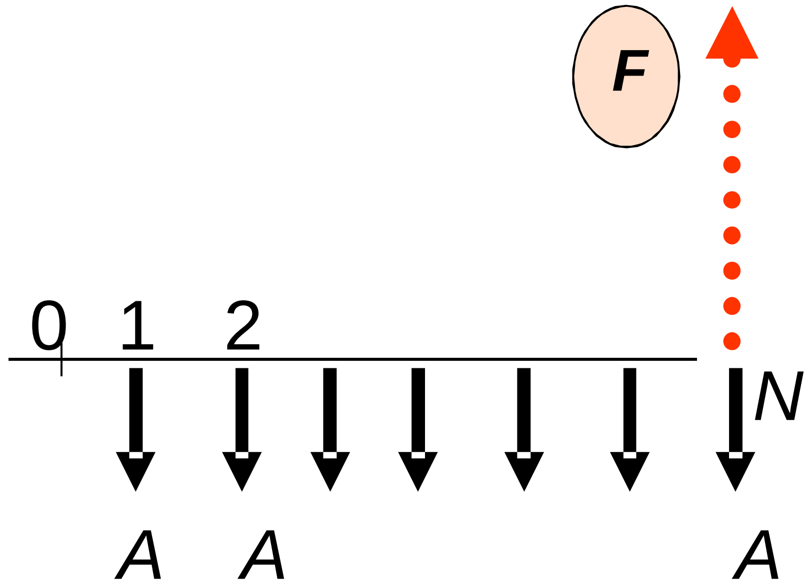


Equal Payment Series – Compound Amount Factor

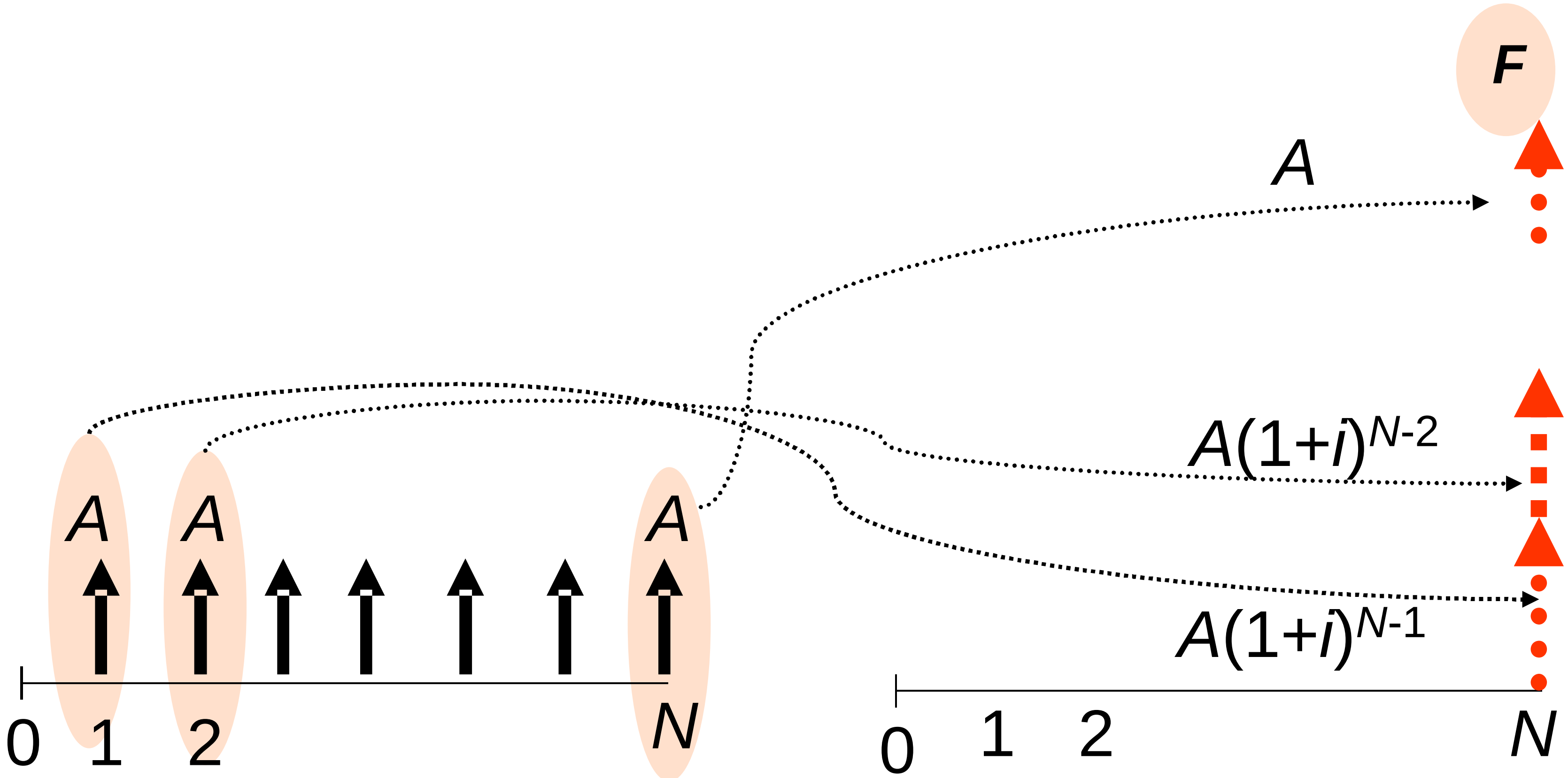
A = annual energy saving
N = number of years
F = future value





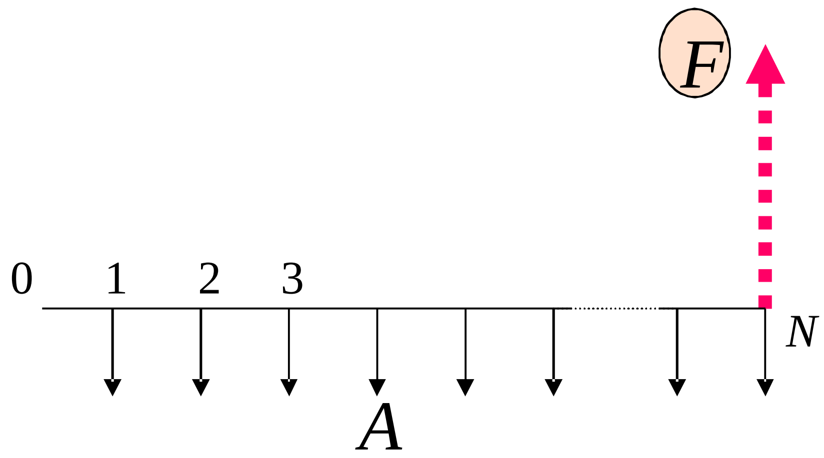


Equal Payment Series – Compound Amount Factor (cont'd)



$$F = A(1+i)^{N-1} + A(1+i)^{N-2} + \cdots + A = A\left[\frac{(1+i)^N - 1}{i}\right]$$

Equal Payment Series – Compound Amount Factor
(Future Value of an annuity) (Find *F*, Given *A*, *i*, and *N*)



$$F = A\frac{(1+i)^N - 1}{i}$$

$$= A(F/A, i, N)$$

Example:

- Given: A = \$5,000, N = 5 years, and i = 6%
- Find: F
- Solution: F = \$5,000(F/A, 6%, 5) = \$28,185.46

Equal Payment Series – Compound Amount Factor
(Future Value of an annuity) (Find *F*, Given *A*, *i*, and *N*)

$$\$5,000(1+0.06)^4 = \$6,312.38$$

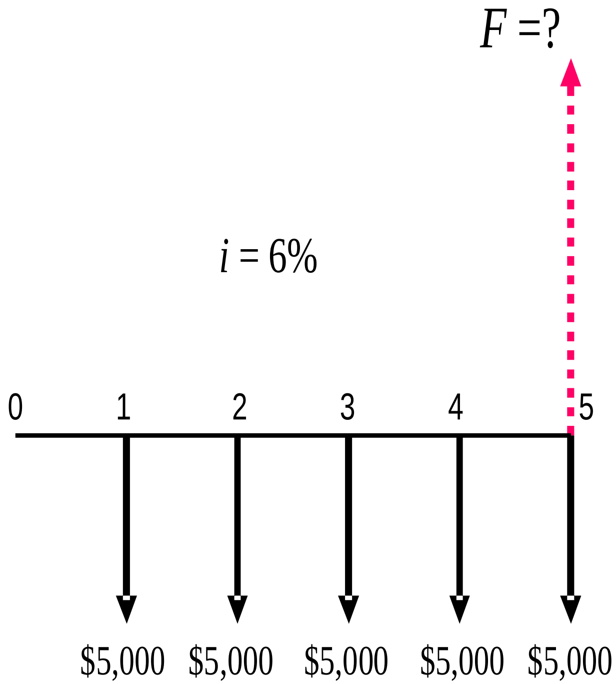
$$\$5,000(1+0.06)^3 = \$5,955.08$$

$$\$5,000(1+0.06)^2 = \$5,618.00$$

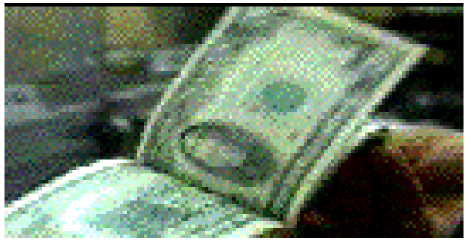
$$\$5,000(1+0.06)^1 = \$5,300.00$$

$$\$5,000(1+0.06)^0 = \$5,000.00$$

$$\$28.185.46$$



Investment Appraisal



- Internal rate of return (IRR)
  - Closely related to NPV, it is a percentage figure that describes the yield or return on an investment (ROI) over a multiyear period
  - For a given series of cash flows, the IRR is the discount rate that results in an NPV of zero*
  - Compare IRR to the interest rate on the financing (i.e. cost of capital in the securities market)
    - If IRR is greater than the returns in the financial markets, the investment is financially worthwhile

(*See also http://en.wikipedia.org/wiki/Internal_rate_of_return)

Table 3: Comparing The Profitability Of Upgrade Options

Year	Upgrade Option 1A Occupancy Sensors		Upgrade Option 1B Central Timeclock	
	Initial Cost	*Savings Generated*	*Initial Cost*	*Savings Generated*
0	$ 42,000	$ 0	$ 9,000	$ 0
1	0	12,200	0	3,550
2	0	12,200	0	3,550
3	0	12,200	0	3,550
4	0	12,200	0	3,550
5	0	12,200	0	3,550
6	0	12,200	0	3,550
7	0	12,200	0	3,550
8	0	12,200	0	3,550
9	0	12,200	0	3,550
10	0	12,200	0	3,550

Cumulative Savings

	Upgrade Option 1A	Upgrade Option 1B
Over Ten Years	$122,000	$ 35,500
Simple Payback	3.4 years	2.5 years
IRR	26%	38%
NPV	$ 7,623	$ 4,903

Do you know how to interpret them?

(Source: EnergyStar Building Manual, available at www.energystar.gov)

Table 4: Assemble A Profitable Package

Stage Two Lighting Options		NPV	First IRR	Annual Net Cost	Cash Flow	Omitted Savings	Risk
1a	Install Occupancy Sensors	$7,623	26%	$42,000	$12,200	Neutral	Neutral
1b	Install Central Timeclock	4,902	38%	9,000	3,550	Neutral	Neutral
2	Install LED Exit Signs	5,606	73%	3,250	2,380	Neutral	Neutral
3	Improve Corridor Lighting	5,106	38%	9,490	3,725	Neutral	Neutral
4	Improve Office Lighting	4,751	23%	57,605	15,100	Neutral	Neutral
5	Upgrade Task Lighting	(929)	16%	9,500	2,000	Neutral	Neutral
6	Install Daylighting Controls	(26,524)	2%	59,080	6,500	Neutral	Neutral

Package Results

	NPV	First IRR	Annual Net Cost	Cash Flow
Options 1a-4	$23,091	27%	$112,345	$33,405
Options 1a-5	$22,161	26%	$121,845	$35,405
Options 1a-6	$(4,363)	19%	$180,925	$39,905

(Source: EnergyStar Building Manual, available at www.energystar.gov)

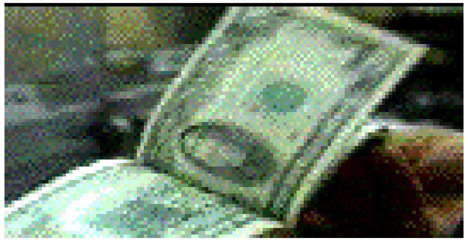
Table 2: Performance Comparison of Fluorescent Retrofit Options

	Base case: T12 Lamps w/magnetic ballasts **Case 1**	"Energy saving" T12 lamps **Case 2**	T8 lamps, electronic ballasts **Case 3**	T8 lamps, electronic ballasts, reflector lens, + 50% delamping **Case 4**	Same as Case 4 + occupancy sensors **Case 5**	Same as Case 5 + maintenance **Case 6**
Avg. maintained footcandles (fc)	28	25	30	27	27	27
Input watts per fixture	184	156.4	120	60	60	50
Total kW	2.208	1.877	1.440	0.720	0.720	0.600
Annual energy use (kWh)	8,832	7,507	5,760	2,880	1,800	1,500
Costs						
Energy savings (%)	N/A	15%	35%	67%	80%	83%
Annual operating cost for energy ($)	883.70	750.74	576.00	288.00	212.40	177.00
Upgrade cost ($)	N/A	312	1,440	1,620	1,970	1,970
Savings						
Energy savings (%)	N/A	15%	35%	67%	80%	83%
Operating cost savings (%)	N/A	15%	35%	67%	76%	80%
Simple payback (years)	N/A	2.4	4.7	2.7	2.9	2.8
Internal Rate of Return (10-year)	N/A	41%	17%	35%	32%	34%

Source: Adapted from E Source, *Lighting Technology Atlas*, Table 3.1.

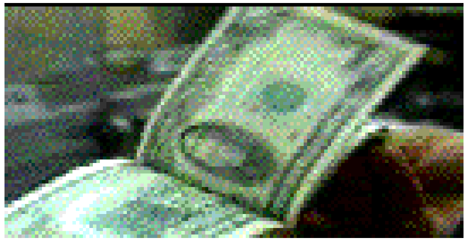
(Source: EnergyStar Building Manual, available at www.energystar.gov)

Investment Appraisal

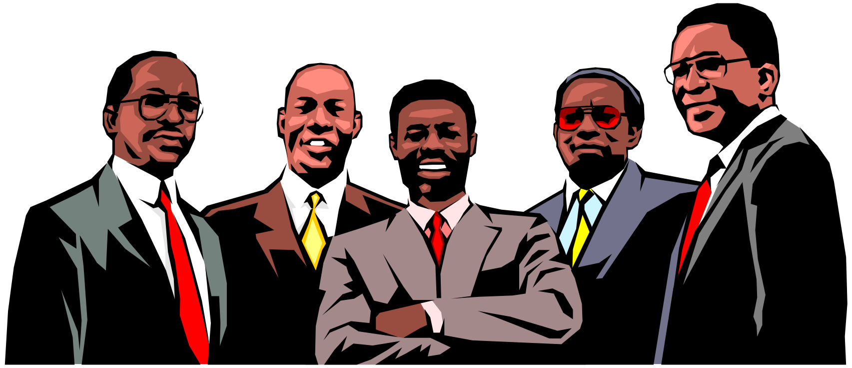


- Key points to note for the investment analysis
  - Choose the right time frame (say, 10 years)
  - Consider all of the impacts on cash flow
  - Account for interactions among measures
  - Include anticipated price changes (energy prices)
  - Adjust for taxes (where applicable)
  - Examine the sensitivity of results to changes in key assumptions

Investment Appraisal



- Human resources
  - People's commitment to energy efficiency
  - Promote the culture of energy efficiency
  - Supportive senior management (board of directors)
  - Clear lines of responsibility
  - Joint forces with account/finance department



Financing Options

- Funding of energy efficiency projects
  - Well prepared proposals
  - Energy or environmental policy with board level backing (senior management commitment)
  - Take account of potential risks
  - Keep track of investment & accrued year-on-year savings, e.g. using a capital return budget
- Financing options for private and public organisations may be different

Financing options for a public or private organisation

	Public	Private
Purchasing		
▪ Cash	X	X
▪ Loans		X
▪ Bonds	X	X (rare)
Leasing		
▪ Operating lease	X	X
▪ Municipal lease	X	
▪ Capital lease		X
Performance Contracting		
▪ Guaranteed savings	X	X
▪ Shared savings	X	X
▪ Paid-from savings	X	X
Other		
▪ Utility incentives	X	X
▪ State incentives	X	X
▪ Foundations and nonprofits	X	X

Financing Options

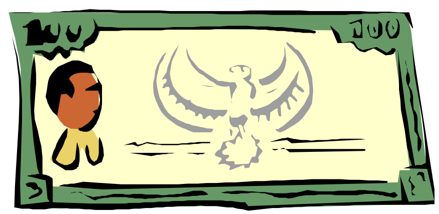
- Purchase by cash
  - Makes sense for organizations with cash reserves and a strong balance sheet
  - Disadvantages: reduced liquidity and a potential for lost investment opportunities that require cash
  - Generally cash is most appropriate for relatively inexpensive, simple efficiency measures that are likely to pay for themselves quickly
  - Large and complex projects are best funded with debt or off-balance-sheet financing

Financing Options

- Purchase by loans
  - From banks or lenders (debt financing)
  - An ideal way for an organization to avoid expending cash on the project
  - A borrower's ability to negotiate favorable terms (down payment, soft costs, interest rate, payment structure) depends largely on the lender's perception of the risk

Financing Options

- Purchase by bonds
  - Bonds are debt instruments sold by public- and private-sector organisations to borrow money from capital markets
  - Complex agreements and therefore have high transaction costs
  - Common in the public sector to raise money with bonds to create pools of money for funding smaller projects



Financing Options

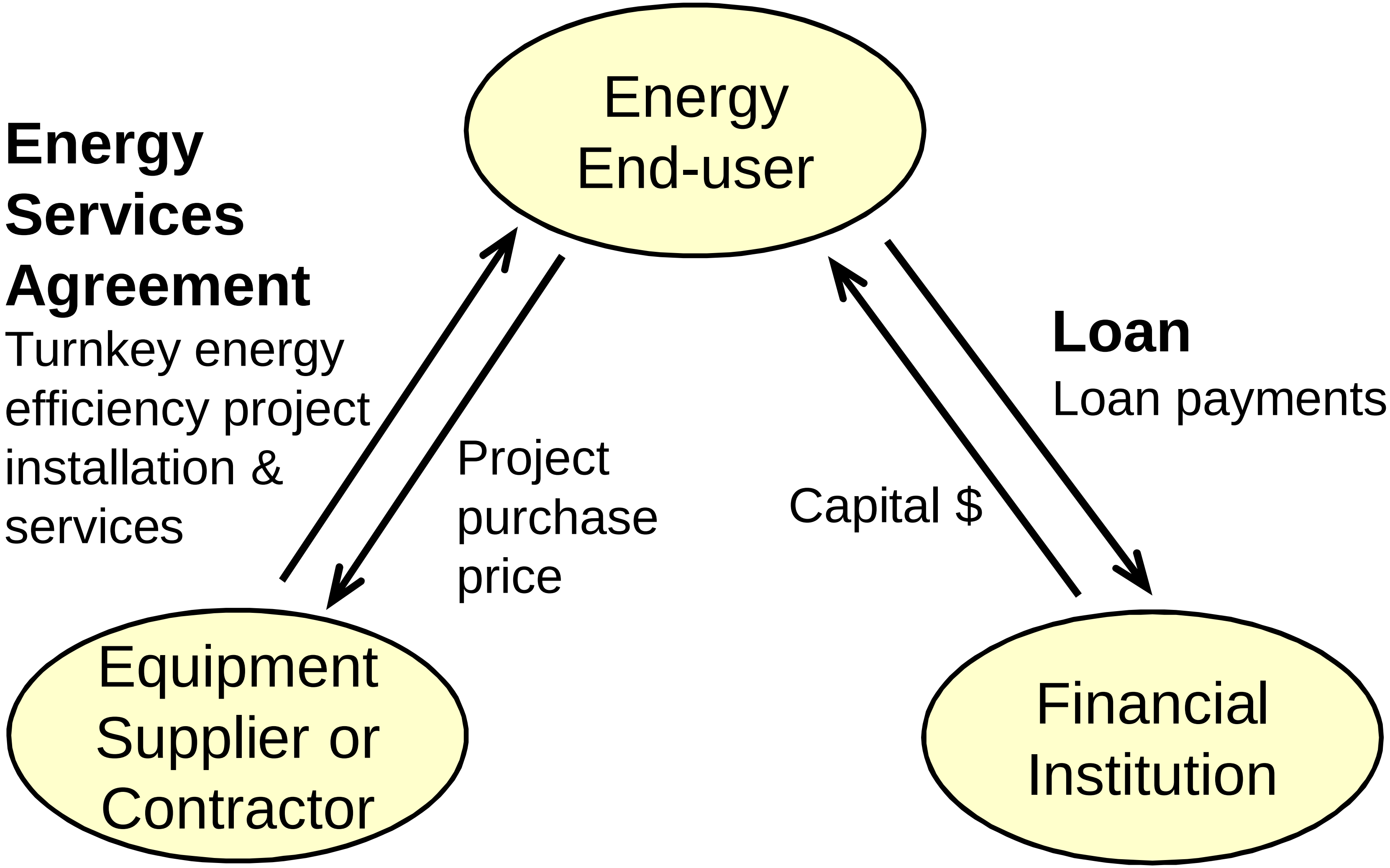
- [Leasing]
  - A lease is essentially a *loan* in which the lessor (the lender) retains legal title to the property being leased (i.e. the possession of this asset)
  - Leases are quick and easy to set up and administer
  - Operating leases (lessor owns the equipment & rent it to the lessee)
  - Capital leases (installment purchases of equipment)
  - Municipal leases (a tax-exempt lease purchase agreement)

Financing Options

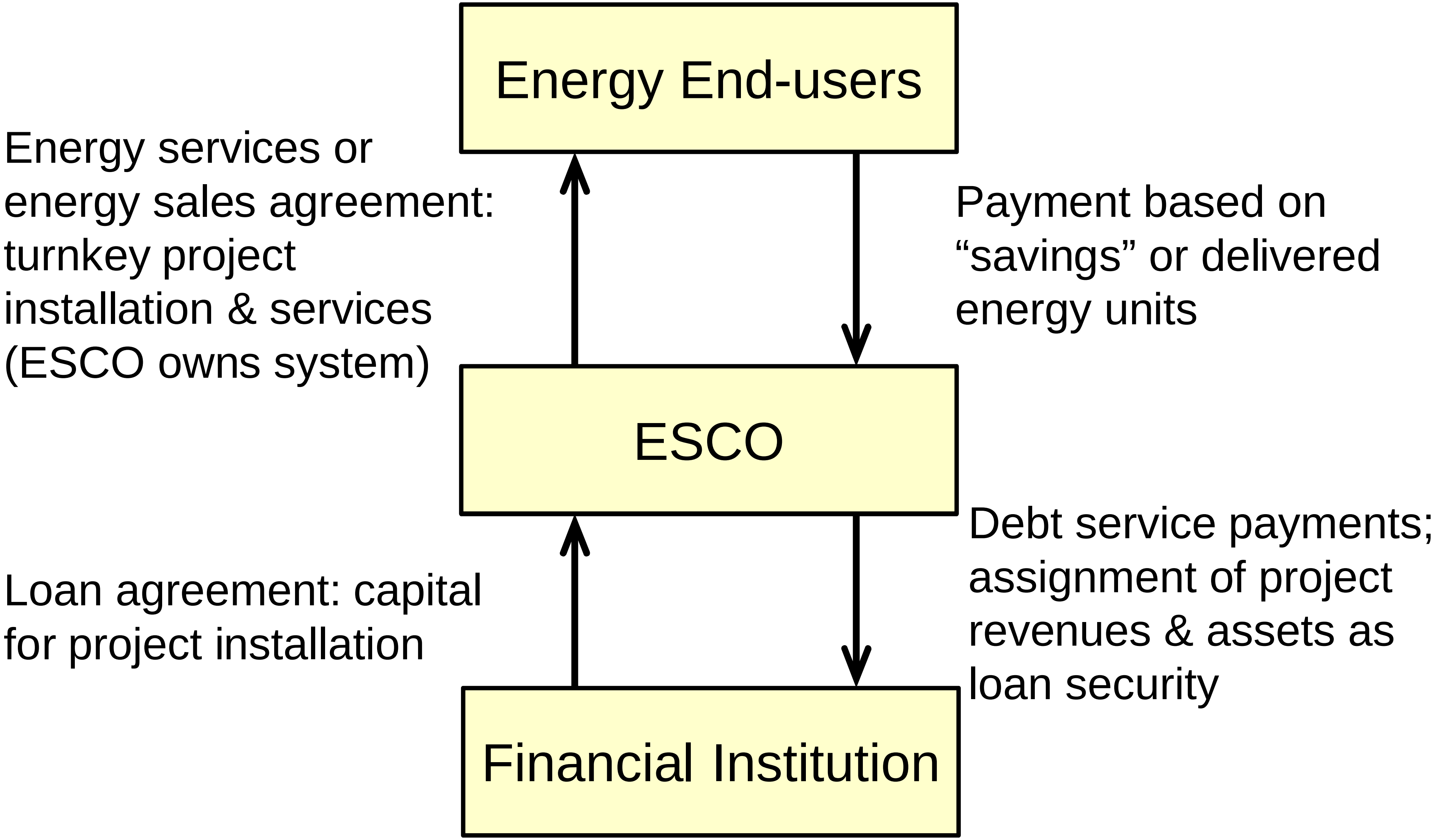
- <u>Performance contracting</u>
  - An agreement with an energy service company (ESCO) to manage a group of efficiency projects
  - Especially well suited for financing large and complex projects, with a large savings potential
  - <u>Advantages</u>:
    - No up-front costs and no debt to the balance sheet
    - Minimize the burden on contracting
  - <u>Disadvantages</u>:
    - A significant portion of the savings goes to the ESCO
    - It can be complex and take a long time to negotiate

Risk transfer & risk sharing

Debt Financing Model 1: End-user as Borrower



Debt Financing Model 2: ESCO as Borrower
(typical performance contracting structure)



Two alternatives to Model 2:

- Bank loan to ESCO; with matching fixed payments from end-user
- ESCO loan to end-user; ESCO *sells* this payment stream to bank, factoring or forfeiting

Financing Options

- How to obtain financing at a min. cost and risk
  - Major evaluation factors:
    - Total cost of the project
    - Constraints on internal capital availability
    - Owner's balance sheet impact (e.g. off-balance sheet)
    - Initial payment (initial capital outlay)
    - Payment structure (to receive financial benefits)
    - Preferred ownership status
    - Tax deductions (e.g. for loan interest)
    - Performance risk (who bears the risk of failure)

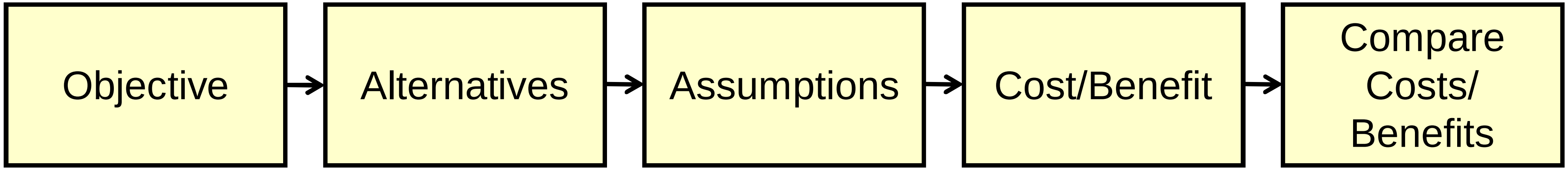
	Purchase			Lease			
Evaluation factor	Cash	Loan	Bond	Operating	Capital	Municipal	Performance contract
Down payment (%)	100	20 to 25	0	0	0	0	0
Transaction cost[a]	—	Medium	High	—	Low	Low	Medium
Balance sheet	Asset	Asset and liability	Asset and liability	—	Asset and liability	—	—
Tax deductions	Depreciation	Depreciation and interest	Depreciation	Lease payments	Depreciation	—	—
Interest rate	—	Medium	Low	—	High	Low	—
Financing term	—	3 years	10 to 20 years	—	3 to 5 years	Project life	Project life
Approval process	Internal	Bank	Referendum	Internal	Lessor	Lessor	Internal
Approval time	Short	Medium	Very long	Short	Short	Short	Long
Flexibility	Usually small projects	Limited to equipment value	Large projects only	Usually small projects	Equipment cost + 20 to 40 percent	100 percent of project cost	100 percent of project cost
Capital or operating budget	Either	Capital	Capital	Operating	Capital	Operating	Operating

Notes: a. Transaction costs include professional services and staff time devoted to the transaction.

Courtesy: E SOURCE; adapted from EPA

(Source: EnergyStar Building Manual, available at www.energystar.gov)

Economic Analysis Process

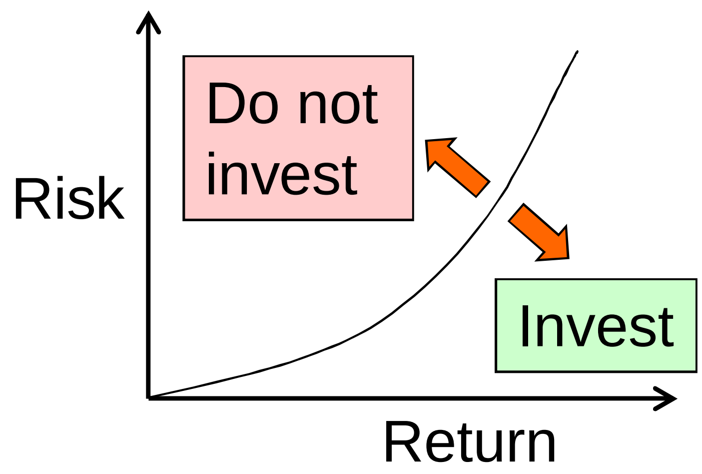


1. Define the problem and the objective.
2. Identify feasible alternatives for accomplishing the objective, taking into account any constraints.
3. Determine whether an economic analysis is necessary, and if so, the level of effort which is warranted.
4. Select a method or methods of economic analysis.
5. Select a technique that accounts for uncertainty and/or risk if the data to be used with the economic method are uncertain.
6. Compile data and make assumptions called for by the economic analysis method(s) and risk analysis technique.
7. Compute a measure of economic performance.
8. Compare the economic consequences of alternatives and make a decision, taking into account any non-quantified effects and the risk attitude of the decision maker.

(Source: http://www.wbdg.org/design/use_analysis.php)

Financing Options

- The financier’s perspective
- Risks:
  - Risk assessment and risk control
  - Each of the key risks involved allocated and priced
- Returns:
  - Calculate return on investment
- =>Risk/return profile



Building Economic Analysis

- Learning Unit 05 from the "Increasing Energy Efficiency in Buildings Project, China"*
  - Energy consumption & cost analysis
  - Payback analysis
  - Life-cycle cost analysis
- With real-life examples & case studies in Mainland China, e.g. Tianjin and Harbin

* Jean-Louis,M.-J., Paré, M. and Nichols, L., 2002. *Learning Unit 05: Building Economic Analysis*, Increasing Energy Efficiency in Buildings Project, China, Dessau-Soprin Inc., Montreal, Canada, pp. 1-17. (www.mech.hku.hk/bse/MEBS6016/building_economic_analysis.pdf)

Building Economic Analysis

- The project analysis depends on how to consider the expenditures and the savings
  - Short-term approach
    - Focus on initial costs (the tips of the iceberg)
  - Long-term approach
    - Show complete building costs (hidden portion too)
- Determine when to spend more money now in order to save more money in the long term

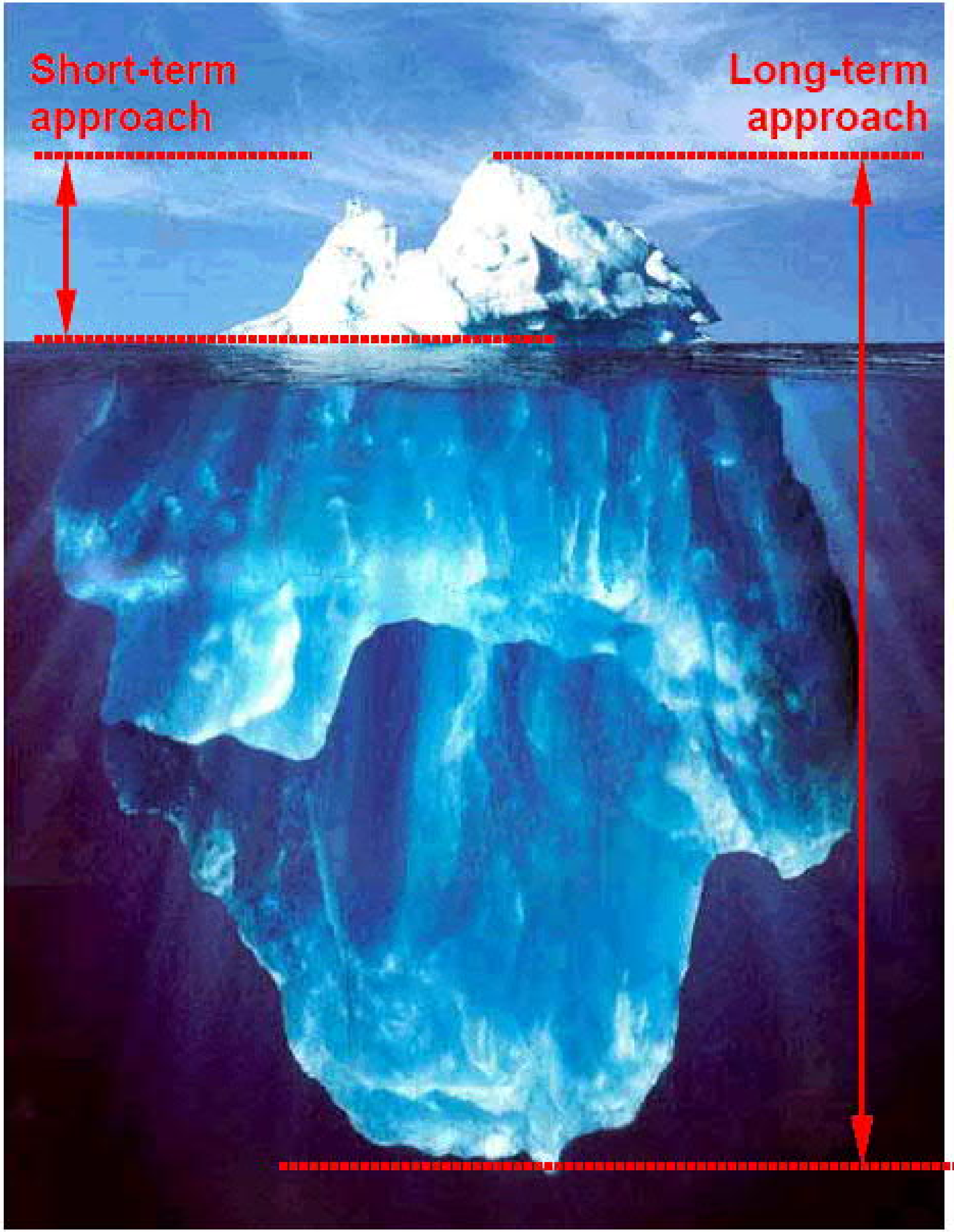


Figure 1.1.1: Two approaches to economic analysis

Building Economic Analysis

- The cost of energy consumption
  - Represents the largest portion of operating costs
  - Can be calculated using building energy simulation tools
- Important to build a reference model
  - Analysis of building retrofit: represent the behaviour of the existing buildings
  - Evaluation of new building design: represent the behaviour of the building to be constructed

Building Economic Analysis

- Payback analysis methods
  - How quickly the initial investment on a project can be recovered
  - Ignores all costs, savings & residual value occurring after the payback time (*time value of money*)
  - Should be used only a screening method that are clearly economical

Building Economic Analysis

- Types of payback methods
  - Simple payback (SPB) method
    - Time it takes to get back the initial investment
    - Limitations:
      - Does not effectively consider the time-value of money
      - Does not consider the life periods
      - Often uses an arbitrary short payback period
  - Return-on-investment (ROI) method
    - Simple rate of return or investor’s rate of return
    - % of the investment that can be recuperated each year

Building Economic Analysis

- Types of payback methods
  - Discounted payback (DPB) method
    - Consider value of money saved over time
    - Discount rate

Discount factor (*DF*)

$$DF = \frac{1}{(1+r)^n}$$

Building Economic Analysis

- Case Study: Tianjin Demonstration Project
  - Single-family dwelling
    - Reference model: based on the traditional Chinese construction method for this area
  - Building parameters evaluated:
    - Types of window
    - Infiltration rate
    - Composition of the exterior wall and roof
    - Boiler efficiency
    - Type of energy source used by the boiler
    - Type of heating and cooling system

Figure 1.2.1: Design of the demonstration project in Tianjin
Source: Digigraph

天津

Table 1.2.1: Energy consumption cost evaluation for the Tianjin demonstration project

Parameters	Electrical cost (Yuan)	Natural gas cost (Yuan)	Coal Cost (Yuan)	Total energy cost (Yuan)	Annual savings (Yuan)
TYPE OF WINDOWS					
Double clear glass windows	872	N/A	6,880	7,752	345
Double clear reflective glass windows	872	N/A	7,542	8,414	-317
AIR CHANGE RATES					
1.50 air change per hour	872	N/A	8,044	8,916	-819
0.75 air change per hour	872	N/A	6,866	7,738	359
0.50 air change per hour	872	N/A	6,703	7,575	522
0.30 air change per hour	872	N/A	6,579	7,451	646
0.30 air change per hour with double clear glass windows	872	N/A	6,447	7,318	779
TYPE OF EXTERIOR WALLS					
25mm polystyrene	872	N/A	5,399	6,271	1,826
50mm polystyrene	872	N/A	4,881	5,753	2,344
75mm polystyrene	872	N/A	4,732	5,604	2,493
TYPE OF ROOF					
75mm polystyrene	872	N/A	5,450	6,322	1,775
100mm polystyrene	872	N/A	5,355	6,227	1,878
125mm polystyrene	872	N/A	5,315	6,187	1,910
150mm polystyrene	872	N/A	5,280	6,152	1,945
150mm polystyrene for roof and 75mm polystyrene for walls	872	N/A	2,854	3,726	4,373
BOILER EFFICIENCY AND HEATING SOURCE					
Coal, 54.0%	872	N/A	6,253	7,125	972
Coal, 58.5%	872	N/A	5,774	6,646	1,451
Coal, 63.0%	872	N/A	5,358	6,230	1,867
Gas, 70.0%	872	9,334	N/A	10,206	-2,109
HEATING AND COOLING SYSTEMS					
Low COP heat pump (coal)	18,270	N/A	1,147	19,417	-5,482
High COP heat pump (coal)	12,320	N/A	923	12,243	1,692
High COP heat pump (water)	3,445	N/A	7,515	10,960	2,975
High COP heat pump (gas)	12,320	1,192	N/A	13,512	423
High COP heat pump (electrical)	15,221	N/A	N/A	15,221	-1,286
Low COP heat pump (electrical)	22,614	N/A	N/A	22,614	-8,679
Low COP electric system	29,221	N/A	N/A	29,221	-15,286
High COP electric system	26,922	N/A	N/A	26,922	-12,987
FINAL DESIGN					
Double clear glass window, 0.30 air charge per hour, 75mm wall insulation, 150mm roof insulation, 70% efficient gas boiler, high COP hot water heat pump	4,005	234	N/A	4,239	3,858

Table 1.2.2: Energy cost

ENERGY SOURCE	Cost
Coal	600 yuan/ton
Electricity	0.55 yuan/ kWh
Natural gas	1.5 yuan/m^3

Table 1.3.1: Simple payback calculations approach

Options	Installation cost	Annual savings	Simple payback period
1. Caulking	40,000.00 YUAN	10,000.00 YUAN	4 years
2. Boiler retrofit	60,000.00 YUAN	15,000.00 YUAN	4 years
3. New boiler	80,000.00 YUAN	20,000.00 YUAN	4 years

Table 1.3.2: Return on investment calculations approach

Options	Installation cost	Annual savings	Return on investment
1. Caulking	40,000.00 YUAN	10,000.00 YUAN	25%
2. Boiler retrofit	60,000.00 YUAN	15,000.00 YUAN	25%
3. New boiler	80,000.00 YUAN	20,000.00 YUAN	25%

Building Economic Analysis

- Case Study: Harbin Demonstration project
  - Retrofitting an existing apartment building
    - Reduce energy consumption by 50% as stipulated in the JGJ 26-95 Standard, while ensuring the retrofit cost be within 10% for a new building of the same type
    - Two types of wall system were considered: a rain screen system and an EPS wall
    - Compare also material and labour costs between China and Canada

哈爾濱

Figure 1.3.1: Harbin-1 Demonstration

Table1.3.3: Composition of exterior wall options

	Rain Screen System	EPS wall
Exterior facing:	Fibre cement panel	Mesh and finish (vapour & air barrier)
Air gap:	35 mm	0 mm
Insulation:	70 mm	70 mm expanded polystyrene
Vapour and air barrier:	Elastomeric membrane	From exterior facing
Brick wall:	149 mm (existing brick wall)	149 mm (existing brick wall)
Interior mortar:	10 mm (existing interior mortar)	10 mm (existing interior mortar)

Table1.3.4: Wall construction cost* comparison

	Rain Screen System		EPS wall	
	Canadian	Chinese	Canadian	Chinese
Material	390 YUAN/ m^2	348 YUAN/ m^2	90 YUAN/ m^2	82.2 YUAN/ m^2
Labour	504 YUAN/ m^2	84 YUAN/ m^2	84 YUAN/ m^2	13.8 YUAN/ m^2
Transportation	96 YUAN/ m^2	84 YUAN/ m^2	24 YUAN/ m^2	20.4 YUAN/ m^2

* 1 CAD = 6 CNY (1996)

Table1.3.5: Construction cost of the design propositions for Harbin

	Option-1 (Canadian costs)	Option-1 (Chinese costs)	Option-2 (Canadian costs)	Option-2 (Chinese costs)
Walls (ext.)	990.00 Yuan/ m^2	517.98 Yuan / m^2	196.50 Yuan / m^2	99.60 Yuan / m^2
Stair walls	990.00 Yuan / m^2	517.98 Yuan / m^2	196.50 Yuan / m^2	99.60 Yuan / m^2
Windows	2,880.24 Yuan / m^2	2,125.98 Yuan / m^2	46.50 Yuan / m^2	20.88 Yuan / m^2
Roof	373.50 Yuan / m^2	208.50 Yuan / m^2	293.28 Yuan / m^2	127.44 Yuan / m^2
Total	5,233.74 Yuan / m^2	3,370.44 Yuan / m^2	732.78 Yuan / m^2	347.52 Yuan / m^2

Table 1.3.6: Savings based on coal at 200 Yuan per ton

Savings (Yuan /yr)		Payback for Option-1 (Canadian costs) (Years)	Payback for Option -1 (Chinese costs) (Years)	Payback for Option -2 (Canadian costs) (Years)	Payback for Option -2 (Chinese costs) (Years)
Walls-exterior	8,443.08	277	145	62	37
Stair walls	1,335.36	342	179	85	50
Windows	2,186.16	589	434	14	8
Roof	2,046.18	84	47	115	58
Total	14,010.78	288	167	64	37

Table 1.3.7: Savings based on coal at 1,000 Yuan per tons

Savings (Yuan /yr)		Payback for Option -1 (Canadian) (Years)	Payback for Option -1 (Chinese) (Years)	Payback for Option -2 (Canadian) (Years)	Payback for Option -2 (Chinese) (Years)
Walls-exterior	26,880.00	55	29	11	7
Stair walls	4,630.00	68	36	14	8
Windows	5,450.00	118	87	2	1
Roof	7,790.00	17	9	13	7
Total	44,750.00	58	33	10	6

Building Economic Analysis

- Life-cycle cost (LCC) analysis, or LCCA
  - A long-term approach
  - Takes into account the total cost of the building over its lifetime
  - All costs, from owning, operating, maintaining, and disposing of a building are considered
- Reference:
  - NIST (U.S. National Institute of Standards and Technology) Handbook on LCC method
    - www.wbdg.org/ccb/NIST/hdbk_135.pdf

Building Economic Analysis

- Key steps for applying LCC analysis
  - 1. Define the problem and state the objectives
  - 2. Identify the feasible alternatives
  - 3. Establish common assumptions and parameters
  - 4. Estimate costs and times of occurrence for each alternative
  - 5. Discount future costs to present values
  - 6. Compute and compare LCC for each alternative
  - 7. If required, compute supplementary measures for project prioritization
  - 8. Assess uncertainty of input data
  - 9. Take into account effects for which dollar costs or benefits cannot be estimated
  - 10. Advise on the decision

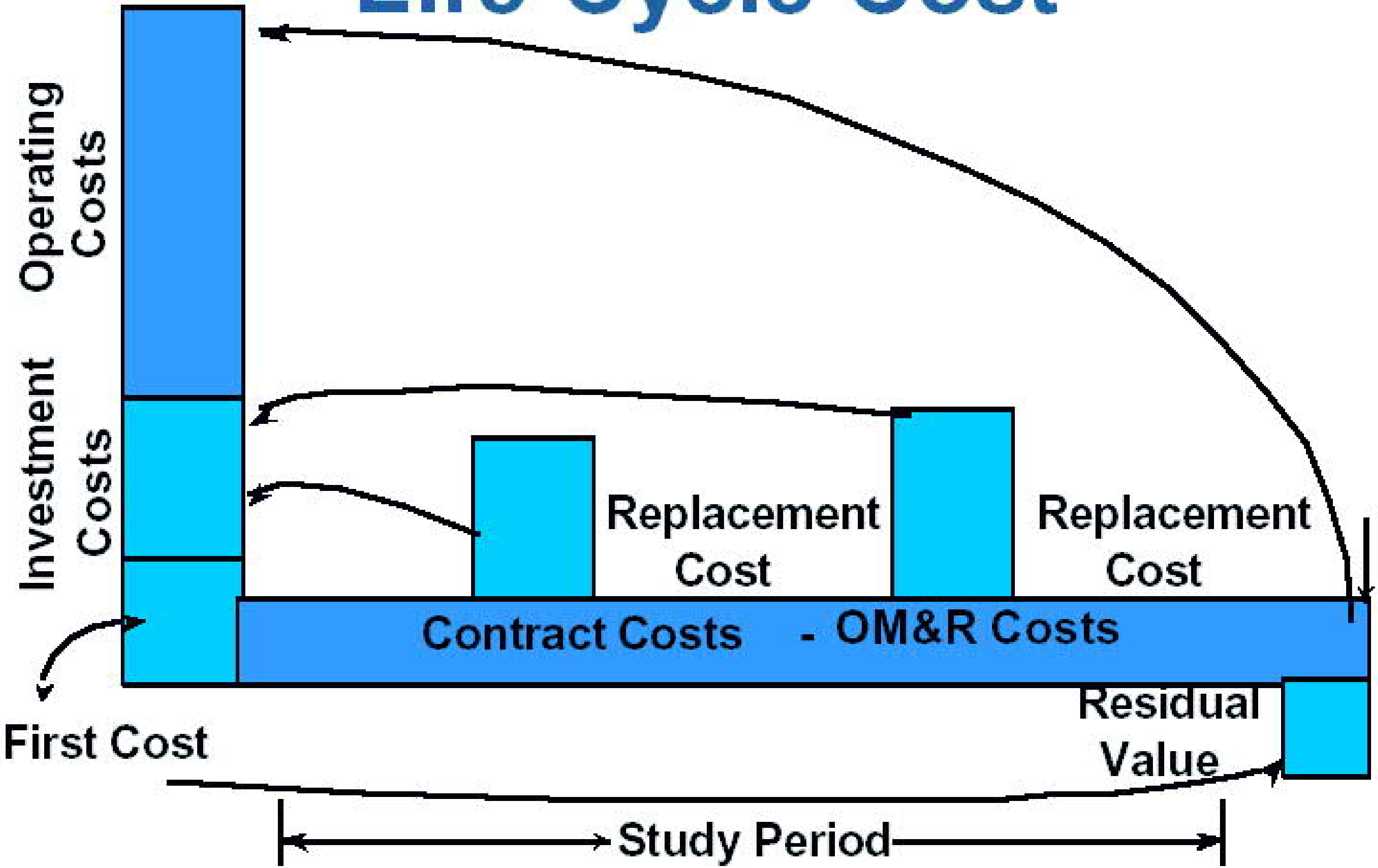
Building Economic Analysis

- General life cycle cost (LCC) equations

$$LCC = \sum_{t=0}^{N} \frac{C_t}{(1+d)^t} \qquad PWF = \frac{\left[1 - \frac{1}{(1+d)^N}\right]}{d}$$

  - C_t = sum of all relevant costs occurring in year t
  - N = number of years in the study period
  - d = discount rate used to adjust cash flow to present value
  - PWF = present worth factor

Life-Cycle Cost



Building Economic Analysis

- Simplified LCC equation: (for energy projects)*
  - $LCC = I + Repl - Res + E + W + OM\&R$
  - Where:
    - *LCC* is the total LCC in present-value dollars of a given alternative
    - *I* is the present-value investment cost
    - *Repl* is the present-value capital replacement cost
    - *Res* is the present-value residual value (resale value, scrap value, salvage value) minus the disposal costs
    - *E* is the present-value energy cost
    - *W* is the present-value water cost
    - *OM&R* is the present-value non-fuel operating, maintenance, and repair costs

May be estimated by building energy simulation

* Need to use engineering judgment when estimating these costs

Building Economic Analysis

- Example of HVAC system cost over 30 years:
  - Energy cost = 50%
  - Maintenance cost = 4.7%
  - Replacement cost = 2.3%
  - HVAC first cost = 43%
- Residual value:
  - Based on value in place, resale value, salvage value, or scrap value, net of any selling, conversion, or disposal costs

Building Economic Analysis

- Other financial indicators
  - *Net Savings (NS)*: are a relative measurement of the economic performance for investments, which reduces operational cost (= operational savings less difference in capital investment costs)
  - *Adjusted Internal Rate of Return (AIRR)*: is a relative measure of annual percentage yield from a project investment over the study period and must be measured with respect to a base case

Building Economic Analysis

- Other financial indicators (Cont'd)
  - *Savings-to-investment (SIR) ratio*: is defined as being a relative measure of economic performance for a project alternative expressing the relationship between its savings and its increased investment present value cost as a ratio
    - Justified if $SIR > 1$
    - Used to rank projects with other independent projects as a guide to allocate limited investment funding

Building Economic Analysis

- Evaluation Criteria
  - SPB, DPB < than study period (for screening projects)
  - NS > 0 (for determining cost-effectiveness)
  - SIR > 1 (for ranking projects)
  - AIRR > discount rate (for ranking projects)
  - Lowest LCC (for determining cost-effectiveness)
- Uncertainty assessment, e.g. using sensitivity analysis and break-even analysis

Table 1.4.1: Simple payback calculations approach

Options	Installation cost (Yuan)	Life	Gross Savings (Yuan)	Payback loss (8%)	Net Savings (Yuan)	Investment on savings ratio
1. Caulking	40,000	15	150,000	14,419	135,580	29.5 %
2. Boiler retrofit	60,000	20	300,000	21,629	278,370	21.5 %
3. New boiler	80,000	30	600,000	28,839	571,160	14.0 %

Building Economic Analysis

- Case study: LCCA method
  - Purchase of a central air conditioner for a house
    - To select a new central air conditioner for installation in a house with a design-cooling load of 38.0 MJ/hr (36,019 Btu/hr) in a region with approximately 1,500 fullload cooling hours per year
    - Seasonal energy efficiency ratio (SEER)
    - Assumptions:
      - Electricity rates = $0.08/kWh (summer rates), with no demand charge, and are expected to increase at about 3% per year
      - Discount rate = 8%
      - All three systems have an expected life of 15 years and approximately the same maintenance costs

Table 1.4.1 LCC analysis for air conditioners (Source: Marshall 1995)

		System A	System B	System C
Seasonal energy efficiency ratio (Btuh/W) SEER obtained from product literature		10.0	12.0	14.0
Annual kWh use $kWh = \frac{36{,}000 Btuh}{SEER} \times 1{,}500 h/year$		5,400	4,500	3,855
Annual kWh cost ($) $Cost = kWh \times \$0.08/kWh$		432	360	308
Present Value kWh Cost ($) $PV = Cost \times 10.48^{*}$		4,527	3,773	3,234
Without utility rebate	**Initial cost ($)**	2,000	2,500	3,100
	Total LCC	6,527	6,273	6,334
With utility rebate	**Initial cost ($)**	2,000	2,200	2,500
	Total LCC	6,527	5,973	5,734

* 10.48 is the UPV factor for an annually recurring cost increasing at a rate of 3% and discounted at 8% per year

Lowest total LCC w/o rebate (System B, Total LCC without utility rebate: 6,273)

Lowest total LCC w/ rebate (System C, Total LCC with utility rebate: 5,734)

Whole Life Costing

- Definition: **Whole Life Cost (WLC)*** is the analysis of all relevant and identifiable financial cashflows regarding the acquisition and use of an asset (i.e. a wider economic analysis)
  - A technique that quantifies financial values for buildings from inception and throughout the building's life
  - A systematic approach balancing capital with revenue costs to achieve an optimum solution over a buildings whole life, considering risk management
  - A critical step for organisations wishing to move towards sustainability

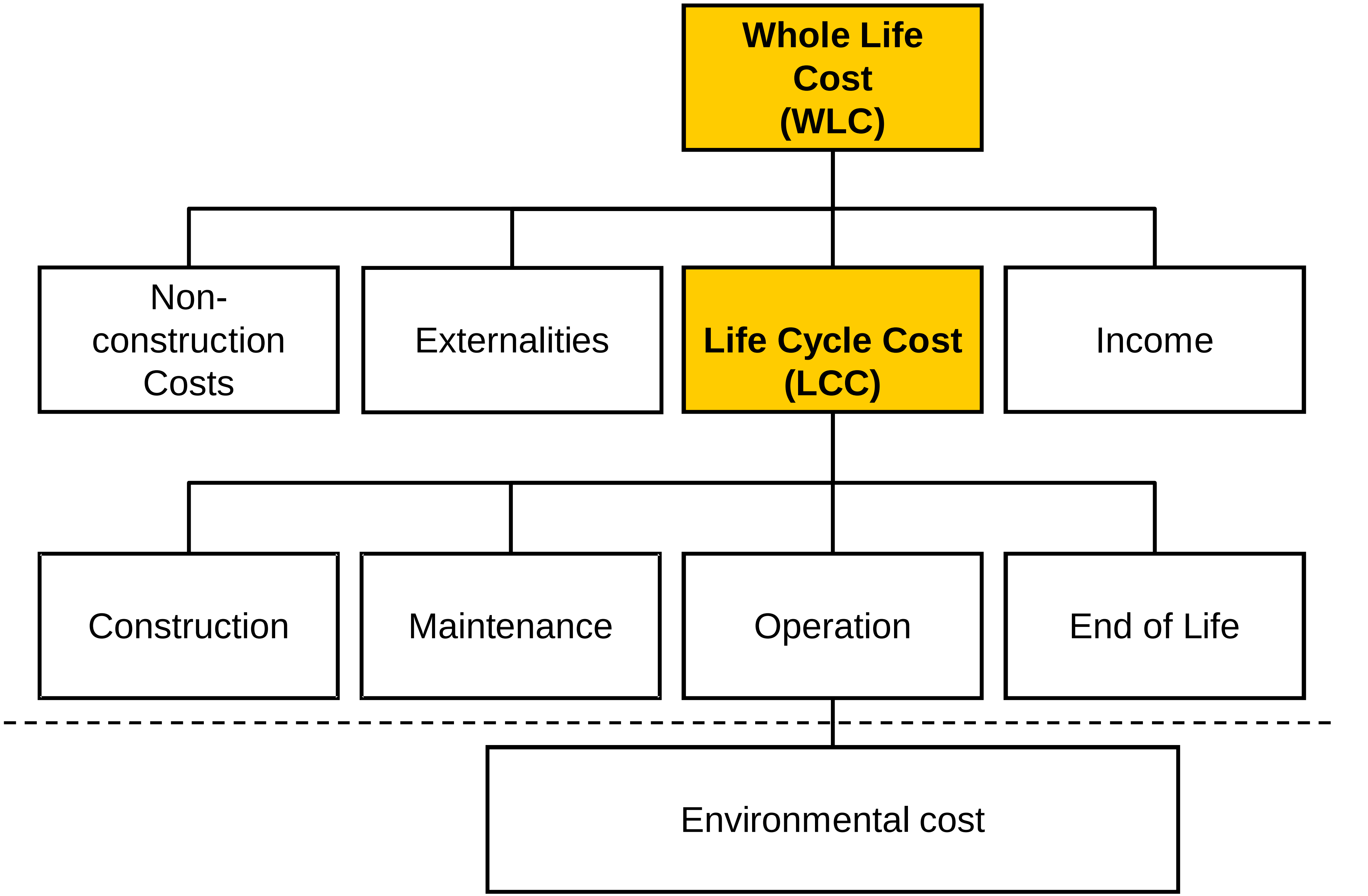
(*Also known as through-life costs or total ownership costs)

Whole Life Costing

- Life cycle cost (LCC) & whole life cost (WLC)
  - **LCC** are those associated directly with constructing and operating the building
  - **WLC** include other costs such as land, income from the building and support costs associated with the activity within the building
  - The expertise of the construction industry is best placed to deliver life cycle costs, which its clients can then use to calculate whole life costs

(See also http://en.wikipedia.org/wiki/Whole-life_cost)

Life cycle cost (LCC) & whole life cost (WLC)



(Source: Adapted from BS ISO 15686-5)

Components of life cycle cost (LCC)

Construction
▪ Professional fees (incl. design)
▪ Temporary works
▪ Construction
▪ Initial adaptation or refurbishment
▪ Taxes
▪ Other (Contingencies)
Maintenance
▪ Replacements of major systems
▪ Adaptation or refurbishment
▪ Repairs and minor replacements
▪ Maintenance management
▪ Cleaning
▪ Grounds Maintenance
▪ Redecoration
▪ Taxes
▪ Other (user definable) (optional)

Operation
▪ Rent
▪ Insurance
▪ Cyclical regulatory costs
▪ Utilities
▪ Taxes
▪ Future regulation
▪ Other (user definable) (optional)
End of Life
▪ Disposal inspections
▪ Disposal and demolition
▪ Reinstatement
▪ Taxes
▪ Other (user definable) (optional)

Components of whole life cost (WLC)

Non-construction Costs
▪ Land and enabling works
▪ Finance
▪ Strategic property management
▪ User charges
▪ User support costs
▪ Taxes
▪ Other (user definable) (optional)
Income
▪ Income from sales
▪ Third party income
▪ Taxes
Life Cycle Cost

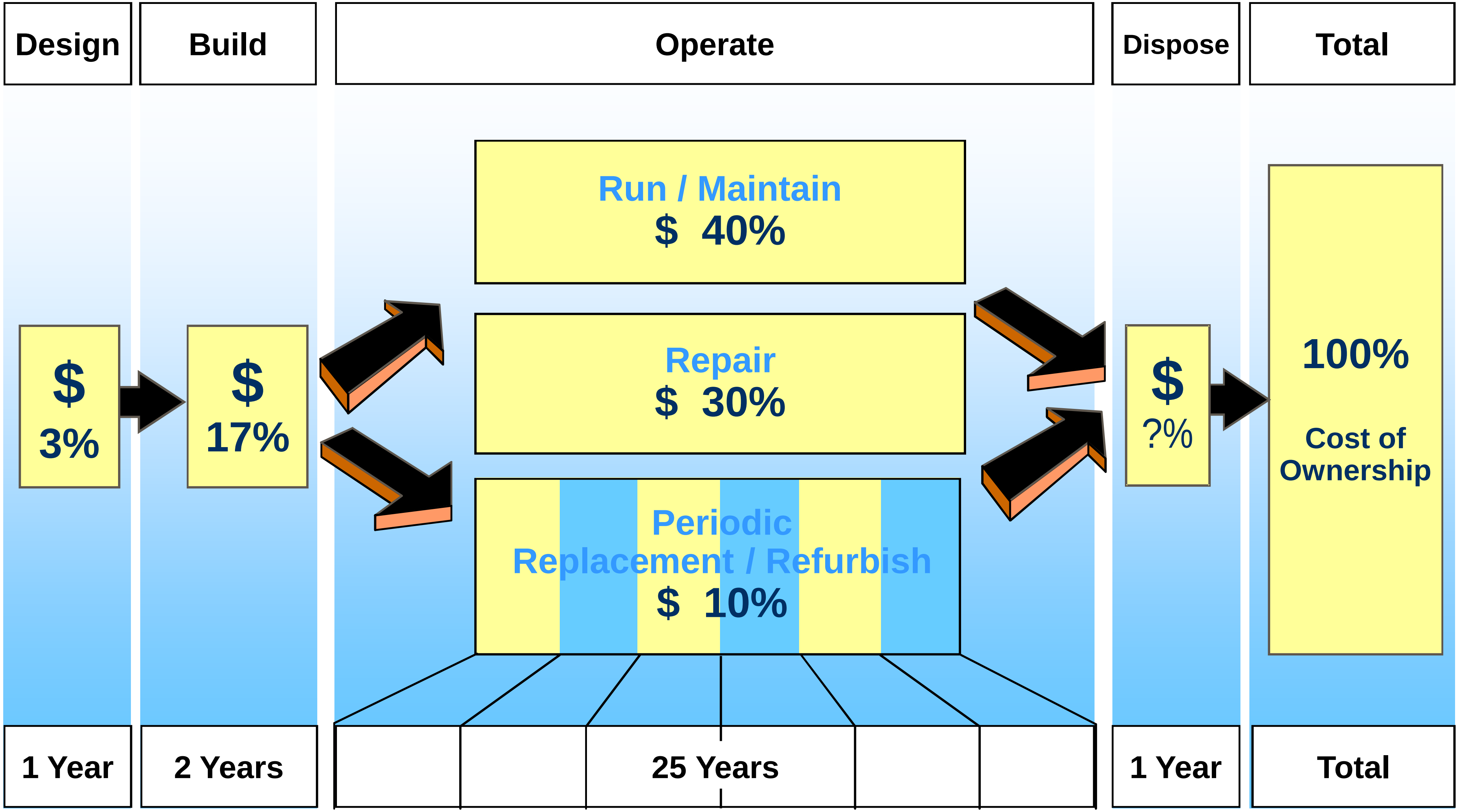
Externalities
▪ Costs associated with an asset which are not necessarily reflected in the transaction costs between provider and consumer ▪ Many *negative externalities* are related to the environmental consequences of production and use. For example, air pollution from burning fossil fuels causes damages to crops, (historic) buildings and public health. ▪ *Positive externalities* are beneficial externality or external benefit. For example, a beekeeper keeps the bees for their honey. A side effect or externality associated with her activity is the pollination of surrounding crops by the bees. The value generated by the pollination may be more important than the value of the harvested honey.

Whole Life Costing

- Whole life cost ratios (typical)*
  - **Capital Cost : Cost in Use : Business Costs**
  - **= 1 : 5 : 200**
    - Cost of initial investment: 1
    - Additional cost for operation & maintenance during the life cycle: 5
    - Economic value embodied over the same period (function and staff load, quality of life, working ambience, comfort & health): 200

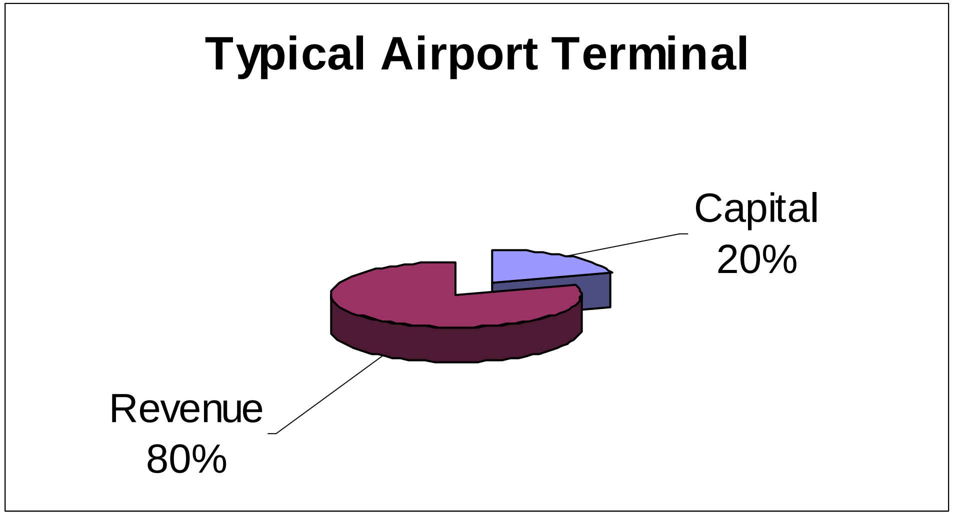
* Source.: "The long term costs of owning and using buildings" – published by The Royal Academy of Engineering (November 1998).

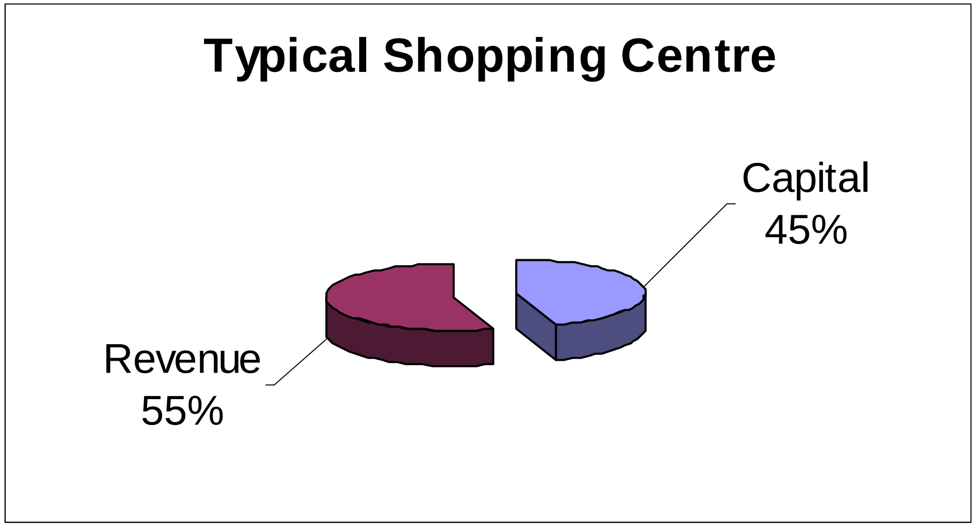
Whole life cost – the Big Picture

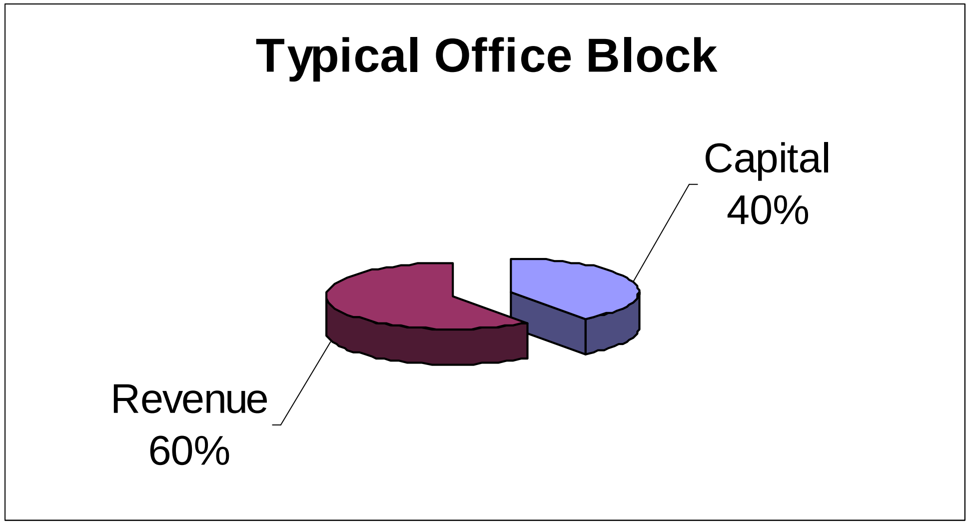


(Source: www.wlcf.org.uk)

Whole life cost – Rules of Thumb

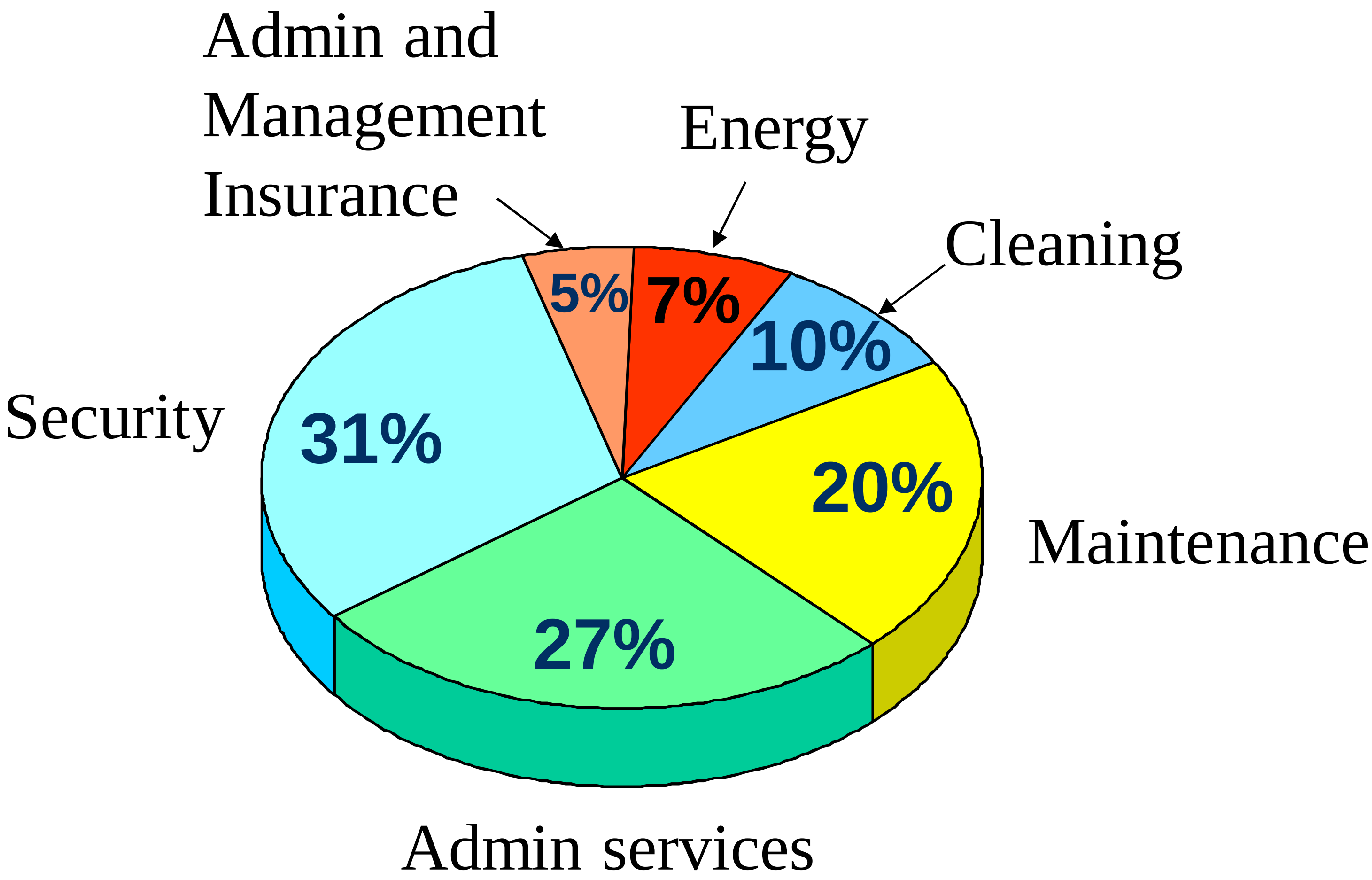






(Source: www.wlcf.org.uk)

Revenue Cost Breakdown

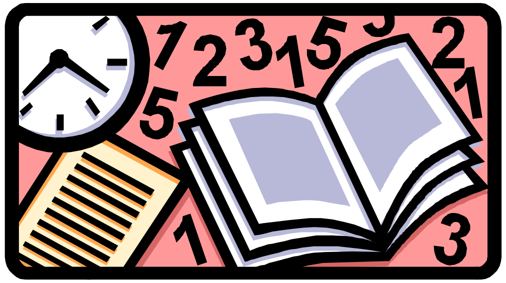


(Source: www.wlcf.org.uk)

Whole Life Costing

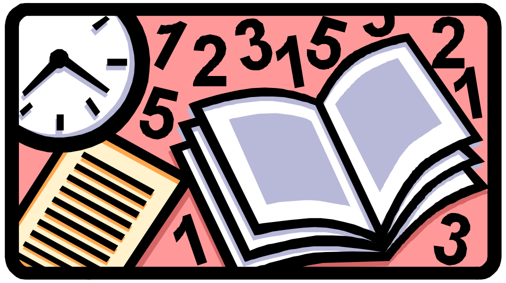
- Design stage
  - Design service life planning
  - Design environmental life-cycle assessment
  - Whole life-cycle cost planning
  - Whole life risk & risk responses
- Construction and occupancy stages
  - Whole life risk & risk responses (construction & operation)
  - Whole life-cycle costing (operation)
  - Whole life costing of building assets occupancy

Further Reading



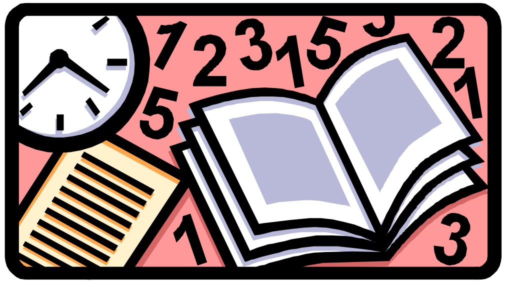
- ETSU, 1995. *Financial Aspects of Energy Management in Buildings - A Summary*, Good Practice Guide 75, Energy Efficiency Best Practice Programme, Energy Technology Support Unit (ETSU), Oxfordshire, UK, 6 pages.
  - http://www.mech.hku.hk/bse/MEBS6016/GPG075.pdf
- Whole Building Design Guide
  - Use Economic Analysis to Evaluate Design Alternatives http://www.wbdg.org/design/use_analysis.php
  - Life-Cycle Cost Analysis (LCCA) http://www.wbdg.org/resources/lcca.php

Further Reading



- Jean-Louis,M.-J., Paré, M. and Nichols, L., 2002. *Learning Unit 05: Building Economic Analysis*, Increasing Energy Efficiency in Buildings Project, China, Dessau-Soprin Inc., Montreal, Canada, pp. 1-17.
  - www.mech.hku.hk/bse/MEBS6016/building_economic_analysis.pdf

References



- USEPA, 2008. *EnergyStar Building Upgrade Manual*, Chp. 3 & 4, U.S. Environmental Protection Agency, Washington, DC. [http://www.energystar.gov/index.cfm?c=business.bus_upgrade_manual]
- Boussabaine, H. and Kirkham, R. J., 2004. *Whole Life-cycle Costing: Risk and Risk Responses*, Blackwell Pub., Oxford. [692.5 B777 w]
- NIST Handbook 135 Life-Cycle Costing Manual, http://www.wbdg.org/ccb/NIST/hdbk_135.pdf
- OGC, 2007. *Whole-life Costing*, Achieving Excellence in Construction Procurement Guide 7, Office of Government Commerce (OGC), London. [PDF]