ECONOMICAL AND FINANCIAL ANALYSIS OF INVESTMENT

1. Capital investment estimation

Expenditure description

In contrast to fuel costs and O&M costs, which are continuous or repetitive in nature, an investment cost is a one-time cost.

According to Tab.1.1, the capital needed to purchase the land, build all the necessary facilities, and purchase and install the required machinery and equipment for a system is called f*ixed-capital investment* (FCI). The fixed-capital investment represents the total system cost assuming a so-called overnight construction, that is a zero-time design and construction period. The *total capital investment* (TCI) is the sum of the fixed-capital investment and *other outlays* (OO).

Cost estimates for fixed-capital investment consist of two major cost elements: direct and indirect costs. *Direct costs* (DC) are the costs of all permanent equipment, materials, labour, and other resources involved in the fabrication, erection and installation of the permanent facilities. *Indirect costs* (DC) do not become a permanent part of the facilities but are required for the orderly completion of the project. Other outlays consist of startup costs, working capital, costs of licensing, research and development, allowance for funds used during construction (interest incurred during construction).

So the following equations can be written:

$$TCI=FCI+OO \qquad (1.1)$$

(Total Capital Investment = Fixed Capital Investment + Other Outlays)

$$FCI=DC+IC \qquad (1.2)$$

(Fixed Capital Investment =Direct Costs + Indirect Costs)

I) **Fixed Capital Investment (FCI)**

Direct Costs (DC)

1. Onsite costs (ONSC)
   - Purchased Equipment cost (PEC)
   - Purchased Equipment installation (PECI)
   - Piping (PIP)
   - Instrumentation and controls (INCO)
   - Electrical equipment and materials (EEM)
2. Offsite costs (OFSC)
   - Land (LAND)
   - Civil, structural, architectural work (CSAW)
   - Service facilities (SF)

Indirect Costs (IC)

1. Engineering and supervision (ES)
2. Construction Costs including contractor's profit (COCO)
3. Contingencies (CO)

II) **Other Outlays (OO)**

1. Startup costs (SUC)
2. Working capital (WC)
3. Costs of licensing research, development (LDR)
4. Allowance for funds used during construction (AFUDC)

Tab. 1.1 – *Estimate of total capital investment (TCI)*

Financing

The money to cover the total capital requirement of an investment can come through the following sources:

- Borrowing capital, for instance, by selling bonds (debt financing)
- The sale of common and preferred stocks (equity financing)
- Existing funds of the company

Since a non-zero cost of money can be applied also to existing funds of the company, in the framework of GTPOM project just the first two types of financing have been considered. The available financing sources are:

1. Debt (d)
2. Preferred Stock (ps)
3. Common Equity (ce)

Every combination of such financing sources is possible.

The returns on debt and equity represent the amount that investors (stockholders and debtors, respectively) are paid for the use of their money. The average cost of money in a project depends on the fractions of the total capital requirement financed through debt, preferred stock and common stock and on the required return on each type of financing.

Debt return is considered to be deductible on tax calculation for the company.

Also during plant construction time interests will be paid to investors: such returns are called *Allowance for Funds Used During Construction* (AFUDC) and depend on the total capital investment distribution during all the construction period[1]. In such time interval each annual expenditure is supposed to be concentrated in the middle of the year. Thus, AFUDC for each type of financing cab be calculated through the following equation:

$$AFUDC_{tp} = \sum_{I=1}^{con\_t} Alloc\_inv_{tp}(I) \cdot \left(1 + r_{tp}\right)^{(con\_t - I + 0.5)} \qquad (1.3)$$

where

"tp"	type of financing: d,ps,ce
con_t	construction period
$Alloc\_inv_{tp}$ (I)	investment fraction allocated in the I-th year of construction period (different in general for each type of financing)
r_{tp}	cost of money (depends on the type of financing)

Total AFUDC is given summing the interest for each type of financing:

$$AFUDC= AFUDC_d+ AFUDC_{ps}+ AFUDC_{ce})$$

[1] Since just the working capital (WC) is charged at the end of the last year of construction, AFUDC is calculated basing on the distribution curve (given by the program user) of FCI+SUC+LDR, that is TCI-WC-AFUDC (see Tab.1).

Depreciation and Total Capital Recovery calculation

Depreciation reflects the fact that the value of an asset tends to decrease with age (or use) due to physical deterioration, technological advances and other factors that ultimately will lead to the retirement of the asset. In addition, depreciation is a mechanism for repaying the original amount obtained from debt holders if debt is to be retired. Finally, depreciation is an important accounting concept serving to reduce taxes during plant operation: in that respect the asset life used for tax purposes (as determined by statute) could be shorter than the asset's anticipated economic life.

The *Total Depreciable Investment* (TDI), that must recovered during the system economic life, can be expressed as follows

:

$$TDI=TCI-(LAND+WC+AFUDC_{ce}) \qquad (1.4)$$

Working capital (WC) and cost of land are not recovered during the system economic life since they are considered to be recovered as common equity at the end of the book life[2]. $AFUDC_{ce}$, that is the interest paid to common equities during the construction period, is not accounted by tax depreciation: in that respect it is at the moment subtracted from TDI but will be later added with the term "RCEAF" (*Recovery of Common Equity Allowance Funds*)", as shown by eq.1.9 .

The annual *Book Depreciation* (BD) is calculated basing on TDI:

$$BD_j=[TDI-(Salvage)]\cdot f_j \qquad (1.5)$$

where

"Salvage" is the salvage value of the property at the end of system economic life

f_j is the depreciation factor at the j-th year of book life

[2] Land and working capital (raw materials and fuel stocks), that is always renewed during plant life, do not depreciate.

With respect to f_j , there are many methods for depreciating the value of an asset. Tab.1.2 summarises the mathematical relationships that can be used to calculate the depreciation allocation and the cumulative depreciation at the end of a year of the property life.

	Method	$\mathbf{f_j}$	$\sum_{z=1}^{j} f_z$
1.	Straight line	$1/n$	j/n
2.	Sum-of-the-years digits	$2/n\cdot(n+1-j)/(n+1)$	$j\cdot(2n+1-j)/[n(n+1)]$
3.	Double declining balance (n>=3) *	$2/n\cdot[(n-2)/n]^{j-1}$	$1-[(n-2)/n]^j$
4.	125% declining balance *	$1.25/n\cdot[(n-1.25)/n]^{j-1}$	$1-[(n-1.25)/n]^j$
5.	Sinking fund	$r_i\cdot(1+r_i)^{j-1}/[(1+r_i)^n-1]$	$[(1+r_i)^j-1]/[(1+r_i)^n-1]$

(n=book life=plant economic life; r_i = interest rate - inflation rate; z= attained age of the property [1,n])

* These two methods require a salvage value of the property at the end of the economic life equal to zero.

Tab. 1.2 – *Summary of depreciation methods*

Tax Depreciation (TXD) at the j-th year of the asset tax life can be obtained with the following formula:

$$TXD_j=TDI\cdot ftx_j \tag{1.6}$$

where ftx_j is the annual tax depreciation factor at the j-th year of plant tax life: in general, it is different from the previous f_j .

Since a difference between the annual tax depreciation (TXD) and the annual book depreciation (BD) usually exists, the *Deferred Income Taxes* (DITX) can be defined:

$$DITX_j=(TXD_j-BD_j)\cdot t \tag{1.7}$$

where t is the average income tax rate.

The common equity allowance for funds used during construction ($AFUDC_{ce}$) which is not considered in the total depreciable investment (TDI, eq.1.4) is recovered using the annual *Recovery of Common Equity Allowance Funds* (RCEAF), which is defined, in accordance with book depreciation (BD), as:

$$RCEAF_j=AFUDC_{ce}\cdot f_j \tag{1.8}$$

The *Total Capital Recovery* (TCR) for the j-th year of book life is the sum of book depreciation (eq.1.5), deferred income taxes (eq.1.7) and recovery of common equity allowance funds (eq.1.8):

$$TCR_j=BD_j+DITX_j+RCEAF_j \tag{1.9}$$

The sum of total annual capital recovery values plus working capital and cost of land is equal to the total plant investment.

Returns on Equity and Debt

The total capital investment (TCI) is distributed at the beginning of the first year of book life among debt, preferred stock and common equity with specified financing fractions (named respectively ff_d, ff_{ps}, ff_{ce}). This assumption determines the balances at the beginning of the first year ($BBY_{1,tp}$) for each type of financing:

$$BBY_{x,1}=TCI\cdot ff_x \qquad x=d,ps,ce \tag{1.10}$$

It is assumed further that deferred taxes are distributed among each type of financing according to the corresponding fraction. Adjustments (ADJ) becomes necessary in order to account deferred income taxes (DITX) into calculation of the balances at the beginning of the j-th year ($BBY_{x,j}$):

$$ADJ_{x,j}= DITX_j\cdot ff_x \qquad x=d,ps \tag{1.11}$$

$$ADJ_{ce,j}= DITX_j\cdot ff_{ce}+RCEAF_j \tag{1.12}$$

The adjustments for common equity (ADJ_{ce}) also includes the recovery of common equity allowance for funds used during construction.

The balance at the beginning of the j-th year ($BBY_{x,j}$) for each type of financing is:

$$BBY_{x,j}= BBY_{x,j-1}-(ff_x\cdot BD_{j-1} + ADJ_{x,j-1}) \qquad x=d,ps,ce \tag{1.13}$$

The balance at the beginning of the year immediately following the last year of operation is zero for debt and preferred stock but equal to the value of land and working capital for common equity.

According to the total revenue requirement method of economic analysis, the depreciation funds are assumed to be used to pay back investors for the principal. This assumption is used because it helps to compare alternative investments. In an expanding company, however, these funds would likely be reinvested.

For each investment type, the *return on investment* (ROI) calculation for any year of the system operation is based on the outstanding investment: the balance at the beginning of the year (BBY) for the corresponding investment. That is, the return on investment for year j is:

$$ROI_{x,j} = BBY_{x,j} \cdot r_x \qquad x=d,ps,ce \tag{1.14}$$

where r_x is the annual nominal rate of return for the x-th investment type.

Taxes and Insurance

The annual sum of taxes (property taxes), without the annual *income taxes* (ITX), and insurance costs (OTXI) may be calculated as a constant percentage (f_{OTXI})of the plant facilities investment, that is the fixed capital investment (FCI) less the cost of land:

$$OTXI_j = f_{OTXI} \cdot (FCI-LAND) \tag{1.15}$$

The underlying assumption is that, since property taxes increase with time and insurance costs decrease with time, the sum of the two remains constant..

In order to calculate the annual income tax (ITX), the annual *taxable income* (TXI) must be determined first. It can be evaluated by subtracting annual tax-deductible expenditures from the annual *total revenue requirement* (TRR).

The total revenue requirement (TRR) is equal to the sum of the following nine annual amounts: total capital recovery (TCR); minimum return on investment (ROI) for common equity, preferred stock and debt; income taxes (ITX); other taxes and insurance (OTXI); fuel costs and supply materials (FuelC); operating and maintenance costs (O&MC); environmental costs (EnvC, costs for the emissions of pollutants):

$$TRR_j = TCR_j + ROI_{d,j} + ROI_{ps,j} + ROI_{ce,j} OTXI_j + ITX_j + O\&MC_j + FuelC_j + EnvirC_j \tag{1.16}$$

To calculate the annual taxable income (TXI), the tax-deductible expenditures for the j-th year of operation consist of interest on debt ($ROI_{d,j}$), other taxes and insurance ($OTXI_j$), fuel costs ($FuelC_j$), operating and maintenance costs ($O\&MC_j$), environmental costs ($EnvC_j$) and tax depreciation (TXD_j):

$$TXI_j = (TCR_j + ROI_{d,j} + ROI_{ps,j} + ROI_{ce,j} + OTXI_j + ITX_j + O\&MC_j + FuelC_j + EnvirC_j) - (ROI_{d,j} + OTXI_j + FuelC_j + O\&MC_j + EnvirC_j + TXD_j) \quad (1.17)$$

The eq.1.17 becomes:

$$TXI_j = TCR_j + ROI_{ce,j} + ROI_{ps,j} + ITX_j - TXD_j \quad (1.18)$$

where TXD_j is found using eq.1.6. Note that the income taxes to be paid during the j-th year (ITX_j) are part of the same year's taxable income (TXI_j). The income taxes are:

$$ITX = t \cdot TXI \quad (1.19)$$

where t is the average income tax rate.

Equations 1.18 and 1.19 lead to the following expression for ITX:

$$ITX_j = t/(1-t) \cdot (TCR_j + ROI_{ps,j} + ROI_{ce,j} - TXD_j) \quad (1.20)$$

Combining equations 1.9 and 1.20, the following relation can be obtained:

$$ITX_j = t/(1-t) \cdot (ROI_{ps,j} + ROI_{ce,j} + RCEAF_j) - DITX_j \quad (1.21)$$

Eq. 1.20 and 1.21 can be used alternatively for calculating the income taxes of the j-th year.

It should be noted that ITX_j are the income taxes for annual revenue equal to the total revenue requirement (TRR): if greater revenues are collected, additional income taxes must be paid (see eq.2.2).

Total Revenue Requirement

The already mentioned *Total Revenue Requirement* (TRR, eq.1.16) represents the minimum acceptable revenue for the plant at each year of its operating life. It can be divided in two major addends: annual fixed capital costs (A_{TRRj}) and annual variable costs (B_{TRRj}):

$$TRR_j = A_{TRRj} + B_{TRRj} \quad (1.22)$$

where:

$A_{TRRj}=TCR_j+ROI_{d,j}+ROI_{ps,j}+ROI_{ce,j}$

$B_{TRRj}=OTXI_j+ITX_j+O\&MC_j+FuelC_j+EnvC_j$

Eq.1.22 is equivalent to eq.1.16.

All the variable costs (fuel, supply materials, O&M) and revenues are escalated at the end of each year of plant operating life.

Other taxes (property taxes) and insurance costs (OTXI) have been included in the term “B_{TRRj}“ just to better define the parameters for investment analysis, explained in the next paragraph.

2. Profitability evaluation of investment

Before capital is invested in a project, it is necessary to estimate the expected profit from the investment. Most capital expenditure decisions involve choosing the "best" of a number of alternative solutions that, often, are mutually exclusive. Thus, calculating the profitability of an investment and choosing the best alternative are important objectives of an economic analysis. In profitability calculations profits and costs that will occur in the future will be considered, so that the associated risks and uncertainties may be significant. However, the analysis of investments and decisions under risk and uncertainty is outside the scope of GTPOM project: in that respect, a *deterministic investment analysis* has been implemented inside the economic module.

Before presenting the most significant parameters for investment profitability evaluation, calculation of the annual gross and net profit is necessary. Considering the j-th year of plant operating life, the annual *gross profit* (GP_j) is found by subtracting the annual *total revenue requirement* (TRR_j) to the annual *revenue* (Rv_j) that is collected by selling plant products (electricity and heat):

$$GP_j = Rv_j - TRR_j \tag{2.1}$$

Annual *net profit* (NP_j) is:

$$NP_j = GP_j \cdot (1-t) \tag{2.2}$$

where t is the average income tax rate.

Finally, the sum of net profit (NP_j) and total capital recovery (TCR_j) gives the annual *net cash flow* (CFN_j):

$$CFN_j = NP_j + TCR_j \tag{2.3}$$

Sometimes net cash flow CFN is also called "contribution".

Now, the following parameters can be defined:

Average rate of return (ARR)

$$ARR = \overline{NP} / TCI \tag{2.4}$$

The *average rate of return* (ARR) on the initial investments is the ratio between the average annual net profit ($\overline{NP}$) and the total capital investment (TCI), including working capital (WC). Although the average rate of return method is sometimes used to evaluate and compare projects, it could give misleading results because the time value of money is not included in the calculation.

Payback Period (PBP)

$$TCI=\sum_{j=1}^{PBP} CFN_j \quad (2.5)$$

The *payback period* (PBP) is defined as the length of time required for the cash inflows received from a project to recover the original cash outlays required by the initial investment. Mathematically it is defined by eq.2.5, where "PBP" can also be a fractional number of years (3.4, 3.8, 4.2, etc…).

The payback period is often used as a limit rather than as a direct criterion. However, such a method may be used to rank various project alternatives: those with the shortest payback periods are given the highest preference. Although this parameter is quite popular, it does not consider the time value of money and discriminates against long-lived projects.

Discounted Payback Period (DPBP)

$$TCI=\sum_{j=1}^{PBP} [CFN_j/(1+r_{DPBP})^j] \quad (2.6)$$

The *discounted payback period* (DPBP) is defined similarly to payback period, but the annual net cash flows are discounted with a specific discount rate (r_{DPBP}) to the last year of construction. The discounted payback period has the same features of payback period with, in addition, the consideration of the time value of money. In that respect, it is a more complete parameter to compare different project solutions.

Net Present Value (NPV)

$$NPV=\sum_{j=1}^{BL} [CFN_j/(1+r_{NPV})^j] - TCI \quad (2.7)$$

The *net present value* (NPV) of an investment is defined as the difference between the sum of all discounted net cash flows and the initial total capital investment (TCI). The net present value can be either positive or negative: the projects with negative present values should be rejected and the projects with the highest net present values should be given the highest preference.

Net present value method accounts for time value of money through the discount rate r_{NPV} that is, in general, different from the inflation rate. In fact, it implies that each net cash flow at the end of each time period is re-invested at an annual rate of return equal to r_{NPV}.[3]

Benefit-Cost Ratio Method

Three benefit-cost ratios that can be use to evaluate the profitability of an investment are:

Benefit-Cost Ratio(**BCR**) BCR=(NPV+TCI)/TCI (2.8)

Net Benefit-Cost Ratio(**NBCR**) NBCR=NPV/TCI=BCR-1 (2.9)

Eckstein Benefit-Cost Ratio(**EBCR**)

$$EBCR = \sum_{j=1}^{BL}[Rv_j/(1+r_{EBCR})^j] \Big/ TCI + \sum_{j=1}^{BL}[B_{TRRj}/(1+r_{EBCR})^j] \qquad (2.10)$$

The benefit-cost ratio method provides a criterion based on the net present value (or the present value of net cash inflows) per unit of initial investment, which is a criterion expressing the cost efficiency of a project. In decision making, however, there is no particular advantage in using the benefit-cost ratio method over the net-present-value method.

Internal Rate of Return (IRR)

$$\sum_{j=1}^{BL} [CFN_j/(1+IRR)^j] - TCI = 0 \qquad (2.11)$$

Both the net present value and benefit-cost methods use an interest rate that is usually based on the company's cost of money but is external to the specific project being considered. The *internal rate of return* (IRR) method seeks to avoid the arbitrary choice of an interest rate; instead, it calculates an interest rate, initially unknown, that is internal to the project: in eq.2.11 the internal rate of return IRR is the unknown variable and has to be found iteratively. The projects with the highest internal rates of return are given the highest preference.

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[3] This consideration is valid for all the parameters that accounts for time value of money and use a discount rate.

The internal rate of return does not express the rate of return of the initial investment. It represents instead the rate of interest earned on the time-varying, unrecovered balances of an investment such that the final investment balance is zero at the end of the project life.

Cumulative curves

In addition to the previous parameters, it can be useful to look at the following two cumulative curves:

- Net Cash Flow cumulative curves

  During the construction period it is negative till the value "-TCI". When the plant starts operating, its slope becomes positive and it comes to zero after a time interval equal to the payback period (PBP).
- Discounted Net Cash Flow cumulative curves

  During the construction period it is negative till the value "-TCI". When the plant starts operating, its slope becomes positive and it comes to zero after a time interval equal to the discounted payback period (DPBP).

3. Economic analysis options

Current money / Constant money

The *real interest rate* (*real discount rate*) is the money paid for the use of capital that does not include an adjustment for the anticipated general price-inflation rate in the economy. This adjustment is included, however, in the *nominal interest rate* (*nominal discount rate*). The relationship between the real interest rate (r_r) and the nominal interest rate (r_n) is:

$$(1+r_n)=(1+r_i)\ (\ 1+r_r) \quad (3.1)$$

where r_i is the general inflation rate.

An economic analysis can be conducted either in *current money* by including the effect of inflation in projections of capital expenditures, fuel costs, O&M costs, or in *constant money* by excluding inflation and considering only real escalation rate in cost projections and the real cost of money. In general, a current-money analysis gives the impression that the project being analysed is more costly than we would expect on today's cost values, whereas a constant money analysis presents the project as less costly than it ultimately will be. The choice between the two different methods depends on the purpose of the analysis. Short and middle term studies (less than 10 years) can be performed and presented in current money. Longer-term studies may be presented in constant money so that the effect of many years of inflation does not distort the resulting cost analysis.

The constant money method requires the definition of two quantities:

- Discount rate (r)
- Zero-year (zy) : the year which all the amounts of money will be discounted to using the discount rate r

The discount rate is usually taken equal to or greater than the inflation rate r_i. Typical zero-years, concerning power plants, can be the present year, the first construction year, the last construction year, the first operating year.

If Φ_j is a general quantity at the j-th year, like TCR_j, ROI_j, TRR_j, the relationship between its value in a current money analysis and in a constant money analysis is the following:

$$\Phi_j^{const} = \Phi_j^{curr} / (1+r)^{j-zy} \quad (3.2)$$

All the previous equations (1.1-1.22 and 2.1-2.11) are valid in both cases of current or constant money analysis if instead of nominal discount rates real discount rates are used.

Levelisation

The concept of levelisation is general and is defined as the use of time-value-of-money arithmetic to convert a series of varying quantities to a financially equivalent constant quantity (annuity) over a specified time interval (i.e. n years), through a discount rate r_{LEV}. If P_j represents the variable quantity at the j-th year and A is the equivalent annuity, the following equation can be written:

$$P_o + \sum_{j=1}^{n} [A/(1+r_{LEV})^j] = \sum_{j=0}^{n} P_j/(1+r_{LEV})^j \quad (3.3)$$

Subtracting P_0 from both sides, eq.3.3 becomes:

$$\sum_{j=1}^{n} [A/(1+r_{LEV})^j] = \sum_{j=1}^{n} P_j/(1+r_{LEV})^j \quad (3.4)$$

From eq.3.4 the annuity A can be obtained as follows:

$$A = [\sum_{j=1}^{n} P_j/(1+r_{LEV})^j] / [\sum_{j=1}^{n} 1/(1+r_{LEV})^j] \quad (3.5)$$

A is the levelised value of the variable quantities P_j in the time interval of n years, through the discount rate r_{LEV}.

If P_j increases during the years with a fixed nominal escalation rate r_n, it is possible to find a simpler formula equivalent to eq.3.5.

If k is defined as follows:

$$k = (1+r_n)/(1+r_i) \quad (3.6)$$

where r_i is the general inflation rate, it can be demonstrated that eq.3.5 becomes:

$$A = P_0 \cdot k \cdot \frac{(1-k^n)}{(1-k)} \cdot \frac{r_i \cdot (1+r_i)^n}{(1+r_i)^n - 1} \quad (3.7)$$

Acronyms

ADJ	Adjustment
AFUDC	Allowance for Funds Used During Construction
ARR	Average rate of return
BBY	Balance Beginning Year
BCR	Benefit-Cost Ratio
BD	Book Depreciation
BL	Book Life.
CFN	Net Cash Flow
CO	Contingencies
COCO	Construction Costs
CSAW	Civil structural and architectural work
DITX	Deferred Income Taxes
DC	Direct Costs
DPBP	Discounted Payback Period
EBCR	Eckstein Benefit-Cost Ratio
EEM	Electrical equipment and materials
EnvC	Environmental costs
ES	Engineering and supervision
FCI	Fixed capital investment
FuelC	fuel and supply material costs
GP	Gross profit
IC	Indirect Costs
INCO	Instrumentation and Controls
IRR	Internal rate of return
ITX	Income Taxes
LAND	cost of land
LDR	costs of Licensing, Development and Research
NBCR	Net Benefit-Cost Ratio
NP	Net Profit
NPV	Net Present Value
O&MC	Operating and Maintenance costs
OFSC	Off-Site Costs
ONSC	On-Site Costs
OO	Other Outlays
OTXI	Other Taxes and Insurance
PBP	Payback Period
PEC	Purchased Equipment Cost
PECI	Purchased Equipment Cost Installation
PIP	Piping
RCEAF	Recover Common Equity Allowance Funds
ROI	Return On Investment
SF	Service Facilities
SUC	Startup Costs

TCI	Total Capital Investment
TCR	Total Capital Recovery
TDI	Total Depreciable Investment
TL	Tax Life
TRR	Total Revenue Requirement
TXD	Tax Depreciation
TXI	Taxable Income
WC	Working Capital

THERMAL DESIGN AND OPTIMIZATION

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subscript ps) and debt (subscript d); income taxes (ITX); other taxes and nsurance (OTXI); fuel costs (FC); and operating and maintenance costs OMC):

$$\underset{(9)}{\text{TRR}_j} = \underset{(1)}{\text{TCR}_j} + \underset{(2)}{\text{ROI}_{j,ce}} + \underset{(3)}{\text{ROI}_{j,ps}} + \underset{(4)}{\text{ROI}_{j,d}} + \underset{(5)}{\text{ITX}_j} + \underset{(6)}{\text{OTXI}_j} + \underset{(7)}{\text{FC}_j} + \underset{(8)}{\text{OMC}_j} \quad (7.40)$$

he subscript j refers to the jth year of system operation. The numbers given elow each term of Equation 7.40 key the variables to the categories of Figure .3. If the actual annual revenues exceed the annual TRR value calculated om Equation 7.40, the actual rate of return on equity becomes higher than e minimum value assumed in the calculation.

The *year-by-year analysis,* which illustrates the projected costs and revenue quirements for every year of the system economic life, is used to calculate e levelized revenue requirement and the levelized cost of the main product. addition, this analysis is very useful for comparing technical alternatives ee Section 7.5). The cogeneration system considered previously will be used demonstrate the year-by-year analysis. The results are summarized in Table 12 in which each column numbered 1 through 9 corresponds to a term of uation 7.40. The following sections provide details concerning the calcu- ion of the values provided by these columns of data. Additional examples given in References 1, 19, 20.

3.1 Total Capital Recovery

e net investment must be recovered during the system economic life. Table 3 shows the year-by-year calculation of the total capital recovery for the generation system. Column D of this table corresponds to column 1 of ble 7.12. The annual book depreciation (BD), shown in column A of Table 3, is calculated from the book life (BL) and the total depreciable invest- nt (TDI) using the straight-line method:

$$\text{BD}_j = \frac{\text{TDI}}{\text{BL}}, \qquad j = 1, \ldots, \text{BL} \qquad (7.41)$$

index j refers to the jth year of book life. The deferred income taxes TX) for the jth year of tax life (TL), shown in column B of Table 7.13, based on the difference between the annual tax depreciation (TXD), found Equation 7.37a and Table 7.11 (using the MACRS method), and the an- l book depreciation (BD), determined using Equation 7.41:

$$\text{DITX}_j = (\text{TXD}_j - \text{BD}_j)t, \qquad j = 1, \ldots, \text{TL} + 1 \qquad (7.42)$$

Table 7.12 Year-by-year revenue requirement analysis for the cogeneration system (all values are round numbers given in thousand dollars)

Year	Calendar Year	(1) Capital Recovery	(2) Return on Common Equity	(3) Preferred Stock Dividends	(4) Interest on Debt	(5) Income Taxes	(6) Other Taxes and Insurance	(7) Fuel Cost	(8) O&M Costs	(9) Total Revenue Requirement (current dollars)	Total Revenue Requirement (constant dollars)
1	1998	2,533	2,808	939	2,674	2,363	885	8,336	4,981	25,517	20,993
2	1999	3,362	2,688	892	2,540	1,432	885	8,836	5,230	25,865	20,266
3	2000	3,187	2,526	830	2,365	1,470	885	9,366	5,491	26,120	19,491
4	2001	3,030	2,372	772	2,199	1,497	885	9,928	5,766	26,448	18,796
5	2002	2,888	2,227	716	2,040	1,515	885	10,524	6,054	26,849	18,172
6	2003	2,760	2,089	663	1,889	1,527	885	11,155	6,357	27,323	17,613
7	2004	2,699	1,958	612	1,744	1,476	885	11,825	6,674	27,872	17,111
8	2005	2,699	1,830	562	1,602	1,367	885	12,534	7,008	28,486	16,655
9	2006	2,701	1,702	512	1,460	1,256	885	13,286	7,359	29,160	16,237
10	2007	2,699	1,574	462	1,318	1,149	885	14,083	7,726	29,896	15,854
11	2008	2,701	1,446	413	1,176	1,038	885	14,928	8,113	30,699	15,505
12	2009	2,699	1,318	363	1,034	931	885	15,824	8,518	31,571	15,186
13	2010	2,701	1,190	313	892	820	885	16,773	8,944	32,518	14,897
14	2011	2,699	1,062	263	749	713	885	17,780	9,392	33,542	14,634
15	2012	2,701	934	213	607	602	885	18,847	9,861	34,650	14,398
16	2013	2,155	806	163	465	1,039	885	19,977	10,354	35,845	14,185
17	2014	1,612	707	123	351	1,496	885	21,176	10,872	37,221	14,028
18	2015	1,612	636	92	263	1,434	885	22,447	11,415	38,784	13,921
19	2016	1,612	565	62	175	1,372	885	23,793	11,986	40,450	13,828
20	2017	1,612	494	31	88	1,310	885	25,221	12,586	42,225	13,747

Table 7.13 Year-by-year capital-recovery schedule for the cogeneration system (all values are round numbers and are given in thousand dollars)

Year of Commercial Operation	Calendar Year	(A) Annual Book Depreciation	(B) Deferred Income Taxes	(C) Recovery of Common Equity AFUDC	(D) Total Capital Recovery
1	1998	2,424	0	109	2,533
2	1999	2,424	829	109	3,362
3	2000	2,424	654	109	3,187
4	2001	2,424	497	109	3,030
5	2002	2,424	356	109	2,888
6	2003	2,424	227	109	2,760
7	2004	2,424	166	109	2,699
8	2005	2,424	166	109	2,699
9	2006	2,424	168	109	2,701
10	2007	2,424	166	109	2,699
11	2008	2,424	168	109	2,701
12	2009	2,424	166	109	2,699
13	2010	2,424	168	109	2,701
14	2011	2,424	166	109	2,699
15	2012	2,424	168	109	2,701
16	2013	2,424	−378	109	2,155
17	2014	2,424	−921	109	1,612
18	2015	2,424	−921	109	1,612
19	2016	2,424	−921	109	1,612
20	2017	2,424	−921	109	1,612
Subtotal		48,475	0	2,185	50,660
Cost of land and working capital					2,820
Total investment					53,480

Note: Cost of land and working capital are recovered as common equity at the end of economic life.

where t is the total income tax rate. The deferred income taxes for the years (TL + 2) through BL are obtained from

$$\text{DITX}_j = -\frac{\sum_{k=1}^{\text{TL}+1} \text{DITX}_k}{\text{BL} - (\text{TL} + 1)}, \qquad j = \text{TL} + 2, \ldots, \text{BL} \qquad (7.43)$$

The common-equity allowance for funds used during construction (CEAF), which is not considered in the net depreciable investment, is recovered using a constant annual amount (RCEAF), shown in column C of Table 7.13, and obtained through

where CEAF is the common-equity AFUDC at the end of the design and construction period, Table 7.10.

The total capital recovery (TCR) for the jth year of book life is the sum of book depreciation (Equation 7.41), deferred income taxes (Equations 7.42 and 7.43), and recovery of the common-equity AFUDC (Equation 7.44):

$$\text{TCR}_j = \text{BD}_j + \text{DITX}_j + \text{RCEAF}_j, \qquad j = 1, \ldots, \text{BL} \qquad (7.45)$$

The TCR values are shown in column D of Table 7.13 and column 1 of Table 7.12. As Table 7.13 shows, the sum of total annual capital recovery values plus working capital and cost of land is equal to the total plant investment. Working capital and cost of land are not recovered during the system economic life and appear as common equity at the end of the book life, as shown in the last common equity balance of Table 7.14.

7.3.2 Returns on Equity and Debt

Table 7.14 shows the year-by-year distribution of capital recovery among debt, preferred stock, and common equity for the cogeneration system. With the aid of this table we calculate the balance at the beginning of each year for each type of financing. This balance is the basis for obtaining the returns on equity and the debt interest in Table 7.12, columns 2–4.

The year-by-year distribution of capital recovery (Table 7.14) is obtained as follows: The total net investment (TNI) is distributed at the beginning of the first year of book life among debt, preferred stock, and common equity using the corresponding financing fractions (Table 7.9) f_d (=0.5), f_{ps} (=0.15), and f_{ce} (=0.35), where the subscripts d, ps, and ce refer to debt, preferred stock, and common equity, respectively. This assumption determines the balances at the beginning of the first year ($\text{BBY}_{1,x}$) for the xth type of financing:

$$\text{BBY}_{1,x} = \text{TNI}\, f_x, \qquad x = d, ps, ce \qquad (7.46)$$

We assume further that deferred taxes are distributed among each type of financing according to the corresponding fraction. The columns labeled adjustment in Table 7.14 for debt and preferred stock consist of the appropriate portions of deferred income taxes. The adjustment column for common equity also includes the recovery of common-equity allowance for funds used during construction, Table 7.13:

$$\text{ADJ}_{j,d} = \text{DITX}_j f_d, \qquad j = 1, \ldots, \text{BL} \qquad (7.47a)$$

(7.47b)

Table 7.14 Year-by-year distribution of capital recovery for the cogeneration system (all values are round numbers and are given in thousand dollars)

		Debt			Preferred Stock			Common Equity			
Year	Calendar Year	Balance Beginning of Year	Book Depreciation	Adjustment	Balance Beginning of Year	Book Depreciation	Adjustment	Balance Beginning of Year	Book Depreciation	Adjustment	Total Capital Recovery
1	1998	26,740	1,337	0	8,022	401	0	18,718	686	109	2,533
2	1999	25,403	1,337	414	7,621	401	124	17,923	686	399	3,362
3	2000	23,651	1,337	327	7,095	401	98	16,838	686	338	3,187
4	2001	21,987	1,337	249	6,596	401	75	15,814	686	283	3,030
5	2002	20,402	1,337	178	6,121	401	53	14,845	686	234	2,888
6	2003	18,887	1,337	113	5,666	401	34	13,926	686	189	2,760
7	2004	17,437	1,337	83	5,231	401	25	13,052	686	167	2,699
8	2005	16,017	1,337	83	4,805	401	25	12,199	686	167	2,699
9	2006	14,597	1,337	84	4,379	401	25	11,346	686	168	2,701
10	2007	13,176	1,337	83	3,953	401	25	10,492	686	167	2,699
11	2008	11,756	1,337	84	3,527	401	25	9,640	686	168	2,701
12	2009	10,335	1,337	83	3,101	401	25	8,786	686	167	2,699
13	2010	8,916	1,337	84	2,675	401	25	7,933	686	168	2,701
14	2011	7,495	1,337	83	2,248	401	25	7,080	686	167	2,699
15	2012	6,075	1,337	84	1,822	401	25	6,227	686	168	2,701
16	2013	4,654	1,337	−189	1,396	401	−57	5,373	686	−23	2,155
17	2014	3,506	1,337	−461	1,052	401	−138	4,710	686	−213	1,612
18	2015	2,629	1,337	−461	789	401	−138	4,238	686	−213	1,612
19	2016	1,753	1,337	−461	526	401	−138	3,765	686	−213	1,612
20	2017	876	1,337	−461	263	401	−138	3,293	686	−213	1,612
21	2018	0	0	0	0	0	0	2,820	0	0	0
Totals			**26,740**	**0**		**8,022**	**0**		**13,713**	**2,185**	**50,660**

The columns labeled book depreciation in Table 7.14 are calculated for each type of financing (debt, preferred stock, or common equity) using straight-line depreciation from

$$BD_{j,x} = \frac{BBY_{1,x} - \sum_{k=1}^{BL} ADJ_{k,x}}{BL}, \qquad j = 1, ..., BL, \quad x = d, ps, ce \qquad (7.48)$$

with $BBY_{1,x}$ according to Equation 7.46. The balance at the beginning of the jth year for each type of financing is

$$BBY_{j,x} = BBY_{j-1,x} - (BD_{j,x} + ADJ_{j,x}),$$
$$j = 2, ..., BL, \quad x = d, ps, ce \qquad (7.49)$$

The balance at the beginning of the year immediately following the last year of plant operation (calendar year 2018 for the cogeneration system) is zero for debt and preferred stock but equal to the value of land and working capital ($2.82 × 10^6) for common equity. The sum of the totals for book depreciation and adjustments for all types of financing is equal to the total capital recovery ($50.66 × 10^6). The annual capital recovery values shown in the last columns of Tables 7.13 and 7.14 are repeated in the first column of Table 7.12.

According to the total revenue requirement method of economic analysis, the depreciation funds are assumed to be used to pay back investors for the principal. This assumption is used here because it helps to compare alternative investments. In an expanding company, however, these funds would likely be reinvested.

For each investment type, the return-on-investment (ROI) calculation for any year of system operation is based on the outstanding investment: the balance at the beginning of the year (BBY) (Equation 7.49 and Table 7.14) for the corresponding investment. That is, the return on investment for year j is

$$ROI_{j,x} = BBY_{j,x} i_x, \qquad j = 1, ..., BL, \quad x = d, ps, ce \qquad (7.50)$$

Here i_x is the annual (nominal or real) rate of return for the xth investment type. As discussed in Section 7.2.9, for the cogeneration system, i_x is 10.0, 11.7, and 15.0% for debt, preferred stock, and common equity, respectively. It is apparent that the annual amount of return on each type of investment declines with the increasing number of years of operation. For the cogener-