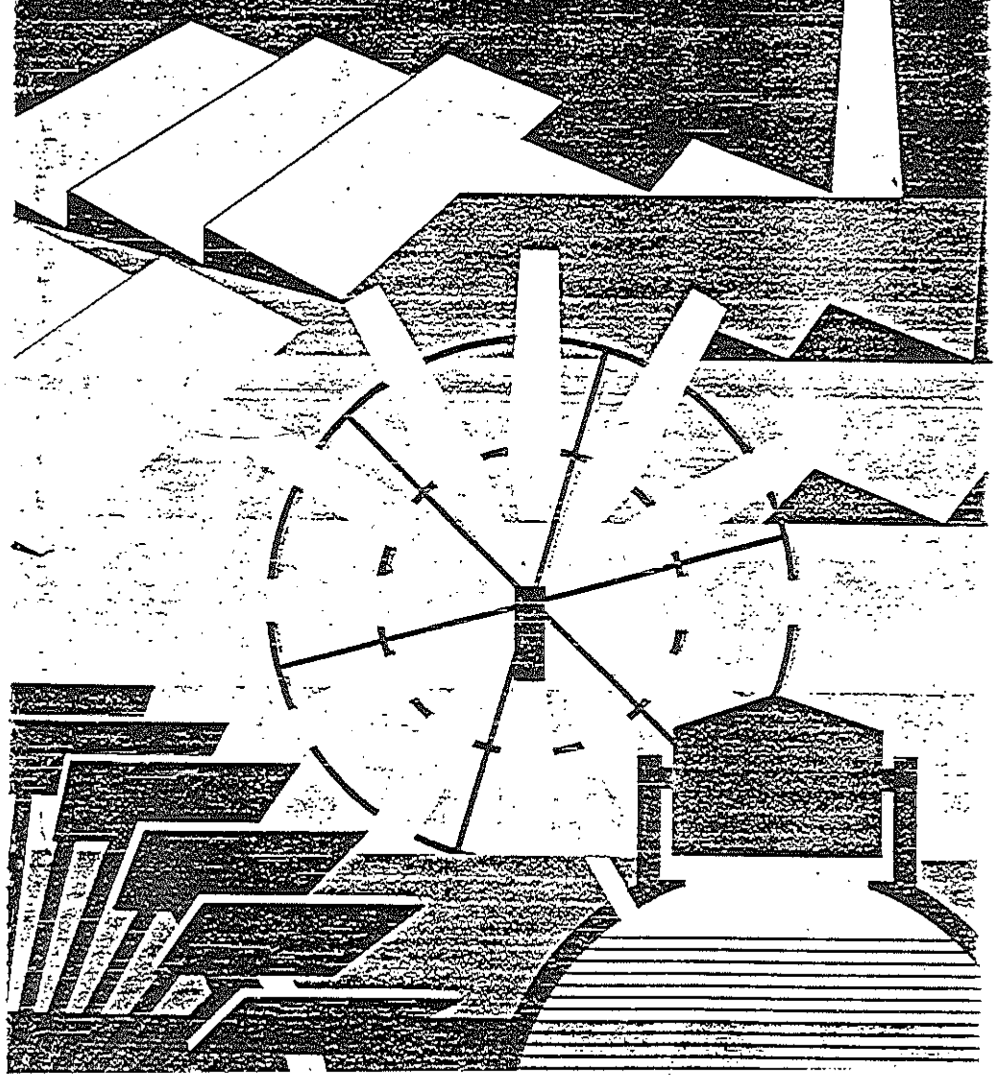
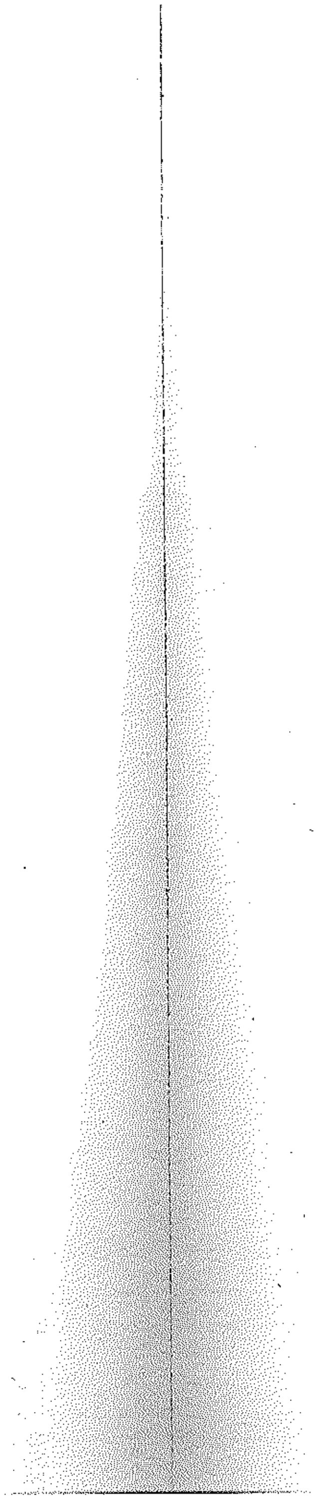
Horst Finck, Gerhard Oelert

A guide to the financial evaluation of investment projects in energy supply





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Compiled and prepared by
Horst Finck, Gerhard Oelert

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and Paul McGuire

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PREFACE

Anyone currently involved with the planning and execution of development projects will almost inevitably be faced with the subject of energy.

Given the world-wide shortage of available energy resources, we must strive to apply those resources as rationally as possible: this is equally true for the developing countries.

Of primary importance are the long-term preservation of local resources, the minimising of ecological damage and a reduction in dependence on imports of primary energies, particularly oil.

In all projects which aim either to produce or to consume energy it is an increasingly urgent necessity to choose the most economical energy supply for a given requirement.

As a result of the development of oil prices in recent years, the range of possibilities, particularly in the field of regenerative energies, is going to become wider. The hopes which are attached to their usefulness, especially for the developing countries, are generally too optimistic and are often more indicative of wishful thinking rather than any sober consideration or of the state of development. Nevertheless for the individual case "alternative" options considerably extend the scope for decisions on suitable and rational forms of energy utilisation.

These decisions can only be made competently if appropriate criteria and methods of selection are available. GTZ Division 34 "Mining and Energy" in the GTZ's "Infrastructure" Department is at present working together with other divisions on a system of "energy budgeting", intended for accounting energy-inputs and for evaluating energy utilisation in development projects.

An important component is the evaluation of the economic feasibility of solutions to the energy problem, which is of central importance in view of its frequently over-proportional share of the total operating and production costs.

The present publication is a summary, in form of a manual, of the necessary aids for examining and evaluating the acceptability of investments in energy supply from the viewpoint of business economics. This manual alone will not suffice for a final evaluation since it does not encompass ecological and socio-economic effects or the effects on overall economic goals: however it forms a necessary tool for the planner.

The manual should be seen as a contribution towards facilitating orientation in a difficult techno-economic decision-making process. It is intended to assist those involved in development cooperation to become familiar with the instruments for profitability calculations in business economics and with the advantages and disadvantages they entail in evaluating energy projects.

The manual is deliberately presented in an applications-oriented form and provides a connection to general practice by means of case studies. It helps to overcome initial resistance of dealing with this, for many people unfamiliar ground. It is therefore addressed not only to those who are professionally involved with energy projects but also to all those who see the improvement of the economics of projects to be a constant and necessary demand of our work — including topics which are not necessarily involved with the application of energy.

Dr.-Ing. Hinrich Eylers

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LIST OF ABBREVIATIONS AND SYMBOLS

a = Inflation rate
A = Annuity
A_I = Annuity of investment expenditure
A_L = Annuity of liquidation yield
A_K = Cost annuity
A_R = Annuity of returns

e = Interest factor ($e = 1 + a/100$; a = inflation rate)
E_n = Expenditure item $n = 1, 2 \ldots, m$

i = Assumed interest (discount) rate
i^* = Actual interest rate
IRR = Internal Rate of Return
I_t = Investment costs at the time or during the period t

K = Total costs per time period
K_A = Average capital tied-up per time period
K_O = Operating costs/expenditure per time period
kW = Kilowatt
kWh = Kilowatt hour

L = Liquidation yield/residual value
L_T = Liquidation yield at end of service life T
ltr. = Litre

n = Pay-back period
NCF_t = Net cash flow at the time or during the period t
n_{max} = Maximum acceptable pay-back period
N_n = Income item $n = 1, 2 \ldots, m$
NP = Net profit (return minus depreciation)
NP_D = Net profit on investment of difference
NPV = Net present value

p = Market interest rate (%)
PF (i,t) = Present value factor (PF factors for interest rates (i) of 1 – 30 % and years(t) from 1 – 30 are given together with the calculation formula in Table 3, Appendix IV)

q = Interest factor ($q = 1 + i/100$)
q^t = Compounding factor (Compounding factors for interest rates (i) from 1 – 30 % and years (t) from 1 – 30 are given in Table 4, Appendix IV)
q^{-t} = Discounting factor (discounting factors for interest rates (i) 1 – 30 % and years (t) from 1 – 30 are given in Table 1, Appendix IV)

r	Interest factor (r = 1 + p/100)
RF (i,t)	Capital recovery factor (RF factors for interest rates (i) from 1 - 30 % and years (t) from 1 - 30 are given in Table 2, Appendix IV)
ROI	Return on investment (%)
ROI_D	Profitability of investment of the difference
ROI_{min}	Minimum acceptable profitability (%)
R_t	Return at the time or during the period t
RUE	Rational use of energy
T	Service life of the project (= planning period); T = t-periods, usually years; also: end of the service life
t	Point in time or period (usually one year) during the service life of the project
t = 0	Time or period before commissioning (beginning of the project)

INTRODUCTION

This "Guide to the financial evaluation of investment projects in energy supply" attempts to present the most commonly used methods of investment calculation and their application in a form which will make it possible even for someone inexperienced in business economics to use this indispensable tool in the preparation of investment decisions.

Although this guide is tailored to the calculation of the feasibility of investment projects in the energy field and in particular to the introduction of technologies for the utilisation of renewable energy sources, it can also be used as an introduction to the analysis of investment projects in other fields. The calculation techniques which are described in the following are applicable to any type of investment, it being simply necessary to modify the data collection and processing to the individual case.

The primary objective is to impart, regardless of previous practical experience, the necessity for investment calculations, the procedures to be applied and the conditions for and limits of their application. Chapter A therefore considers the problems of system optimisation according to technical and economic criteria as applied to the energy field.

Chapter B then describes the data upon which a calculation of profitablility must be based and at the same time indicates actual methods for collecting and preparing the necessary information.

In Chapter C the theoretical bases of static and dynamic procedures for financial evaluations are presented and the application of the different techniques is illustrated by means of the data given in the case study (Appendix I). An attempt is also made to show how the problem of inflation, which is of particular importance in developing countries, can be treated within the context of the investment calculation. The work concludes with a presentation on sensitivity analyses, the necessity for them and their practical execution.

It is important to stress that this guide, in presenting the tools needed to evaluate the profitability of investment projects from the point of view of business economics, can provide only an initial, albeit very important, element in a comprehensive assessment of investment projects, particularly in developing countries. Nevertheless we feel that this document provides both the conceptual and mathematical basis for understanding and carrying out further very important analyses such as the socio-economic evaluation of investment projects, or of liquidity analyses to enable timely solutions to be found for anticipated financing problems.

Our thanks are due to Prof. Dr. E. Eckstein of the Higher College of Technology Nuremberg and Prof. Dr. R. H. Schmidt of the University of Göttingen for their critical reading of the manuscript and for their suggestions for improvements.

Dr. H. Finck
G. Oelert

SUMMARY OF SELECTED METHODS FOR CALCULATING ECONOMIC FEASIBILITY

	Procedure for calculating economic feasibility	Characteristic parameter	Criterion for the individual profitability of a project	Criterion for the relative profitability of a project	Area of application of the method	Remarks
1 Static Methods –	Cost comparison calculation (Section C I 1)	Cost per unit time (e.g. DM/year) or per production unit (e.g. DM/kWh)	It is not possible to determine individual profitability by this procedure since there is no project-linked income to offset expenditures	Investment project I is more profitable than other projects when it produces lower unit costs than investment alternatives II, III, etc	Approximate cost estimation and comparison of various investment projects with identical goals (e.g. for the supply of 500m^3 drinking water per day): particularly for preselection of alternatives and components within the framework of a system optimisation. Also for evaluating the replacement problem when considering cost minimisation	....
	Cost annuity comparison method (static) (Section C I 2)	Costs per year (cost annuity) or costs per production unit.		Investment project I is more profitable than alternative projects when its cost annuity or its annual unit production cost is less than that of investment alternatives II, III, etc. $A_K^I < A_K^{II}; A_K^{III}$, etc		a) Since compound interest is taken into account, this method is more exact than the cost comparison calculation. b) Multiplication of the cost annuity by the present value factor - PF (i,T) - gives the net present value of the project-linked costs
	Calculation of profitability Return-on-investment (ROI) - procedure (Section C I 3)	Return-on-Investment (ROI) $ROI = \frac{NP}{K_A} \times 100$ (= % per unit time) NP = average profit per unit time K_A = average capital invested per unit time	An investment project is individually profitable when the calculated profitability (ROI) equals or exceeds the minimum acceptable profitability (ROI_{min}) $ROI \geq ROI_{min}$	Investment project I is more profitable than an alternative project II when the profitability (ROI) of the differential investment exceeds the minimum acceptable profitability $\frac{NP^I - NP^{II}}{K_A^I - K_A^{II}} > ROI_{min}$ (Investment project I is the one with the higher average capital invested)	Rough calculation of the interest rate which will yield the interest expected on the capital invested in a project. Comparison and preselection of investment alternatives on the basis of return on capital even if they are of very different types.	The results of this procedure can be seen as a rough approximation to the results of the internal rate of return (IRR) method
	Calculation of pay-back period (static) (Section C I 4)	Amortisation time or pay-back period pay-off period pay-out period	An investment project is individually profitable when the capital invested will be recovered by means of anticipated excesses of income over outflows within the serviceable life or within a maximum required pay-back period which must be shorter than the technically feasible service life of the plant $n \leq n_{max} \leq T$ (t-years)	Investment project I is more profitable than alternative projects II, III, etc when it has a shorter pay-back period than the investment alternatives $n_I < n_{II}; n_{III}$, etc	Approximate evaluation of a project and comparison of investment alternatives on the basis of investment risk. (It is assumed that the risk of a capital loss increases with the length of the pay-back period)	The length of the pay-back period does not allow conclusions regarding the profitability of a project, therefore, this method should only be applied in conjunction with others. This procedure is also of only limited value for evaluating risk. It can be shown that a project with a shorter pay-back period can still involve a greater risk

	Procedure for calculating economic feasibility	Characteristic parameter	Criterion for the individual profitability of a project	Criterion for the relative profitability of a project	Area of application of the method	Remarks
- Dynamic Methods -	Net Present Value method (Section C.II.1)	Net present value (NPV)	An investment project is only profitable when its net value present is equal to or greater than zero: $NPV \geq 0$ Under this condition the minimum acceptable interest on capital invested is reached or exceeded i.e. is at the level of the cut-off discount rate (i) or greater	Investment project I is more profitable than alternative projects II, III, etc. when its net present value is greater than that of the investment alternatives $NPV^{I} > NPV^{II}; NPV^{III}$; etc	Reliable evaluation of the economic favourability of an investment project and comparison of investment alternatives according to capital yields anticipated to be above the minimum acceptable interest rate	This method can lead to inaccuracies in the comparison of investment alternatives with varying capital requirements and lifetimes. In such cases the investment decision should be based on the less problematic annuity method. The annuity of a project is calculated by multiplying the net present value by the recovery factor $A = NPV \times RF(i,t)$
	Internal rate of return method (Section C.II.2)	Internal rate of return (IRR)	An investment project is individually profitable when its internal rate of return (IRR) is equal to or greater than the cut-off discount rate (i) which gives the minimum acceptable interest rate: $IRR \geq i$	A comparison of investment alternatives should not be undertaken by means of this method since it is necessary to adopt assumptions which may be unrealistic in practice and as such the danger of an incorrect decision is very great	Exact determination of the rate of interest anticipated on a capital investment when the project is executed	....
	Annuity method (Section C.II.3)	Annuity (A)	An investment project is individually profitable when the calculated annuity is not negative. The following must apply: $A \geq 0$	Investment project I is more profitable than projects II, III, etc. when its annuity is greater than those of the investment alternatives $A_{I} > A_{II}; A_{III}$; etc	Reliable evaluation of the economic favourability of an investment project and comparison of investment alternatives from the anticipated annual return on capital over the minimum acceptable interest rate	When comparing investment alternatives with differing investment costs one should consider whether investing the capital difference would influence the comparison. The net present value of a project can be calculated by multiplying the annuity by the present value factor $NPV = A \times PF(i,t)$
	Cost annuity comparison method (dynamic) (Section C.II.4)	Costs per year (Cost annuity) or Costs per unit production	It is not possible to determine the profitability individually with this procedure since there are no project-linked incomes to be set against expenditures.	Investment project I is more profitable than other projects when its dynamic cost annuity or annual production expressed per unit is less than that of investment alternative II, III, etc. $A_{K}^{I} < A_{K}^{II}; A_{K}^{III}$; etc	For exact determination of costs per year or per unit production and comparison of investments with identical project goals. Applicable to the replacement problem	When the annual operating costs are constant, the results of the dynamic and static cost annuity comparison methods are identical
	Calculation of pay-back period (dynamic) (Section C.II.5)	Amortisation time or pay-back period pay-off period pay-out period	An investment project is individually profitable when the capital invested including a minimum acceptable interest rate, will be recovered by means of the anticipated excesses of income over expenditures within the serviceable life or within a maximum acceptable pay-back period which must be shorter than the technically feasible service life. $n \leq n^{max} \leq T$	Investment project I is more profitable than alternative projects II, III, etc. when it has a shorter pay-back period than the investment alternatives. $n_{I} < n_{II}; n_{III}$; etc.	Reliable evaluation of an investment project and comparison of investment alternatives based on investment risk.	The length of the pay-back period does not allow conclusions regarding the profitability of a project; therefore this method should only be applied in conjunction with others. This procedure is also of limited use for evaluating risk. It can be shown that a project with a shorter pay-back period can involve a greater risk

A. OPPORTUNITIES AND PRECONDITIONS FOR THE USE OF RENEWABLE ENERGY SOURCES

I. Renewable versus conventional energy sources

In the last few years excessive increases in the prices of commercial energies, paticularly oil, have resulted in increased efforts towards a more rational utilisation of the available energy sources.

At the same time there has been intensified effort to expand appreciably the available energy supply by the utilisation of alternative and regenerative energy sources such as solar, wind, biomass, hydro and geothermal energy. This has been particularly relevant to the developing countries where further economic development has been considerably hindered by the increase in the price of oil. On the other hand they have the most favourable preconditions for the utilisation of renewable energy sources and are eager to make use of the enormous potential in regenerative energy sources for their future development.

Whether regenerative energy sources can be used to any significant extent in the foreseeable future to satisfy the growing energy requirement of the developing countries will depend partly on the success in solving the problems associated with the introduction and spread of these technologies, as regards the social, cultural and institutional environments of developing countries.

Technical systems must also be developed which allow a series production, with design characteristics and layout to guarantee a high degree of operating security and which are economically suited to widespread introduction in developing countries on account of their performance and cost characteristics.

But even when the above criteria can basically be fulfilled, the application of renewable energies remains problematic. Can any of the technical systems available for the use of renewable energies be applied in a definite energy supply situation and if so, which?

This question can only be answered with reference to the specific conditions at the projected installation site. The problem of reconciling energy supplies which are subject to great local and regional variations and furthermore sometimes fluctuate considerably in the course of the day or even the year, with energy demands which also usually vary according year, with energy demands which also usually vary according to the time of day and season, means that individual solutions must be developed and tested. However, it is conceivable that in numerous cases it will not be possible to cover the total energy requirement by renewable energy sources because it would be impossible to justify on economic grounds the installation of the expensive energy storage systems which would be necessary. Thus renewable energy sources are only suited to a limited degree for replacing conventional energy sources. Often it will only be possible to optimally meet a defined energy demand, considering the technical and economic aspects, by the combined use of renewable and conventional energy sources.

In view of the importance which is attached to such solutions some concrete approaches towards the combined utilisation of renewable and conventional energy sources are set out and commented upon in the following section.

For decision-makers concerned with the practical application of equipment and systems to utilise renewable energies or for the rational use of energy (RUE), it is indispensable to support their decision with an examination of the economics of the planned investment. For this reason an attempt is made in this book to present in as clear and understandable a form as possible some of the most commonly used methods for calculating the feasibility of investment projects and to illustrate their application by means of examples from the field of RE[1] technologies.

First of all it must be stated that the methods of calculation dealt with here are limited to those costs and benefits which are directly attributable to the RE project concerned. They cannot encompass any possible external benefits such as:

- Improvements in the physical quality of life as a result of a wider range of energy supply
- Improvements in the local economic structure
- Reduction in environmental pollution
- Creation of employment opportunities
- Improvement in the trade balance through the substitution of imported energy sources
- Training effects
- Reduction of rural migration
- Reduction in timber-felling
- More secure supply basis, etc.

or external costs such as:

- Increase in environmental pollution
- Loss of employment
- Shortage of capital and increase in interest rates because funds which could be used as future operating costs in systems utilising conventional energies become immediately payable as investment costs for the utilisation of renewable energies.

External costs and benefits can be of considerable importance in the widespread use of such RE technologies. An investment project which is unprofitable for an individual business can prove extremely worthwhile for the overall economy when considering the social benefits it generates. Such external effects should be investigated separately and made a subject of political discussion with the aim of improving the economic feasibility of RE and RUE projects at the level of the individual enterprise by means of tax concessions, direct subsidies, import relief and similar government measures.

RE technologies = technologies for the utilisation of renewable energies

II. Problems of techno-economic system optimisation[1]

Given the present state of the art, the renewable energy sources sun, wind and biomass are under the most severe competitive pressure from the conventional systems whenever the latter are available even though they may be expensive. This is generally a result of the comparatively low energy densities of the renewable energy sources which necessitate the installation of material-intensive systems for concentrating the energy flows. The example of solar energy demonstrates this aspect when considering the large absorber areas required, even for relatively low output. Likewise, although an energy flow of high density is produced when gasifying forestry wastes and converting it to electricity, the preceding collection of the biomass from a defined forest area presents a laborious process. From this one is easily led to the standard optimised solution i.e. that units of this kind should preferably be operated where there are already concentrations of suitable quantities of biomass e.g. at sawmills.

However, as indicated in Chapter I, a careful optimisation is much more complex if all the technical and economic characteristics of system components are to be considered with reference to a competitive overall system.

For example, to operate a wind power unit for electricity generation at an isolated site where the wind speeds are relatively uniform but occasionally high with, on the other hand, distinct periods of dead calm, the following solutions could be considered to obtain a continuous supply of electricity:

a) either add a storage battery to the system
or
b) provide a diesel unit as back-up
or
c) depending on the economic feasibility of the alternatives under consideration, drop the concept of a wind power unit completely and provide conventional electrification.

The basic selection procedure in the search for an optimal solution should include "subroutines" in the form of layout and economic feasibility calculations although these steps

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[1] In this discussion the system boundaries are fixed directly around the energy conversion and distribution systems.

cannot be further examined in detail at this time; there is of course still a range of other technical and non-technical criteria which play a role and which can be of overriding importance ((isolated-) grid load condition, technical supervision, culture, environmental protection, acceptability, etc.).

Thus one of the "subroutines" to be run for alternative "a" might be to reconcile the rotor and generator size with the size of store (i.e. batteries) with the aim of minimising the initial costs of the components with the highest specific cost. Thus the wind power unit must be overdimensioned in the electricity power demand to provide the necessary electrical energies required in a short period.

Subsequently it would have to be established whether the economic viability of the combined system (alternative "b") were superior to that of the storage system (alternative "a"), for then the overdimensioning of the wind power unit would no longer apply. From the point of view of initial costs a small diesel unit appears an attractive solution compared to batteries for a small isolated grid. Of course this solution requires the availability of fuel and lubricants but it offers a high degree of technical flexibility and given the present state of the technology it also has a higher degree of dependability. It must also be seen in the light of security of supply (fuel) and must be carefully analysed in respect to assumed fuel-price increases (e.g. total costs over the lifetime). Finally (depending on the boundary conditions) the economically self-sufficient storage system (alternative "a") may still emerge as the optimal solution.

This type of consideration can be examined in more depth in a further example:

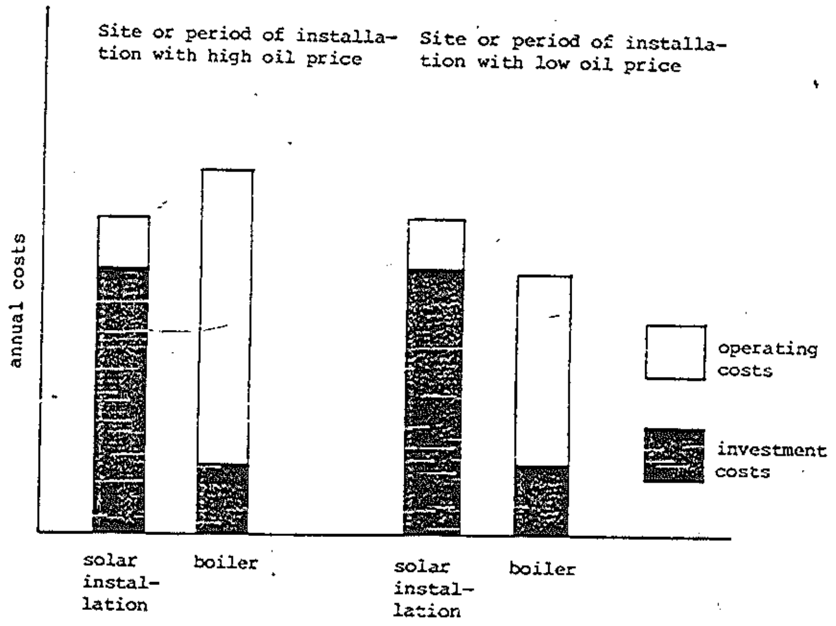
Let us suppose that the aim is to supply a small industrial drying plant with process heat at about 100°C for 8 h/d. The site has a high potential for direct solar radiation; ambient temperatures are high all through the year. Therefore one might consider installing concentrating collectors, whereby the process heat is transported to the drying plant by means of the circulation of a heating medium. For starting up the drying plant each morning and to compensate for short-term variations in the solar radiation, a heat reservoir is provided. The reservoir should be designed for a temperature of ca. 110°C taking account of the heat-exchanger thermal efficiency and heat losses.

It is now assumed that there are no fundamental supply problems at the site where the system is to be set up and that the system has itself been optimised by detailed calculations (selection of the most economic solar-collector to match with the layout of the reservoir and the requirements of the drying operation).

On this basis a comparison of economic feasibility can be made with that of a conventional low pressure steam boiler. In the comparison the solar installation appears expensive, complex, large, material-intensive, less dependable in operation and presents problems in the estimation of its technical lifetime. On the other hand the conventional boiler represents low initial costs, a high degree of reliability and easily predictable operating costs.

A detailed calculation of e.g. annual costs of the two systems would give the following picture (Fig. 1).

Fig. 1: Total costs (examples)



For the sake of simplicity we will not consider at this point all the boundary conditions which should be quantified in the operating and investment costs. This will follow in subsequent sections.

However the simple diagram in Fig. 1 and the preceding remarks indicate that system optimisation is an iterative process and takes place on various levels sometimes simultaneously.

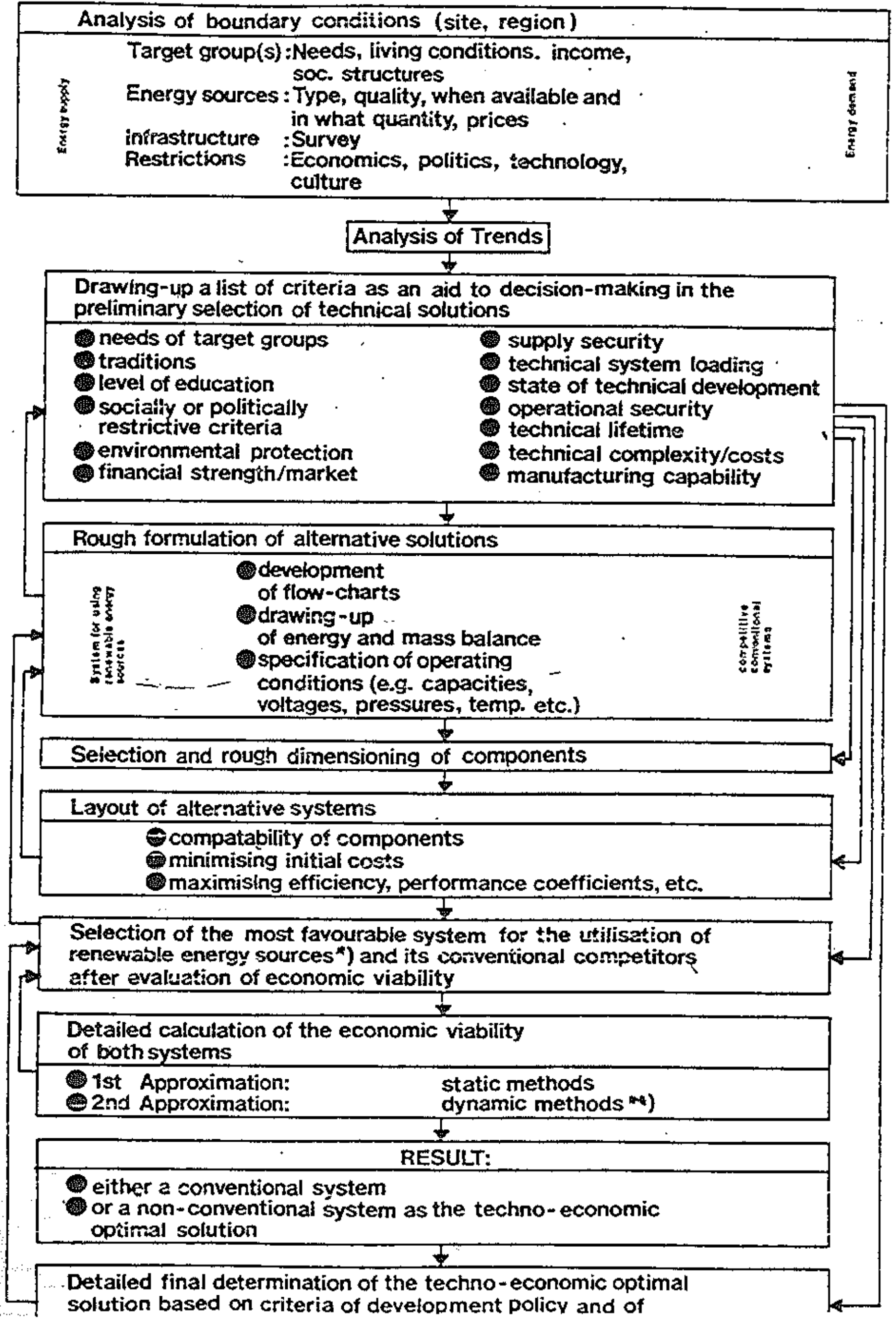
Level 1: Selection and dimensioning of components.
Level 2: Combination of systems (technical optimisation).
Level 3: Techno-economic comparison of alternative solutions (economic optimisation).
Level 4: Examination of chosen solutions based on criteria relevant to development policy.

The quantitative determination of the economic viability can be adapted to the level in question according to the calculation effort required, i.e. simple assessments will often suffice for reaching decisions at Level 1 while the methods described in the following chapters should be employed at Level 3 for achieving more exact results.

This also applies to the criteria of development policy and environmental compatibility. While one may be fully aware of these criteria in making the intermediate decisions (Levels 1 - 3) they are only brought into play and applied after the clear presentation of a proposed system and its alternatives at Level 4.

A possible procedure for the technical and economic optimisation of systems using renewable energy sources in developing countries can be made clear by means of Fig. 2.

Fig. 2:



B DATA COLLECTION AND PREPARATION

A complete compilation of all expenditures and incomes (expenditures avoided are to be equated with incomes) connected with the planned investment is a necessary first step in calculating the viability of investment projects.

Table I: Project "(Title)", (Country), (date) – data review (in currency units)

No.	Period		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	Year		19..	19..	19..	19..	19..	19..	19..	19..	19..	19..	19..	19..	19..	19..	19..	19..	19..	19..	19..	19..	19..	19..	19..	19..	19..
0.1	Assumed interest rate																										
0.2	Gen. inflation rate																										
0.3	Infl. rate of energy prices																										
0.4	Serviceable life of the unit (years)																										
1.1	Investm. expend. (total table 2)																										
1.2	Residual value of unit (after service years)																										
2.1	Manpower costs																										
2.2	Mainten. + repair costs																										
2.3	Energy + related costs																										
2.4	Auxiliary materials																										
2.5	Administr. costs (excl. manpower)																										
3.1	Taxes + levies not dependent on profit																										
3.2	Other expenditures																										
3.3	Total of operating costs (2.1-3.2)																										
4.1	Energy supplied (units)																										
	X selling price/unit																										
	= revenues fromenergy sales																										
	Energy substituted (units)																										
	X buying price/unit																										
	= saving on energy costs																										
	Energy related production (units) (e.g. drinking water-m^3)																										
	X price/unit																										
	= operating income																										
4.2	Other incomes																										
4.3	Subsidies																										
4.4	Total incomes (4.1-4.3)																										
5.1	Returns (4.4 minus 4.3)																										
5.2	Depreciation																										
5.3	Profit (5.1 minus 5.2)																										

However, as already indicated the expenditures and incomes resulting from a particular technical system to utilise renewable energy sources or for the rational use of conventional energy sources possibly with alternative solutions, can only be accurately determined when all the parameters of a specific application are known. These factors may vary considerably from one place to another.

In order to facilitate the complete and exact collation of the relevant data, a matrix has been developed (Table 1) which is tailored to the data requirement of the various procedures employed in the financial evaluation of this type of installation. Since the data listed in Table 1 will not be needed for every calculation procedure, it is recommended that the required data for the chosen method of analysis be checked before data collection begins.

0.1 Interest rates

In some of the procedures used to evaluate the favourability of an investment it is necessary to fix a rate of interest at which the incomes and expenditures can be discounted or compounded to a fixed time. This rate is also used to calculate the assumed interest accrued on the average capital invested during the time of the project.

We will not at this point discuss the problem of determining the assumed interest rate (this has been extensively dealt with in the specialist literature). However we would advise with **external financing** of investment costs that this rate be fixed at the rate of interest which would be charged to the user as the effective rate of interest on the balance of the debt during the period of the loan. This should take account of other existing or planned banking commitments. With **internal financing** one should use the rate of interest on capital deposits of corresponding size, duration and risk which would accrue to the investor in the normal course of business.

For mixed financing with both external and internal capital a correspondingly weighted mean value can be taken as the inerest (or discount) rate[1].

0.2 General inflation rate/actual interest rate

Because of the uncertainty of future project-dependent expenditures and incomes and the fact that this uncertainty increases with the duration of the investment project, most economic calculations assume that today's prices will also apply in the future, i.e. will remain constant. So long as there is no anticipated alteration in incomes and expenditures due to technical or marketing factors effecting volume, e.g. an increase in sales, this assumption allows the calculation to be made on the basis of constant annual inflows and outflows and also of constant annual returns.

The assumption of constant prices is basically acceptable in countries with a high degree of price stability. However there are considerable reservations as to the accuracy of the results for developing countries with inflation rates of up to

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1) The problem of inflation in fixing the interest rate is also treated in Sections 0.2 and 0.3.

30 % or more if, as described above, the market interest rate is applied as the interest rate for external or internal financing. Market interest rates are usually determined not only to account for a return on capital transferred (in many cases including a risk supplement) but also an allowance for the loss in purchasing power which is brought about by inflation.

This problem can be accounted for in different ways:

a) for the interest rate (i) the actual interest rate (i*) is applied, i.e. the market interest rate adjusted by the inflation rate, whereby constant prices are assumed for incomes and expenditures (this is the method used in Sections C.I and C.II of this book).

b) for the interest rate (i), the market interest rate (p) is applied. However – as will be demonstrated in Section C.III – the annual incomes and expenditures for the anticipated inflation rate is added to the calculation.

For both of these methods it is necessary to estimate the expected annual rate of price increase for the planning period. So long as there is no strong indication to the contrary, such as anticipated long-term changes in the politico-economic arena, the future inflation rate can be estimated by extrapolating from known previous values.

It can be seen that both methods lead to the same result if it is assumed that all expenditures and incomes will alter at the same rate of increase with time, so that in such cases the method mentioned under a) can be recommended as being simpler. The actual interest rate can then be calculated as follows:

$$q=\frac{r}{e}$$

where:

$q = 1 + \frac{i^*}{100}$ i^* = actual interest rate

$r = 1 + \frac{p}{100}$ p = market interest rate

$e = 1 + \frac{a}{100}$ a = inflation rate

Hence:

$$i^* = \frac{100+p}{100+a} \cdot 100 - 100$$

Assuming for example, a market interest rate of 32 % and an inflation rate of 22 %, the actual interest rate (i*) becomes:

$$i^* = \frac{100+32}{100+22} \cdot 100 - 100 = 8.2\,\%$$

0.3 Inflation rate of energy prices

Since it cannot always be assumed that all expenditures or income will alter in sequence with the general inflation rate, it may be necessary to consider the anticipated rate of price increase separately for particularly important individual incomes or expenditures and to incorporate this rate separately in the calculation. The experience of the last decade shows that this is particularly important for the prices of conventional energy sources and it is likely that this deviation from the general price development will continue in the foreseeable future. In the analysis of investment projects which are heavily dependent on energy it is now customary to take separate account of the development in energy prices (see Section C.III).

However, it is likely that the prices development of the various energy sources in the different countries or installation sites will vary. In many cases, therefore, the projection of future income should not be made on the basis of a general price index for all energy sources but rather on the basis of the price development of those energy sources for which there is a limited possibility for substitution. This is always the case when a given conventional energy source, e.g. diesel oil, is to be replaced either partially or totally by renewable energy sources. In this case the calculation could be limited to the anticipated price development of the energy source to be replaced.

0.4 Service life of the installation

When considering the economic viability of an investment, the possible service life of the technical system, buildings, auxiliary and service equipment is an extremely important parameter. If an installation with an initial cost of e.g. DM 10,000.-- can be used for 10 years, then, given linear depreciation, there is a reduction in value of DM 1,000.-- each year. However, if the maximum service life (= lifetime) of this installation is only 5 years, then the annual depreciation at DM 2,000.-- is twice as high and requires correspondingly higher income to achieve the profitability threshhold.

This consideration implies the need to estimate carefully the foreseeable lifetime of the industrial system to be installed. Although very dependable empirical values for conventional systems are available, it must be recognised that there is no such experience for most technologies for the utilisation of renewable energy sources and for the rational use of conventional energy sources. Manufacturer estimates on this point do not constitute an absolutely dependable source of information. Within the framework of a sensitivity analysis an investigation should be made on the viability of the investment considering assumptions on the serviceable life.

1.1 Investment costs

In all procedures for calculating the economics of RE and RUE proposals, the size of the required investment is a very significant factor. Particular attention should therefore be devoted to the collection and quantification of all cost components.

Table 2 gives a survey of the various cost groups which make up the total investment costs. This survey was designed as a working basis for evaluating very different technical systems, so it is necessary when considering any one project to decide which cost components apply.

It should be noted that individual investment costs must be indexed according to their time of accrual. For this reason, the table is laid out in such a way that it is possible to clearly order the investment expenditures (and any additional or replacement investments needed during the service life) according to a time schedule as is required for proper calculation of the economic acceptability.

1.2 Residual value of the plant/liquidation yield

The residual value of the plant (-components) after the lapse of a fixed service life is also a significant factor when making an exact calculation of the favourability of an investment project.

Assuming a uniform (or linear) reduction in value during the time in which the installation is technically serviceable,

ble 2: Survey of investment costs (project title, place and country) (currency units)

Item	Period	0	1	2	3	4	5	6	7	8	9	10
	Year	19..	19..	19..	19..	19..	19..	19..	19..	19..	19..	19..
lanning												
and acquisition/leasing												
ivil works												
lant buildings and structure												
onnection to water, electricity, gas, sewage nd traffic networks												
achinery (ex-works)												
main unit equipment												
additional unit A												
additional unit B, etc.												
equipment for workshop												
ansport to port of loading[1)]												
ansport from port of loading to factory site[1)]												
ssembly and commissioning												
stoms, taxes, duties, fees												
her costs												
tal of investment costs												

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ncluding insurance

the residual value of an installation is calculated by the formula

$$\textit{residual value} = \frac{\textbf{Investment costs (in currency units)}}{\textbf{technical lifetime (in years)}} \times \textit{remaining servicable life (in years)}$$

Hence the residual value is equal to zero when the serviceable life and technical life are equal, since in this case the remaining serviceable life has the value zero (technical life minus serviceable life = remaining serviceable life). In such cases it is usually assumed where machinery is involved that any remaining salvage value of the unit just covers the dismantling costs.

If the serviceable life of a unit is shorter than the technical life of the total unit or of individual components, the residual value as calculated from the above formula can often only be taken as a rough value. The owner of a plant or parts of a plant which he no longer uses himself should rather derive its residual value from the possibilities for its alternative use. Assuming that equipment or parts of the plant can be sold, the expected liquidation yield from the sale at a fixed point in time is usually taken as the residual value. However, if a later sale or any further use of the parts appears improbable, then a residual value of zero would have to be employed.

It is particularly difficult to evaluate the residual value when an investment project includes building works, since their service life is usually much longer than the service life of machinery. In such cases there may be a very high residual value from land acquisition, civil works and the erection of buildings if the site has favourable communications and varied possibilities for further use. But on the other hand it is quite likely that the buildings are only suited to one particular use, so that at the end of the service life of the machinery the only remaining residual value depends on additional investments to enable further similar use of the land and buildings.

2.1 Manpower costs

Since costs for operating and administrative staff may form a considerable proportion of the total operating costs of an investment project, it is recommended that a very exact determination should first be made of the number of personnel required, their qualifications and periods of employment.

There is usually no problem in collecting information relating to the usual market wage and salary rates specific to the country or region. Nevertheless it may prove difficult to evaluate associated personnel costs such as social security contributions and any other standard or compulsory social surcharges (holiday pay, bonuses for particular occasions, allowances at the end of employment and so on). It is recommended that these surcharges be set as a percentage of the agreed wage or salary payment. The relevant figures are available from companies in the country concerned and from pertinent institutions (e.g. chambers of commerce).

When estimating trends in personnel costs over subsequent years, particularly with labour-intensive projects of long duration, it is necessary to consider carefully any increase in these costs on the basis of the anticipated general inflation rate. If wage and salary increases of recent years are found to deviate significantly from the increase in prices (observation period at least three years), the calculation of personnel costs would have to take account of any such increase or decrease from the general inflation rate.

Often it will be necessary in operating and maintaining RE units to employ staff whose cost will not be included in the calculation of economic feasibility, since no specific payments arise; for example where the user provides his own time or uses otherwise underemployed workers. A small farmer does not incur any manpower costs necessitating actual expenditure if he operates his biogas unit himself. But there may be a reduction in his income if this means that he has to neglect his fields. If such so-called opportunity costs reach a significant level they should be accounted for by an appropriate sum in the financial evaluation.

2.2 Repair and maintenance costs

It is very difficult to estimate the expenses of maintaining and servicing a plant since the need for repairs on a fixed unit cannot be predicted. On the basis of their experience with the same or similar units, the plant manufacturers nevertheless give a reference value (usually expressed as a percentage of the capital cost) for the anticipated maintenance and servicing costs. However, such manufacturer's information can sometimes be very optimistic, particularly with RE units, in view of the very meagre experience of long-term operation of these units. Any adjustments made should therefore be upwards rather than downwards.

It should also be examined at this point whether and to what extent repair and maintenance work can be carried out by in-company operating staff or by the user himself. This item of expenditure could then in some cases be reduced to the cost of materials and replacement parts.

2.3 Energy and related costs

In utilising solar, wind and hydro-energy as well as geothermal energy it can be assumed that the energy source will be directly available in the required quantity and quality, free of charge, after the installation of the necessary plant at any suitably selected site. On the other hand when using biomass or conventional energy sources it must be noted that costs will arise for the procurement, transport, processing and storage of the relevant energy source, for feeding the plant and for discharging and discarding of residues. These costs must be included in the financial evaluation.

Consideration should be given to the fact that biomass such as waste wood or other organic wastes which were previously available free of charge, might assume a market value because of their potential economic utilisation and would then have to be paid for. Additionally one should determine whether or not cost-free biomass could be directed to alternative uses such as livestock fodder, meaning that opportunity costs should be calculated.

2.4 Auxiliary materials

Although the costs entailed by auxiliary materials are of minor importance, a close examination and estimation of the anticipated consumption of auxiliary materials such as grease, oil, water (biogas plants), charcoal (pyrolysis plants) etc., should be made for the particular plant to be employed.

2.5 Administration costs (excl. manpower)

Although the administration costs in smaller plants for the utilisation of renewable energy sources are either non-existent or insignificant, such costs can arise for energy supply to larger villages and to small- and medium-sized towns and must be taken into account in an examination of economic feasibility. Therefore in projects of this size one must check whether expenditures for office rents, communications, office supplies and similar items will incur and at what level.

3.1 Taxes and duties

Similarly taxes and duties will only come into consideration for larger investment projects which are designed to run at a profit, such as the construction of smaller energy utilities. In this case concrete information on the tax laws and duty regulations would have to be consulted for the individual case in order to facilitate the calculation of the anticipated cost burden.

3.2 Other costs

Under this item one should collect those costs specific to the technology or the country concerned which cannot be classified in the categories described above.

3.3 Total operating costs

From the addition of items 2.1 - 3.2 we obtain the total operation-linked running costs or simply, the operating costs.

4.1 Income from the investment project

Depending on its aim, the energy-linked investment projects will give rise to income in the form of:

a) revenues from the sale of energy to third parties,
b) savings on commercial energy (expenditures saved = income) and/or
c) sale or self-utilisation of goods whose production is increased or made possible by the utilisation of energy (e.g. increased income from improved agricultural production achieved by the use of wind energy for irrigation).

The income listed under b) (saving on expenditures) is usually fairly easy to calculate from the performance loads of the plant to be installed on the one hand, and the previous requirement for commercial energy on the other. However, it can be extremely difficult to estimate the potential income from a) and c). It would hardly be possible when constructing an isolated grid to supply electricity to a specific location to state exactly how many kilowatt hours per annum can be sold at a fixed price in subsequent years. However, the future income from an investment project is of great importance for its profitability. Thus, using the most suitable method in each case, the most realistic possible assumption of income trends should be made, particularly for capital-intensive projects. Furthermore, a sensitivity analysis is imperative to investigate the effect that deviations in annual income from the predicted value obtained from market studies and other analyses would have on the financial viability of the planned project.

Item 4.1 of the data sheet provides for the three possible sources of income from an energy-linked project as mentioned above.

4.2 Other income

Possible sources of income specific to the technology or country which, in the light of their investment aim (energy production or conservation), are neither directly related to performance nor subsidies; for example, revenues from the sale of slurry from biogas for use as fertilizer can be included under this item.

4.3 Subsidies

In view of the precarious foreign trade balance of the majority of developing countries, it is very likely that investments for energy supply to rural areas by utilisation of RE sources or the substitution of conventional energy, either receive or will receive subsidies from the state in question. Such income should be included under this item in order to keep it separate from performance-related revenues.

4.4 Total income

The addition of items 4.1 - 4.3 gives the total annual income from the investment project in the individual years of operation.

5.1 Returns

The annual returns from the investment project can be calculated as the difference between item 4.4 "total incomes" and 3.3 "operating costs".

5.2 Depreciation

Depreciation is to be seen as a periodic reduction in the value of the assets employed in a project. Depreciation is not linked to expenditures in the period of productive use of the capital goods; the initial investment for providing capital goods items arises even before they come into use. Depreciation therefore does not influence the periodic returns but rather the periodic profit which is calculated as the returns minus the depreciation.

5.3 Profit

In the context of an investment calculation, the question of the favourability of an investment project is of primary importance with respect to the achievable interest on the total capital invested, without emphasizing the source of the capital. To that extent, item 5.3 represents the periodic profit on the total capital to be expected from the investment project. The profit for the private investor can be calculated very easily from this value by subtracting the financial costs i.e. interest on external capital.

C. PROCEDURES FOR THE FINANCIAL EVALUATION

Up to now we have spoken of the feasibility or favourability of an investment project without defining these terms. This section presents procedures for calculating those parameters upon which any evaluation of the absolute or relative acceptability of an investment project must be based.

The methods for a financial evaluation of individual investment projects are divided into static and dynamic procedures. The two types of procedures differ from each other in that the dynamic procedures take into account the different times at which payments on an investment are receivable. In other words, in the dynamic procedures all payments linked with an investment project are compounded at a fixed point in time*) if they fall due before this time, or they are discounted if they come after this time. Therefore, by using dynamic procedures, receipts and payments are given a higher value the earlier they fall due and a lower value later. This means for example that a return of DM 1,000 in the first year of operation will have a higher relative value than a return of the same size in, for example, the fifth year of operation.

Because they take account of the time component in evaluating investment-linked payments, the dynamic procedures undoubtedly produce better results than the static procedures. On the other hand, it is easier to carry out calculations with static procedures and their results are useful as valid approximations to those of the dynamic procedures. We shall therefore begin with an explanation of the static procedures for financial evaluation studies.

I. STATIC PROCEDURES FOR FINANCIAL EVALUATIONS

1. Cost comparison calculation

The aim of the cost comparison calculation is to identify the most cost-effective plant in each case by comparing the costs of two or more investment alternatives for the production of an identified production quantity.

For investment in the energy sector this means that the cost comparison calculation can be applied whenever a clear decision has already been made in favour of producing/saving energy and it only remains to select that system which will

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*) Usually before the plant is commissioned (t = 0)

engender the minimum costs amongst the possible alternatives. A comparison of the feasibility of alternative investments in quite different fields (e.g. energy production versus tinned food production) by means of this calculation procedure is not possible.

The cost comparison procedure can be interpreted as a supplier of input data for the cost annuity comparison, since the average costs per time period (usually one calendar year) can be determined from the formula:

$$K = K_o + \frac{I_o}{T} + \frac{I_o}{2} \cdot i$$

Whereby

K *the total costs per time period,*

K_o *the operating costs per time period,*

T *the project duration in t-time periods*

I_o *the investment costs,*

$\frac{I_o}{T}$ *the linear depreciation = amortisation of the bound capital per time period,*

i *the assumed interest rate,*

$\frac{I_o}{2} \times i$ *the assumed interest per time period on the average bound capital for the duration of the project as a continuous rate of amortisation*

Assuming one of the plants to be compared will produce a positive liquidation yield (L) at the end of its service life, the plant will not be 100 % written off and its total costs would have to be calculated according to the formula:

$$K = K_o + \frac{I_o - L}{T} + \left(\frac{I_o - L}{2} + L\right) \cdot i$$

There are two ways to determine the operating costs (K_o) per time period involved with the introduction of a certain plant. Either we can calculate an average value from the expected operating costs[1] during the life-time of the plant, or, more simply, assume that the costs for the first year of operation, which are easily estimated, correspond to the average operating costs of the plant.

Where the only concern is to identify the most cost-effective plant, i.e. where the size of the periodic costs or the cost per unit of production is not being calculated, we can ignore those cost components which are identical for all the alternatives under consideration. Their omission does not influence the result of the selection process.

The expression $\frac{I_o - L}{T}$ represents the linear depreciation charge per time period of the plants under comparison. Assuming, for example, a project duration of 5 years, the annual linear depeciation charge becomes $\frac{I_o - L}{5}$.

In calculating the interest on the capital invested in the last term of the above formula:

$$\left(\frac{I_o - L}{2} + L\right) \cdot i$$

it is assumed that the amount of bound capital which exceeds the expected liquidation yield is continuously amortised, so that in each individual year of the project duration on the average only one half of this amount is tied up and accrues interest charges. On the other hand the expected liquidation yield is completely bound for the entire service life of the plant and therefore interest must be charged on it for each year. If the time period under examination is longer or shorter than one year, the assumed interest rate which usually relates to one year must be re-determined.

In carrying out a cost comparison calculation we arrive at the average cost for each of the alternative technical systems for the time period on which the calculation is based. The comparison of the costs per time period shows which system is the most cost-effective and therefore the most favourable.

Since we assume that the plants to be compared are required for the production of a defined number of units of production, i.e. that the work to be accomplished within a given time is the same for all alternatives, the cost comparison calculation can also be made on the basis of the cost per unit of production, e.g. per kWh. This is done by dividing the costs per time period by the productivity during this time period.

Hence Plant I is more favourable than Plant II when Plant I incurs lower costs per time period and per unit production than the possible alternative plants.

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[1] Item 3.3 of the data survey

As shown by the comparison of the costs per year and per kWh calculated in Example 1 for the two alternative plants, the small hydro-power plant is considerably more cost-effective, given the assumptions made, than the diesel unit and is therefore the more favourable of the investment alternatives.

Example 1:
Identification of the more cost-effective plant for providing electricity to a small town on the basis of a comparison of annual costs with continuous amortisation of the capital invested[1].

	small hydro-power plant	diesel unit
Investment costs (DM)	540,000	87,000
Lifetime (years)	25	7
Liquidation yield at end of lifetime	---	10,000
Production units per annum (kWh)	350,000	350,000
Depreciation (DM/year)	21,600	11,000
Interest (DM/year)	21,600	3,880
Manpower costs (DM/year)	16,000	16,000
Repair and maintenance costs (DM/year)	18,900	14,400
Energy and related costs (DM/year)	---	105,000
Auxiliary materials (DM/year)	---	---
Administration costs (DM/year)	5,000	5,000
Total costs (DM/year)	83,100	155,280
Cost per unit production (DM/kWh)	0.24	0.44

One of the most commonly-asked questions in the energy sector, particularly from the aspect of the rational use of energy, is whether it would be economic to replace an existing plant by a new one which uses either less of a conventional energy source or none at all. The cost comparison calculation can help to answer this question by comparing the costs per unit of time of the old plant with those of a new plant of equal capacity.

Replacement of the old plant by a new one is economically sound when the average costs of the old plant for the comparison period are higher than the average costs of the new plant.

In Example 2 it has been assumed that the diesel unit as detailed in the case study (Appendix) has already been in operation for four years. A comparison of the average costs per year and per kWh of the old plant (diesel unit) and those of the new plant (small hydro-power plant) indicates a clear cost advantage for the new plant in spite of lower capital servicing costs for the old plant. Replacement of the diesel unit by the small hydro-power plant at the beginning of the next year of operation is therefore advantageous.

2. Cost-annuity-comparison method (static)

It has already been indicated that the cost comparison calculation can be taken as a simple approximation to the cost-annuity-comparison method. In the cost-annuity-comparison method the investment costs are converted to equal annual payments (annuities) over the duration of the project. The conversion of the investment costs is done by means of a recovery factor whose value depends on the given interest rate and the number of years of use. The correct recovery factor (RF) for the different interest rates (i) and durations of use can be taken from Table 2, Appendix IV.

As in the cost comparison calculation, the annual operating costs (K_O) are the average annual costs or alternatively the operating costs of the first year if it is thought that they will basically correspond to the anticipated average costs.

The liquidation yield of the plant represents the capital tied-up over the complete service life and as a consequence interest charges accrue over the complete period.

The annual total costs of a plant are then calculated from the formula:

$$A_K = K_O + (I_O - L) \cdot RF\ (i,t) + L \cdot i$$

The cost annuity expresses first of all the annual anticipated costs of an investment and also, after dividing these costs by the number of units produced (e.g. kWh p.a.), the costs per unit production.

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[1] The data used here are taken from the case study (Appendix). It is assumed that the cost components for the first year of operation also apply for subsequent years

Example 2:
Examination of the favourability of replacing an old diesel unit by a small hydro-power plant with continuous amortisation of the capital invested. 1)

	Old plant (diesel unit)	New plant (small hydro-power plant)
Investment costs (DM)	87,000	540,000
Units produced per annum (kWh)	350,000	350,000
Lifetime (years)	7	25
Residual service life of the <u>old</u> plant (years)	3	—
Comparison period (years)	3	3
Residual value of the <u>old</u> plant at the beginning of the comparison period (DM)	43,000	—
Liquidation yield of the <u>old</u> plant at the end of the comparison period (DM)	10,000	—
Liquidation yield of the <u>new</u> plant at the end of its lifetime (DM)	—	0
Depreciation of the <u>old</u> plant (DM/year) ((43,000 - 10,000)/3)	11,000	—
Depreciation of the <u>new</u> plant (DM/year) ((540,000-0)/25)	—	21,600
Interest (8 % on average capital invested)(DM/year)	1,880	21,600
Manpower costs	16,000	16,000
Repair and maintenance costs (DM/year)	14,400	18,900
Energy costs (DM/year)	105,000	—
Auxiliary costs (DM/year)	—	—
Administrative costs (DM/year)	5,000	5,000
Total costs (DM/year)	153,280	83,100
Cost per unit production	0.44	0.24

Example 3:
Calculation of the cost annuity for a small hydro-power plant (c.f. case study, Appendix).

The project has the following data:

K_o (*for years of operation 1 – 25*) = 39,900 *DM*
I_o =540,000 *DM*
L (*after 25 years of operation*) = 0
i (*assumed interest rate*) = 8%

$$A_K = K_o + (I_o - L) \cdot RF\,(8\%, 25) + L \cdot i$$

$$A_K = 39{,}900 + (540{,}000 - 0) \cdot 0.094 + 0 \cdot 0.08 =$$

$$= 39{,}900 + 50{,}585.50 = \underline{90{,}485.50 \ DM}$$

By taking account of compound interest, the cost-annuity-comparison method provides more exact values than the simple cost comparison method introduced earlier. In the latter the capital servicing factor (depreciation (= amortisation) and interest on the capital invested) is always lower than the recovery factor used in the annuity method. However, this means that calculators and/or tables must be used to obtain the recovery factors.

It should be noted that the cost annuity calculated according to the **static** procedure is equal to the cost annuity determined by the **dynamic** procedure if one can assume constant annual operating costs, or when the expenditures of the first year can be inserted as the probable average values.

When there are several possibilities for providing a given performance, then the plant chosen by this method is the one with the lowest cost annuity or with the lowest cost per production unit.

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1) The data used here are taken from the case study (Appendix). It is assumed that the cost components for the first year of operation also apply to subsequent years

Example 4 shows that in solving the selection problem, the cost-annuity-comparison method will lead to the same result as the cost comparison calculation in this case. Nevertheless the values of the capital-linked costs are now higher than with the cost comparison calculation because compound interest is taken into account. This is particularly the case for the more capital-intensive investments.

The cost-annuity-comparison method can be used just like the cost comparison calculation for evaluating the replacement problem.

Hence an old plant should be replaced by a new one when the cost annuity of the new plant is lower than that of the old plant.

Example 5 shows that if the cost annuity comparison method is applied, it would appear advantageous in this case to replace the old diesel unit, which has only been in operation for four years, by a new small hydro-power plant.

Example 4:
Identification of the most cost-effective plant for the supply of electricity to a small town based on the cost annuity comparison[1)]

	Small hydro-power plant	Diesel unit
Investment costs (DM)	540,000	87,000
Lifetime (years)	25	7
Liquidation yield at end of lifetime	—	10,000
Units produced per annum (kWh)	350,000	350,000
Annuity of investment costs (i = 8 %) (DM/year)	50,587	14,790
Operating costs (DM/year)	39,900	140,400
Interest on liquidation yield (i = 8 %) (DM/year)	0	800
Total costs (DM/year)	90,487	155,990
Costs per unit production (DM/year)	0.26	0.45

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1) The data used here are taken from the case study (Appendix). It is assumed that the cost components for the first year of operation also apply for subsequent years.

Example 5:
Examination of the favourability of replacing an old diesel unit by a small hydro-power plant based on the cost annuity comparison[1)]

	Old plant (diesel unit)	New plant (small hydro-power plant)
Investment costs (DM)	87,000	540,000
Units produced per annum (kWh)	350,000	350,000
Lifetime (years)	7	25
Remaining serviceable life of the old plant (years)	3	—
Comparison period (years)	3	3
Residual value of the old plant at the beginning of the comparison period (DM)	43,000	—
Liquidation yield of the old plant at the end of the comparison period (DM)	10,000	—
Liquidation yield of the new plant at the end of its lifetime (DM)	—	0
Annuity of the investment costs of the old plant (DM/year) ((43,000 - 10,000) x RF (8 %, 3))	12,805	—
Annuity of the investment costs of the new plant (DM/year) ((540,000 - 0) x RF (8%, 25))	—	50,587
Operating costs (DM/year)	140,400	39,900
Interest on the liquidation yield (i = 8 %) (DM/year)	800	0
Total costs (DM/year)	154,005	90,487
Cost per unit production (DM/kWh)	0.44	0.26

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1) The data used here are taken from the case study (Appendix). It is assumed that the cost components for the first year of operation also apply in subsequent years.

3. Calculation of profitability

In the static calculation of profitability, also referred to as the Return-on-Investment method, the average profit per time interval on an investment project (normally the profit per annum) is related to the average capital invested.

$$ROI = \frac{NP}{K_A} \cdot 100 \quad (= \% \text{ per time interval!})$$

ROI = Return on investment

NP = average net profit per time interval

K_A = average capital invested per time interval.

With this method, the criterion of absolute profitability is fulfilled when the return on investment either corresponds to or exceeds the minimum acceptable profitability.

The amount to be entered as the average net profit – NP – is the average return per time interval (= excess of income over operating costs) reduced by the amount of linear depreciation charged for each time period. If the annual profitability of an investment project is to be determined then the value established for the first year of operation can be inserted for NP in item 5.3 of the data survey[1], assuming that the returns and depreciation are constant (item 5.2 data survey). On the other hand if annually varying profits are anticipated, the NP must be calculated as their average value.

The average capital invested K_A can be taken into account by means of the simple formula:

$$K_A = \frac{1}{2}\,(I_o - L) + L$$

I_o = investment costs

L = liquidation yield at the end of service life.

In applying this formula it is assumed that a half of the capital to be written off during the service life of the plant will be invested at a uniform rate of amortisation in each time interval while all of the anticipated liquidation yield in each time interval is invested.

Example 6:
Calculation of the profitability (ROI) of a small hydro-power plant
(c.f. case study, Appendix)

Project data:

I_o = 540,000 *DM*

L = 0

K_A = *average capital invested* $(I_o/2) = 270{,}000$ *DM*

NP = *profit (return minus depreciation)* =

= 113,500 *DM*

$$ROI = \frac{NP}{K_A} \cdot 100$$

$$ROI = \frac{113{,}500}{270{,}000} \cdot 100 = 42\,\% \text{ (per annum)}$$

If we assume that the minimum acceptable ROI for this investment project was 11 %, then the project would be advantageous in absolute terms since the value of 42 % considerably exceeds the minimum acceptable interest.

When applying this static method it must be noted that the minimum acceptable interest on the capital invested (ROI_{min}), which is used as a standard for evaluating the absolute favourability of a project, must exceed the assumed interest rate (i) which in turn reflects the real interest requirement on a project. If the project calculated in Example 6 were completely financed by external capital at an interest rate of 8 % (= assumed interest rate), the debt (amortisation and interest on the bound capital) could only be serviced if this calculation method were to result in a rate of return on investment of at least 10.8 %.

---

[1] Table 1

Together with the comparison of the return on investment as calculated in this section and the interest rates established in Section C.II.3 (IRR) for the two examples "small hydro-power plant" and "diesel unit", this shows that the return-on-investment method can provide only a very rough estimation of the interest on the capital invested. It should therefore generally be used only for rough calculations.

The calculation of profitability can also be applied to select the most attractive of two or more alternative investment possibilities. However, it must be noted that the comparison of the ROI values and subsequent choice of the investment alternative with the highest return on investment can be an inaccurate decision. If the investment costs and service lives of the alternatives differ and if it cannot be expected that the difference in capital cost can be invested at the rate of profitability of the less capital-intensive investment (which is most unlikely), then it follows that the profitability of projects with different capital requirements must be compared on the basis of the favourability of an investment of the difference in capital cost.

The difference between the periodic profits of the two investments is expressed as a percentage of the difference in their capital costs and compared with the minimum acceptable profitability. If the profitability of the investment of the difference exceeds the minimum acceptable profitability, then the investment with the higher capital requirement is the more advantageous.

Accordingly:

$$\frac{NP^{I} - NP^{II}}{K_A^{I} - K_A^{II}} \cdot 100 > ROI\ min$$

NP = *average net profit per time interval*

K_A = *average capital invested per time interval*

I = *investment project with the higher average capital requirement*

II = *invesment project with the lower average capital requirement*

$ROI\ min$ = *minimum acceptable profitability*

Example 7:
Selection of the more favourable investment alternative on the basis of the profitability of the investment of the difference in captial cost[1]

	Small hydro-power plant	diesel unit	difference in investment
Investment costs I_o	540,000	87,000	---
Liquidation yield L	---	10,000	---
Lifetime T	25	7[2]	---
Average capital invested K_A $((I_o - L) / 2 + L)$	270,000	48,500	221,500
Average profit NP	113,500	23,600	89,900
Profitability ROI $\frac{NP}{(I_o - L) / 2 + L} \times 100$	42 %	49 %	41 %

[1] The data used here are taken from the case study (Appendix). It is assumed that the receipts/payments for the first year will also apply to subsequent years.

[2] Since the lifetime of the two projects is very different, it has been assumed in determining the average profit for the investment of the difference, that the diesel unit has been replaced at the end of its lifetime by similar units under the same conditions.

The results of Example 7 show that the diesel unit project at 49 % has a higher return on investment than the small hydro-power plant with 42 %. Nevertheless the choice of the "diesel unit" project would in all probability be a wrong decision despite its higher profitability, since it appears highly unlikely that the difference in capital costs between the two projects could be invested equally profitably.

On the other hand, the small hydro-power plant also achieves a very high rate of interest on a considerably higher capital outlay. The profitability of the investment of the difference at 41 % is so much higher than the minimum acceptable interest of 11 % that the small hydro-power plant proves to be the more advantageous investment alternative.

The condition for favourability:

$$ROI_D = 41\% > ROI_{min} = 11\%.$$

is clearly fulfilled by the small hydro-power plant as the investment with the greater capital requirement.

4. Calculation of the static pay-back period

The purpose of calculating the pay-back period is to determine the point in the time at which the capital invested in an investment project will be recovered by the annual returns. The period between the beginning of the investment and this point in time is known as the pay-back, pay-off or payout period.

The pay-back point or end of the pay-back period is reached whenever the sum of the receipts and payments linked to the investment first reach zero.

With the static pay-back calculation there are two possible methods for calculating the pay-back period.

a) With the **cumulative method** the investment expenditures and the annual returns are added together until the total reaches the value zero or is positive in the event of the pay-back point being reached during the course of one year of calculation.
In this method the pay-back period corresponds to the number of years required in the cumulative sum.

Example 8:
Calculation of the static pay-back period of a small hydro-power plant using the "cumulative method" (c.f. case study, Appendix)

	Annual payments	Cumulative value
Investment costs (DM)	- 540,000	- 540,000
Returns (DM/annum)		
1st year	+ 135,100	- 404,900
2nd year	+ 135,100	- 269,800
3rd year	+ 135,100	- 134,700
4th year	+ 135,100	+ 400
up to 25th year	+ 135,100	

In the sample calculation shown above, the total captial outlay is recovered shortly before the end of the fourth year of operation. Hence the pay-back period is only four years.

b) In the averaging method the pay-back period (n) is determined by relating the capital invested to the annual returns:

$$n = \frac{\text{capital invested}}{\text{annual return}}$$

However, this simple method can only be applied when the average return has already been determined or if it is assumed that the return in the first year represents the average return.

Example 9:
Calculation of the static pay-back period of a small hydro-power plant using the "averaging method" (c.f. case study, Appendix)

Capital investment (= investment costs): 540,000 DM
Annual return : 135,100 DM
Pay-back period : n

$$n = \frac{\text{capital invested}}{\text{annual return}}$$

$$n = \frac{540{,}000}{135{,}100} = 3.997 \text{ or approx. 4 years}$$

The result in Example 9 shows that in this case a pay-back period of just four years is calculated by both methods. The comparison of the pay-back period of four years with the expected project duration of 25 years shows that the project will pay itself off long before the end of the technically-expected service life, and hence the minimum criterion required by this method for the favourability of the proposal will be fulfilled.

In applying pay-back period as a criterion for the acceptability of an investment, a given project is to be regarded as absolutely favourable when it pays itself off within the service life or within a set pay-back limit which must be shorter than the technical service life.

At this point it must be noted that the pay-back calculation should be seen as a calculation of risk. We cannot draw conclusions on the profitability of an investment project from the length of the pay-back period. At most it would permit a statement to be made on the economic risk linked with the investment in view of the uncertainty of future developments.

The pay-back period should not therefore be used as the single criterion for evaluating an investment project. This is particularly so in the comparison of investment alternatives. It would be quite possible in such a case for a project to have a shorter pay-back period than an alternative one, but a lower return on investment, so that a selection on the basis of the pay-back period alone would lead to an inaccurate decision.

Example 10:
Comparison of a small hydro-power plant and a diesel unit on the basis of their static pay-back period[1] using the averaging method

	Small hydro-power plant	Diesel unit
Investment costs (DM)	540,000	87,000
Lifetime (years)	25	7
Average return (DM/annum)	135,100	34,600
Pay-back period (years)	4	2.5

[1] The data used here are taken from the case study (Appendix). It is assumed that the return for the first year also applies in subsequent years.

The results of sample calculation (10) show that both projects have a pay-back period which is clearly shorter than the technical life. As stated above, it cannot be assumed that the diesel unit is more profitable because it has a shorter pay-back period but simply that the capital invested can be recovered sooner, given the assumptions made.

Provided that a pay-back period of 4 years is sufficient for the investor - often, particularly in developing countries, only short pay-back periods are acceptable - neither of the two investment alternatives can be ruled out as absolutely unfavourable if the pay-back period is used as the criterion for viability.

It should be pointed out that the pay-back period is of only limited dependability as a risk criterion. In each case an investigation of the sensitivity of the pay-back period to variations in other important parameters is to be recommended. For example, a reduction in the unit sales price of 0.05 DM/kWh would double the pay-back period of the diesel unit from 2.5 years (Example 10) to 5 years, while in such a case the pay-back period of the small hydro-power plant would only be extended by 0.5 years. With a reduction of the selling price of 0.10 DM/kWh, the annual return on the diesel unit would become negative so that the pay-back of the capital invested would no longer be achievable. On the other hand, with a price per kWh of 0.40 DM the pay-back period of the small hydro-power plant would rise to 5.4 years.

These figures should make it clear that it is quite possible for the project with the shortest pay-back period to have the highest financial risk. Therefore the criterion of "pay-back period", so often applied in practice, should be viewed with a certain degree of scepticism unless it is further substantiated by a sensitivity analysis.

II. DYNAMIC PROCEDURES OF FINANCIAL ANALYSIS

1. Net Present Value

It has already been stated at the beginning of this chapter that the dynamic methods of analysis differ from the static methods in that it is assumed that a credit or debit can have a very different value depending on when the transaction takes place.

The value which is to be accorded to a future or past payment at the present time, i.e. before the investment project begins or before the commissioning of an installation, is described as its present value and is calculated from its past amount by compounding or from the future amount by discounting with the aid of a factor which depends on the interest rate adopted and the length of time between the payment and the beginning of the project. It is in practice very rare to compound figures: the necessity would only arise with larger investments when the investment costs extend over several years before the commissioning. Conversely it is necessary to discount for all investment projects with a duration of more than one year. The discounting factors to be applied for alternative interest (discount) rates (i) and years (t) can be taken from Table 1 (Appendix IV).

The net present value (NPV) of an investment project at the point in time $t = 0$ is the sum of the present values of all the cash inflows and outflows linked to the investment.

In order to simplify the calculation, expenditures and items are generally balanced to obtain annual returns so that the net present value of an investment project is simply the sum of the present values of its returns plus the present value of its liquidation yield minus the present values of its investment costs.

$$NPV = (R_o - I_o) \cdot q^{o} + \dots + (R_t - I_t) \cdot q^{-t} + L_t \cdot q^{-T}$$

$$= \sum_{t=0}^{T} \left(R_t - I_t\right) \cdot q^{-t} + L_T \cdot q^{-T}$$

$$= \sum_{t=0}^{T} NCF_t \cdot q^{-t}$$

In this formula:

NPV	*net present value of the investment project at the point in time* $t = 0$
R_o	*the return in the year of commissioning*
R_t	*the return in time period* t
I_o	*investment cost in time period* t
q^{-t}	*discounting factors* $(1+\frac{i}{100})^{-t}$
	i *= discount rate*
	t *= time of the payment*
L_T	*Liquidation yield at the end of service life*
NCF_T	*net cash flow at time* t

When the total investment costs are paid at time $t = 0$ and returns fall due in the years $t = 1, \dots, T$, the formula for calculation is simplified to

$$NPV = -I_o + \sum_{t=1}^{T} R_t \cdot q^{-t} + L_T \cdot q^{-T}$$

The net present value of the small hydro-power plant (c.f. case study, Appendix) was determined in Example 11 as an illustration of the calculation method. First, the investment costs, the residual value (in this case = 0) and the annual returns were brought together in one item which is usually known as the cash-flow. In the next line the discounting factors for the given discount rate of 8 %, taken from Table 1, Appendix IV, were inserted. The present value of each annual net cash flow was established by simple multiplication of the values given in the cash-flow line and the respective discounting factors. The sum of the individual present values represents the net present value of the investment project, in this case DM 902,400.

Since the annual returns in this case are constant at DM 135,000, the net present value NPV could have been determined more easily by means of the present value factor (PF)

$$NPV = -I_o + R \cdot PF + L_T \cdot q^{-T}$$

$$\text{where} \quad I_o = 540{,}000 \ DM$$

$$R = 135{,}100 \ DM$$

$$L_T = 0$$

$$PF \left(\text{for } t = 25 \text{ and } i = 8\%\right) = 10.675$$

$$NPV = -540{,}000 + 135{,}100 \cdot 10.675 + 0$$

$$= -540{,}000 + 1{,}442{,}192.5 = \underline{902{,}192.50 \ DM}$$

(The slight deviation of this value from the NPV given above arises due to rounding errors).

The respective present value factor for various lifetimes and interest rates can be taken from Table 3, Appendix IV. As shown above the NPV of an investment project can be established very easily by using basic calculation procedures.

Example 11:

Calculation of the net present value (NPV) of a small hydro-power plant[1] (in 1,000 DM)

	0	1	2	3	4	5	6	7	8	9	10	11	12
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
nvestment costs (I_t)[2]	(540)	-	-	-	-	-	-	-	-	-	-	-	-
esidual value (L_t)	-	-	-	-	-	-	-	-	-	-	-	-	-
eturn (R_t)	-	135.1	135.1	135.1	135.1	135.1	135.1	135.1	135.1	135.1	135.1	135.1	135.1
ash-flow	(540)	135.1	135.1	135.1	135.1	135.1	135.1	135.1	135.1	135.1	135.1	135.1	135.1
iscounting factor for i = 8 %)	1	0.926	0.857	0.794	0.735	0.681	0.630	0.583	0.541	0.500	0.463	0.429	0.397
resent values	(540)	125.1	115.8	107.3	99.3	92.0	85.1	78.8	73.1	67.6	62.6	58.0	53.6

	13	14	15	16	17	18	19	20	21	22	23	24	25
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
nvestment costs (I_t)[2]	-	-	-	-	-	-	-	-	-	-	-	-	-
esidual value (L_t)	-	-	-	-	-	-	-	-	-	-	-	-	-
eturn (R_t)	135.1	135.1	135.1	135.1	135.1	135.1	135.1	135.1	135.1	135.1	135.1	135.1	135.1
ash-flow	135.1	135.1	135.1	135.1	135.1	135.1	135.1	135.1	135.1	135.1	135.1	135.1	135.1
iscounting factor for i = 8 %)	0.368	0.340	0.315	0.292	0.271	0.250	0.232	0.215	0.199	0.184	0.170	0.158	0.146
resent values	49.7	45.9	42.6	39.4	36.6	33.8	31.3	29.0	26.9	24.9	23.0	21.3	19.7

Net present value (= sum of the present values t_o - t_{25})
<u>NPV = 902,400 DM</u>.

---

[1] The data used here are taken from the case study (Appendix). It is assumed that the cash inflow/outflow of the first year is also valid for subsequent years.

The net present value is an expression of the change in value of the capital resources employed which can be expected during the lifetime of the project, associated with a given interest requirement (assumed discount rate) and with reference to a point in time t_0.

When applying the net present value method an investment can only count as being profitable when its NPV is at least equal to zero. A negative NPV would indicate that the desired minimum interest rate (cut-off discount rate) will not be reached. On the other hand a NPV greater than zero means that the interest rate on capital is greater than the assumed discount rate, and the greater the NPV the more profitable the investment.

When there are several alternative investment possibilities, the NPV of the different projects should be compared with one another and the investment with the highest net present value should be selected. Of course, the alternative selected must also meet the minimum criterion of profitability i.e. its NPV must be positive.

Example 12:
Comparison of a small hydro-power plant and a diesel unit on the basis of their net present value (NPV)[1]

	Small hydro-power installation		diesel unit	
Investment costs (I_o)	(540,000)	(540,000)	(87,000)	(87,000)[2]
Liquidation yield (L_t)	—	—	10,000	
Discounting factor (q^{-T})			x 0.583= (i=8%, t=7)	5,830
Return ($R_1 = R_2 = R_T$)	135,100		34,600	
Present value factor PF (i, t)	x 10.675 = (i = 8 %, t = 25)	1.442.193	x 5.206 = (i = 8 %, t = 7)	180,127.6
Net present value	NPV =	902,193	NPV =	98,958

[1] The data used here are taken from the case study (Appendix). It is assumed that the cash inflows/outflows for the first year also apply to subsequent years.

[2] Negative values are given in brackets (...)

As the results of Example 12 show, both projects have a positive NPV and are therefore both certainly profitable. However since the NPV of the investment project "small hydro-power plant" is much greater than that of the competing project, this project is relatively more favourable and should there-

Problems may arise when identifying the best of several investment alternatives by comparing their respective net present values if, as is true of our example, the alternatives differ considerably both in their capital requirement and in their duration. In such cases project selection by means of the net present value method can only be seen as methodologically sound if it can be assumed that capital can be invested or borrowed at any time at the applied discount rate and in the required volume. (If this applies the NPV of the additional or follow-up investments which can be made with the capital difference is equal to zero and therefore leaves the comparison value unchanged).

However, since this assumption is not always realistic, it will be necessary in practice either to forgo the application of the net present value method for selecting the more acceptable investment possibilities, or to include any possible additional or follow-up investments in some suitable way in the comparison. Specifically this means that the investment alternative with the lower capital requirement and/or the shorter duration will not be treated as an individual investment but that its NPV will be calculated from a series of complementary investments whose cummulative cash flows and duration correspond as closely as possible to those of the investment project with the higher capital requirement and/or longer duration.

In the comparison of the small hydro-power plant and the diesel unit it is assumed that both projects would be 100 % financed with borrowings at the pre-determined rate of 8 %. It is not known whether it would be possible to invest the difference between the capital sums needed for the two projects (DM 453,000) in such a way that the diesel unit alternative, if adopted, could increase its net present value. This would require investment of the difference at an interest rate of over 8 %. The given input information does not allow a meaningful consideration of possible additional investments of the difference.

It can be assumed however that if a diesel unit is installed and if the financial parameters remain unchanged it would be replaced by new unit of the same type at the end of its lifetime. And so one can foresee a chain of similar investments whose total duration cannot be predicted but whose economic feasibility can be judged over a period of 25 years i.e. the foreseeable lifetime of the alternative "small hydro-power plant" investment with which it is being compared.

In Example 13 the expected investment chain is portrayed numerically assuming constant prices and quantities, and its NPV is calculated. As the calculation shows, the NPV is altered considerably by incorporating the follow-up investments on the diesel unit which would be conceivable during

Example 13.

lculation of the net present value (NPV) of a diesel unit assuming subsequent new equipment investments at the end of each lifetime$^{1)}$ (in 1,000 DM)

	0	1	2	3	4	5	6	7	8	9	10	11	12
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
nvestment costs (I_t)$^{2)}$	(87)	-	-	-	-	-	-	(87)	-	-	-	-	-
esidual value (L_t)	-	-	-	-	-	-	-	10	-	-	-	-	-
eturn (R_t)	34.6	34.6	34.6	34.6	34.6	34.6	34.6	34.6	34.6	34.6	34.6	34.6	34.6
ash-flow	(87)	34.6	34.6	34.6	34.6	34.6	34.6	(42.4)	34.6	34.6	34.6	34.6	34.6
iscounting factor for i = 8 %)	1	0.926	0.857	0.794	0.735	0.681	0.630	0.583	0.541	0.500	0.463	0.429	0.397
resent values	(87)	32.0	29.7	27.5	25.4	23.6	21.8	(24.7)	18.7	17.3	16.0	14.8	13.7

	13	14	15	16	17	18	19	20	21	22	23	24	25
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
nvestment costs (I_t)$^{2)}$	-	(87)	-	-	-	-	-	-	(87)	-	-	-	-
esidual value (L_t)	-	10	-	-	-	-	-	-	10	-	-	-	-
eturn (R_t)	34.6	34.6	34.6	34.6	34.6	34.6	34.6	34.6	34.6	34.6	34.6	34.6	34.6
ash-flow	34.6	(42.4)	34.6	34.6	34.6	34.6	34.6	34.6	(42.4)	34.6	34.6	34.6	34.6
iscounting factor for i = 8 %)	0.368	0.340	0.315	0.292	0.270	0.250	0.232	0.215	0.199	0.184	0.170	0.158	0.146
resent values	12.7	(14.4)	10.9	10.2	9.3	8.7	8.0	7.4	(8.4)	6.4	5.9	5.5	11.3

Net present value (= Total of the present values) NPV = 202,200 DM

) The data used here are taken from the case study (Appendix). It is assumed that the cash flow for the first year also apply in subsequent years.

) Negative values are given in brackets (...).

the lifetime of the "small hydro-power plant" alternative. While a NPV of about DM 99,000 is calculated for the diesel unit as an individual one-time plant with a lifetime of seven years, this value rises to DM 202,000 when taking into account the expected follow-up investments during a period of 25 years. In fact, in our comparison of alternatives this does not bring about revised results in the evaluation of the project. The NPV of the "small hydro-power plant" project is still very much greater at DM 902,000, but it is clear that the failure to account for follow-up investments can lead to incorrect decisions. Moreover the danger of deciding wrongly and adopting the less favourable project is increased the larger the difference in service life and investment costs or the smaller the difference in the NPV of the alternatives.

Since the above considerations show that the net present value method only permits a sound methodological evaluation when the investment costs and lifetimes are similar, we would recommend in those cases where these preconditions are not fulfilled that the selection process should be based on the annuity method, further described below, which allows a comparison of investment projects with very different service lives.

2. Internal Rate of Return

The internal rate of return method can be taken as a special form of the net present value method given above.

In the net present value method a minimum acceptable interest rate, i.e. the cut-off discount rate, is assumed and the NPV is established by discounting all cash flows. However, in the internal rate of return method, the interest rate (IRR) at which the NPV is zero must be determined.

This means that the internal rate of return (IRR) of an investment expresses the achievable interest on the capital tied-up in the investment[1].

The formula for calculating the internal rate of return (IRR) can be established directly from the NPV formula, where NPV = 0:

$$0 = -I_0 + \sum_{t=1}^{T} R_t \cdot \left(1 + \frac{IRR}{100}\right)^{-t} + L_T \cdot \left(1 + \frac{IRR}{100}\right)^{-T}$$

If there is no calculator available for establishing IRR, the internal rate of return can be determined from the following procedure.

After selecting suitable discount rates (i_1 and i_2), two net present values NPV_1 and NPV_2 are calculated using the net present value method. One of these values should be negative. By means of graphic or mathematical interpolation or extrapolation the internal rate of return (IRR) can be determined.

$$IRR = i_1 - NPV_1 \frac{i_2 - i_1}{NPV_2 - NPV_1}$$

When applying the internal rate of return method an investment is viewed favourably if the internal rate of return – IRR – is either equal to or greater than the pre-determined cut-off discount rate – i –, that is, when at least the minimum acceptable interest is certain. The following must hold true:

$$IRR \geq i$$

---

[1] The return on investment method described in Section C.I.3, as stated, gives only rough approximations to the interest rates which can be determined very exactly by the internal rate of return method.

Example 14:
Calculation of the internal rate of return (IRR) of the small hydro-power plant (c.f. case study, Appendix)

The project has following data:

Investment costs (I_0) : *540,000 DM*
Lifetime (years) : *25 years*
Return (R_t) : *135,100 DM/annum*
Liquidation yield (L_T) : *0 DM*

$$NPV = -I_0 + \sum_{t=1}^{T} R_t \cdot q^{-t} + L_T \cdot q^{-T}$$

$NPV_1 = 69{,}833$ for $i_1 = 22\%$

$NPV_2 = -58{,}508$ for $i_2 = 28\%$

$$IRR = i_1 - NPV_1 \cdot \frac{i_2 - i_1}{NPV_2 - NPV_1}\ \%$$

Hence:

$$IRR = 22 - 69{,}833 \cdot \frac{28 - 22}{-58{,}508 - 69{,}833} =$$

$$= 22 - 69{,}833 \cdot \frac{6}{-128{,}341} = 22 + 3.3 = \underline{\underline{25.3\%}}$$

For the small hydro-power plant the internal rate of return is 25.3 %.

(Since the basic function underlying the internal rate of return is non-linear, this procedure only gives a first approximation. The result would become more accurate by selecting the discount rates i_1 and i_2 closer together).

Since an IRR of 25.3 % for this project considerably exceeds the minimum acceptable or cut-off rate of 8 %, this investment project is viable on an individual basis.

In order to select between alternative investment possibilities, the internal rates of return are compared.

The choice should be in favour of the investment alternative with the highest IRR where this rate must at least equal the required cut-off rate i.e. fulfil the minimum criterion of favourability.

Example 15:
Calculation of the internal rate of return (IRR) of the diesel unit (c.f. case study Appendix)

Calculation of the internal rate of return (IRR) of the diesel unit (c.f. case study, Appendix)

The project has following data:

Investment costs (I_0) : *87,000 DM*
Lifetime (T years) : *7 years*
Return (R_t) : *34,600 DM*
Liquidation yield (L_T) : *10,000 DM*

$$NPV = -I_0 + \sum_{t=1}^{T} R_t \cdot q^{-t} + L_T \cdot q^{-T}$$

$NPV_1 = 4{,}964$ for $i_1 = 33\%$

$NPV_2 = -2{,}706$ for $i_2 = 37\%$

$$IRR = i_1 - NPV_1 \cdot \frac{i_2 - i_1}{NPV_2 - NPV_1}\ \%$$

Hence:

$$IRR = 33 - 4{,}964 \cdot \frac{37 - 33}{-2{,}706 - 4{,}964} = \underline{\underline{36\%}}$$

The internal rate of return of the diesel unit in Example 15 is 36 %.

Since the IRR of the diesel unit (36 %) is considerably higher than that of the small hydro-power plant (25 %), this calculation suggests that the diesel project is the more attractive.

Of course serious objections can be raised against the internal rate of return method as a basis for project selection by comparing the IRR for projects with differing captial requirements and/or differing service lives. A direct comparison of the internal rates of return in such cases can only give a correct estimation of the alternative projects if it is assumed that additional and follow-up investments can be made at an interest rate equal to the IRR of the original investment. This would mean that the diesel unit is only more favourable than the small hydro-power plant if it is assumed that the difference between the investment costs of the two projects (640,000 - 87,000 = 453,000) plus the resources which become available from the diesel unit project can all be invested as follow-up investments at an interest rate of 36 %.

The more the internal rate of return of an investment departs from the assumed discount rate, as derived from market data, the more unlikely is the expectation to be able to invest any desired amount of capital at practically any desired interest rate. For this reason we should not base our selection simply on a comparison of the internal rate of return of the alternative projects.

As a consequence of this, it has been suggested in the relevant literature that the selection procedure be based on the internal rate of return method used in an analogous way to the return on investment method i.e. by establishing the internal rate of return of the investment of the difference in capital costs[1].

However we do not intend to follow this recommendation here. This quite complicated procedure need not be covered since the annuity method described below and the subsequent cost annuity comparison method allow a somewhat simpler selection procedure where investment alternatives exist.

) cf. Section C.I.3

3. Annuity method

The annuity method, likewise a variant of the net present value method, aims to convert all the net cashflows connected with an investment project into a series of annual payments of equal amount. The conversion takes place by multiplying the net present value NPV (for the calculation of the NPV see also Section C.II.1) by the recovery factor RF (i,T) for a pre-determined discount rate (i) and a known planning period T (T years).

The annuity -A-, the constant annual payment for an investment, is calculated from the formula

$$A = NPV \cdot RF \ (i,T)$$

Example 16:
Calculation of the annuity of a small hydro-power plant
(c.f. case study, Appendix)

The project has the following data:

Net present value NPV	: *902,400 DM (result of the calculation example 11, Section C.II.1)*
Lifetime	: *25 years*
Applied discount rate	: *8%*
Recovery factor RF *RF(8%;25)*	: *0.094*[1]

$$A = NPV \cdot RF \ (i,T)$$

$$A = 902{,}400 \cdot 0.094 = 84{,}534$$

$$\underline{\underline{A = 84{,}534 \text{ DM}}}$$

---

[1] The value of the recovery factor (RF) has been taken from Table 2, Appendix IV.

When the NPV of an investment project has not yet been calculated, the annuity of the project, can be broken down into the following components which can then be calculated separately:

a) Annuity of the investment costs - A_I:

$$A_I = i_o \cdot RF\,(i,T)$$

b) Annuity of the return (excess of annual income over the operating costs) - A_R:

$$A_R = \left(\sum_{t=1}^{T} R_t \cdot q^{-t}\right) \cdot RF\,(i,T)$$

This formula can be simplified to

$$A_R = R\left(R = \text{annual return}\right)$$

if the annual return in all years of the service life can be taken as being constant.

c) Annuity of the liquidation yield - A_L:

$$A_L = L_T \cdot q^{-T} \cdot RF\,(i,T)$$

Then for the annuity of an investment project:

$$A = A_R + A_L - A_I$$

Example 17:
Calculation of the annuity of a diesel unit (c.f. case study, Appendix)

The project has the following data:

Lifetime (T)	: 87,000 DM
Investment costs (I_o)	· 7 years
Return (R)	: 34,600 DM per annum
Liquidation yield (L_T)	: 10,000 DM
Applied discount rate	: 8%
Recovery factor (RF)	: 0·192
RF (8%; 7years)	

a) $A_I = I_o \cdot RF\,(8\%; 7)$

$A_I = 87{,}000 \cdot 0.192 = 16{,}712$

$\underline{\underline{A_I = 16{,}712 \text{ DM}}}$

b) $A_R = \left(\sum_{t=1}^{T} R_t \cdot q^{-t}\right) \cdot RF\,(i,T)$

or

$A_R = \bar{R}$ *given constant annual returns as in this case*

$\underline{\underline{A_R = 34{,}600 \text{ DM}}}$

c) $A_L = L_T \cdot q^{-T} \cdot RF\,(i,T)$

$A_L = 10{,}000 \cdot 0.583 \cdot 0.192 = 1{,}119$

$\underline{\underline{A_L = 1{,}119 \text{ DM}}}$

NOTE: The value for the discounting factor
q^{-T} *for*
$i = 8\%$ *and*
$T = 7$ *years*
was taken from Table 1, Appendix IV.

Thus the annuity of this project is calculated as:

$$A = A_R + A_L - A_I$$

$$A = 34{,}600 + 1{,}119 - 16{,}712 = 19{,}007$$

$$\underline{\underline{A = 19{,}007 \quad DM}}$$

When applying the annuity method, an investment is considered favourable when its annuity is not negative ($A \geq 0$), meaning that interest on the capital invested is obtained at least at the level of the required cut-off rate or an additional surplus, meaning a higher A, is reached.

Since both the "small hydro-power plant" project (Example 16) and the diesel unit project (Example 17) have positive annuities, both projects are completely acceptable using the criterion of the annuity method.

If there are several mutually exclusive investment alternatives to be compared, then the alternative with the highest annuity should be adopted so long as it also meets the minimum criterion, i.e. has either an annuity of zero or a positive value.

From this it can be seen that of the two investment alternatives considered here, the "small hydro-power plant" project is the more attractive since the calculated annuity of DM 84,534 is considerably greater than that of the "diesel unit" at DM 19,007.

One difference from the net present value method on which it is based, is that the annuity method can be used to compare investment alternatives even if they have very different service lifetimes, without the danger of making a false decision. In the annuity method, the comparison is based on the annual returns with the time factor taken into account and not - as in the net present value method - the returns or net cashflows accumulated during the whole service life, which is usually different for each investment alternative.

Of course there are objections to applying the annuity method when choosing between alternatives with varying initial investment costs. If it is unlikely that financial resources can be borrowed or invested at the applied interest (discount) rate at any time and for any required volume, then for a specific individual case, potential additional investments arising should be included in the calculation to obtain a sound basis for comparison. In this case the annuity of any possible additional investments equal to the investment cost difference would be zero and would not therefore alter the conclusions of the comparison.

In our case study "diesel unit" versus "small hydro-power plant" sufficient information is not available on possible additional investments in the event that the diesel unit alternative is adopted. It must therefore be assumed that additional financial resources could be invested at the cut-off rate so that we do not need to incorporate additional investments in the comparison.

The cost annuity comparison method is applicable to the replacement problem in those cases where a new plant will provide the same performance both qualitatively and quantitatively as the plant currently installed.

Where this is not the case, for example when the new plant will produce products either in a greater quantity or at a higher quality, the annuity method can be used to decide whether or not to replace an old plant by a new one.

4. Cost annuity comparison method (dynamic)

The annuity method described above permits an evaluation of both the individual and the comparitive favourability of investment projects where the alternatives compared may serve very different purposes. The cost annuity comparison method, a shortened form of the annuity method without the inclusion of income in the calculation, can only be used for evaluating the relative favourability of investment projects of similar type on the basis of a comparison of costs per annum or per unit production.

In both the dynamic and the previously-described static cost annuity comparison method, the aim is to identify the most cost-effective plant by contrasting the costs of two or more alternative plants for the manufacture of a defined production volume.

In the static cost annuity comparison method, the calculation of the cost annuity can follow the equation:

$$A_K = K_o + (I_o - L) \cdot RF\,(i,T) + L \cdot i$$

where the value to be inserted for K_o is determined as the average of annually varying operating costs, (c.f. Section C.I.2). However, as in all dynamic methods, the dynamic cost annuity comparison method means that the time component must be taken into account since annual operating costs are not always regular. So the following modified equation applies for the calculation of the dynamic cost annuity.

$$A_K = \left[\left(\sum_{t=1}^{T} K_o \cdot q^{-t} \right) \cdot RF\ (i,T) \right] + (I-L) \cdot RF(i,T) + L \cdot i$$

In this equation the expression inside the square brackets means that the present values of all the operating costs (K_o) payable annually during the operating period of the project must first of all be calculated and summed. This is a different procedure from that of the static cost annuity.

In a second phase of the calculation the sum of the present values of the operating costs is multiplied by the recovery factor - RF (i,T) - (The recovery factors for alternative service lifetimes and rates of interest are given in Table 2, Apendix IV).

The annuity of the operating costs is obtained as a result of this very simple mathematical operation when the tables are used.

From the given equation the **total** dynamic cost annuity is calculated as the sum of

- the annuity of the operating costs
- the annuity of the investment costs minus the liquidation yield
- annual interest on the liquidation yield.

The application of the mathematically simpler static method is to be recommended when the **annual operating costs are constant**, since then the static and dynamic cost annuities will be the same.

The dynamic cost annuity represents the costs per annum of the investment project when the annual operating costs are variable after taking the effect of interest payments into account. Or, it may show the cost per unit production if the annual operating costs are divided by the number of units produced (e.g. kWh p.a. or m^3 drinking water).

If there are several possible alternative plants for providing a desired product then the plant with the lowest dynamic cost annuity or with the lowest cost per production unit should be selected.

As with the static method, the dynamic cost annuity comparison method is suitable for investigating the replacement problem.

When applying this method an old plant should be replaced by a new one when the dynamic cost annuity of the old plant is greater than that of the new one.

When calculating the cost annuity of the old plant, the amount which might be expected as the salvage price, given liquidation of the plant in the year of comparison, should be set as the fictitious investment cost.

We shall not go through the mathematical procedure based on the case study (Appendix), since for these investment possibilities constant annual operating costs were assumed, thus the calculation of the dynamic cost annuity would lead to the same results as those of the static cost annuity already carried out in Section C.I.2.

5. Dynamic pay-back calculation

The dynamic pay-back calculation differs from the static method in that the differing times when receipts and payments fall due are taken into account by discounting or compounding the annual net cash flow (annual excesses of receipts over payments) to their value in the year of commissioning.

The determination of the pay-back is then **cumulative.** Beginning with the year of the first payment the present values of the annual net cash flows are summed until the total reaches a value of zero or greater. The time from commissioning up to this point is called the **dynamic pay-back period.**

When using the pay-back period as a criterion for evaluating an investment, an individual project is favourable if the capital invested plus a minimum acceptable rate of interest, is recovered by means of anticipated returns within the service life or within a maximum acceptable pay-back period, which must be shorter than the technical service life.

The results of Example 18 show that, given the assumption made, the dynamic pay-back period for the two projects is considerably shorter than their lifetimes. Thus both projects are favourable on an individual basis. The dynamic pay-back periods are longer than the static pay-back periods since in dynamic pay-back calculation it is necessary to recover not only the capital invested but also the calculatory interest which is due on it.

Example 18:
Comparison of a small hydro-power plant and a diesel unit on the basis of their dynamic pay-back periods[1)]

		Small hydro-power plant		Diesel unit	
Assumed discount rate		8 %		8 %	
Lifetime (years)		25		7	
Liquidation yield (DM)		—[2)]		10,000	
Investment costs (DM)		(540,000)		(87,000)	
Return (DM/year)		135,100		34,600	
Present values			accumulated		accumulated
Investment costs	($xq^{0} = 1$)	(540,000)	(540,000)	(87,000)	(87,000)
Return 1st year	($xq^{-1} = 0.926$)	125,100	(414,900)	32,000	(55,000)
2nd year	($xq^{-2} = 0.857$)	115,800	(299,100)	29,700	(25,300)
3rd year	($xq^{-3} = 0.794$)	107,300	(191,800)	27,500	2,200
4th year	($xq^{-4} = 0.735$)	99,300	(92,500)		
5th year	($xq^{-5} = 0.681$)	92,000	(500)		
6th year	($xq^{-6} = 0.630$)	85,100	84,600		
Pay-back period (dynamic)		5 years		3 years	

1) The data used here are taken from the case study (Appendix). It is assumed that the income/expenditure items for the first year will also apply in subsequent years.

2) Negative values are given in brackets (...)

In evaluating the relative acceptability of alternative investments it is assumed that the investment alternative with the shortest pay-back period is the most favourable.

The result of our calculation example indicates that the diesel unit should be given preference on the basis of the pay-back calculation since, if the diesel unit alternative were adopted, the capital invested plus the calculatory interest would be recovered after about three years i.e. two years sooner than with the small hydro-power plant.

Of course we must emphasize once more that it cannot simply be assumed that one project is more profitable than another because it has a shorter pay-back period.

The pay-back period should rather be seen as a risk criterion, although we must qualify this by saying that the relevant literature is agreed in regarding the pay-back period as a global instrument with only limited suitability for evaluating investment risk. We have already shown in the comparison in Section C.I.4 for the static pay-back periods of the two projects that even a very slight alteration in the assumptions made regarding the selling price would suffice to alter considerably the pay-back period of the diesel unit project. Thus any conclusions drawn from the criterion of the pay-back period must be substantiated by means of a sensitivity analysis.

III. THE PROBLEM OF INFLATION IN THE FINANCIAL EVALUATION OF INVESTMENT PROJECTS

In our presentation of the different methods for evaluating investment projects we have so far assumed that price increases during the lifetime of the project were either so slight that they could be ignored, or that they were compensated for by basing the calculation on the actual rate of interest as the given interest (or discount) rate. Additionally it was assumed that the prices for of all of the production parameters and products would vary at the same annual rate.

This method doubtless has the advantage of simplicity. However there is a danger of making a wrong assumption by lumping together all trends in prices when it is likely that the prices for some important production parameters/products will deviate significantly from the general trend. Experience of the last two decades has proved that this danger is particularly apparent in energy-related projects. In calculating the feasibility of such projects therefore, the anticipated price increases should be included separately for the individual parameters/products.

In order to take account of the differing price development of the various input/output parameters in the evaluation there is no need for methods other than those already presented. It is simply necessary to modify the data basis by compounding the individual annual amounts of payments and receipts using factors which include the respective anticipated rates of inflation.

If, for example, the net present value of an investment project is to be calculated taking explicit account of future price increases, the expected cash flows for the individual years of serviceable life would have to be revised upwards by the assumed rates of price increase. Additionally, the annual amounts are multiplied by a factor which can be taken from Table 4, Appendix IV for each respective year and interest rate (= inflation rate). The discounted annual payments and receipts are then collated as the "cash-flow" item - as shown in Section C.II.1.

The present values of the annual net cash flows are then calculated, using discounting factors which, for both external and invested internal capital, are based on the usual market interest rates as the required discount cut-off rate. The net present value of the investment project can be calculated thereafter as the sum of the present cash values of the annual net cash flows.

This calculation procedure can become somewhat protracted without the assistance of computers, particularly for projects with long service lives. It can be considerably simplified if it is assumed that there will be no variation in the amounts of individual revenue and cost items, i.e. that the returns of subsequent years only differ from those of the first year by the inflation rate.

The starting point is the equation discussed in Section C.II.1:

$$NPV = -I_0 + R \cdot PF(i,t) + L_T \cdot q^{-T}$$

The present value factor (PF) can be defined as

$$PF = \frac{q^t - 1}{q^t(q-1)}$$

where:

$$q = 1 + \frac{i^*}{100}$$

For the expression - q - which comprises the actual rate of interest (i) we can also write*

$$q = \frac{r}{e}$$

$$r = 1 + \frac{p}{100}\,;\ p = \text{market rate of interest}$$

$$a = 1 + \frac{a}{100}\,;\ a = \text{rate of inflation}$$

By replacing q by $\frac{r}{e}$ in the present value factor, the market interest rate and the inflation can be explicitly taken into account:

$$PF = \frac{\left(\frac{r}{e}\right)^t - 1}{\left(\frac{r}{e}\right)^t \cdot \left(\frac{r}{e} - 1\right)}$$

If the annual return (R) is now broken down into its component parts:

$R = N_1 + N_2 + \ldots\ldots + N_m - E_I - E_{II} - \ldots\ldots - E_m$

N_n = Income items $n = 1, 2, \ldots, m$

E_n = Expenditure items $n = I, II, \ldots, m$

each of these components can be multiplied by a present value factor which will express the relevant inflation rate for each of them.

For example:

$$N_1 \cdot \frac{\left(\frac{r}{e_1}\right)^t - 1}{\left(\frac{r}{e_1}\right)^t \cdot \left(\frac{r}{e_1} - 1\right)}$$

The sum of the present values of the annual receipts, increased by the inflation rate, is determined in this term by multiplication of the income term N_1 by its present value factor, or in other words, the present value of this income term, taking account of the particular rate of price increase (e_1).

For the present value of the liquidation yield L_T correspondingly:

$$L_T \cdot q^{-T} = L_T \cdot \frac{e_L^T}{r^T}$$

since $q = \frac{r}{e}$

The present value of an investment project is calculated

from this as:

$$NPV = -I_o + N_1 \cdot \frac{\left(\frac{r}{e_1}\right)^t - 1}{\left(\frac{r}{e_1}\right)^t \cdot \left(\frac{r}{e_1} - 1\right)} + N_2 \cdot \frac{\left(\frac{r}{e_2}\right)^t - 1}{\left(\frac{r}{e_2}\right)^t \cdot \left(\frac{r}{e_2} - 1\right)} + \dots$$

$$-E_I \cdot \frac{\left(\frac{r}{e_I}\right)^t - 1}{\left(\frac{r}{e_I}\right)^t \cdot \left(\frac{r}{e_I} - 1\right)} - E_{II} \cdot \frac{\left(\frac{r}{e_{II}}\right)^t - 1}{\left(\frac{r}{e_{II}}\right)^t \cdot \left(\frac{r}{e_{II}} - 1\right)} + L_T \cdot \frac{e_L^T}{r^T}$$

I_o = Investment costs in the period $t = 0$

N_n = Income items $n = 1, 2, \dots, m$

E_n = Expenditure items $n = I, II, \dots, m$

T = Service life of the project (t years)

L_T = Liquidation yield at the end of the service life

$r = 1 + \frac{p}{100}$; p = market interest rate (%)

$e_n = 1 + \frac{a_n}{100}$; a_n = inflation rate of the income ($n = 1, 2, 3, \dots$) and the expenditure ($n = I, II, III, \dots$) items (%)

$e_L = 1 + \frac{a_L}{100}$; a_L = inflation rate of capital goods

In the following we will demonstrate the calculation of the net present value taking account of varying inflation rates for different production parameters/products on the basis of the two investment projects in the case study, (Appendix). The following alterations in the data are assumed:

a) the interest rate for external capital will be 32 % p.a.
b) the general inflation rate will be 22 % p.a.
c) the inflation rate for diesel oil will be 3 % more than the general inflation rate, i.e. 25 % p.a.

It is further assumed that, due to market forces, the selling price of the electricity produced will only be allowed to increase at the general rate of inflation.

Example 19:
Calculation of the net present value (NPV) of a small hydro-power plant (c.f. case study, Appendix) assuming an inflation rate of 22 % p.a. and a discount rate of 32 % p.a.

The project has the following data:

Investment costs (I_o) : 540,000 DM
Service life ($T = t$ years) : 25 years
Liquidation yield (L_T) : 0 DM
Annual return (R) : 135,100 DM
General inflation rate (a) : 22 %/annum => e = 1.22
Assumed discount rate ($i = p$) : 32 %/annum => r = 1.32

$$NPV = -I_o + R \cdot \frac{\left(\frac{r}{e}\right)^t - 1}{\left(\frac{r}{e}\right)^t \cdot \left(\frac{r}{e} - 1\right)} + L_t \cdot \frac{e^T}{r^T}$$

$$NPV = -540{,}000 + 135{,}100 \cdot \frac{\left(\frac{1.32}{1.22}\right)^{25} - 1}{\left(\frac{1.32}{1.22}\right)^{25} \cdot \left(\frac{1.32}{1.22} - 1\right)} + 0 \cdot \frac{1.22^{25}}{1.30^{25}}$$

$$NPV = -540{,}000 + 135{,}100 \cdot \frac{1.082^{25} - 1}{1.082^{25}\,(1.082 - 1)}$$

$$NPV = -540{,}000 + 135{,}100 \cdot \frac{6.167}{7.167 \cdot 0.082}$$

$$NPV = -540{,}000 + 135{,}100 \cdot 10.493 = \underline{\underline{877{,}630\ DM}}$$

Example 20:
Calculation of the net present value (NPV) of a diesel unit (case study, Appendix) assuming a general inflation rate of 22 % p.a. and a discount rate of 32 % p.a.

The project has the following data:

Investment costs (I_o) : 87,000 DM
Service life ($T = t$ years) : 7 years
Liquidation yield (L_T) : 10,000 DM
Annual return (R) : 34,600 DM
Energy costs (K_E) : 105,000 DM
General inflation rate (a_1) : 22 % p.a. e_1 = 1.22
Inflation rate of diesel (a_2) : 25 % p.a. e_2 = 1.25
Assumed discount rate ($i = p$) : 32 % p.a. r = 1.32

$$NPV = -I_0 + (R+K_E) \cdot \frac{\left(\frac{r}{e_1}\right)^t - 1}{\left(\frac{r}{e_1}\right)^t \cdot \left(\frac{r}{e_1}-1\right)} - K_E \cdot \frac{\left(\frac{r}{e_2}\right)^t - 1}{\left(\frac{r}{e_2}\right)^t \cdot \left(\frac{r}{e_2}-1\right)} +$$

$$+ L_T \cdot \frac{e_1^T}{r^T}$$

$$NPV = -87{,}000 + (34{,}600 + 105{,}000) \cdot \frac{\left(\frac{1.32}{1.22}\right)^7 - 1}{\left(\frac{1.32}{1.22}\right)^7 \cdot \left(\frac{1.32}{1.22}-1\right)} -$$

$$-105{,}000 \cdot \frac{\left(\frac{1.32}{1.25}\right)^7 - 1}{\left(\frac{1.32}{1.25}\right)^7 \cdot \left(\frac{1.32}{1.25}-1\right)} + 10{,}000 \cdot \frac{1.22^7}{1.32^7}$$

$$NPV = -87{,}000 + 139{,}600 \cdot 5.171 - 105{,}000 \cdot 5.660 +$$

$$-10{,}000 \cdot 0.576$$

$$NPV = \underline{\underline{46.332\ DM}}$$

The calculation of the net present value of the small hydro-power plant assuming a discount rate of 32 % and an inflation rate of 22 % (Example 19) results in NPV = 877,630 DM. As expected, this result is similar to that of the calculation with an assumed discount rate of 8 % where NPV = 902,400 DM (Example 11), since a uniform increase of all prices was anticipated. The difference between the two results can be attributed to the fact that the rate of 8 % which was used in Example 11 only roughly corresponds to the actual (inflation corrected) rate of interest at 8.2 %.

On the other hand, the difference in the net present value of the diesel unit calculated in Example 20, NPV = 46,332 DM, and the NPV obtained previously in Example 12, 98,958 DM, can only partly be explained by the deviation in the assumed discount rate from the actual rate of interest. With a discount rate of 8.2 % (= actual rate of interest) we would still have obtained a NPV of 97,696 DM. In this case, the large reduction in the NPV is due to the assumption that the diesel price will increase at an annual rate 3 % higher than the other prices. This demonstrates that a calculation which accounts for varying price increases can lead to considerably different results compared to a calculation which presu-

IV. SENSITIVITY ANALYSIS

In spite of all attempts to refine the evaluation methods, the results of the calculations on the feasibility of investment project are necessarily uncertain since they are based on data which sometimes extend far into an indefinite future.

Consequently the reliability of the assumptions made regarding the future development of important parameters should be verified. At least with the larger projects we should calculate to what extent individual feasibility criterion (e.g. net present value) will alter if the more uncertain data (e.g. project duration, investment costs, interest or discount rate, sales volumes and prices) should deviate by a certain amount from the original values.

The aim of such a sensitivity analysis is not so much to remove uncertainty in deciding whether or not to adopt an investment project but rather to quantify the economic consequences of a potential but unpredictable development in important parameters.

A typical question in the sensitivity analysis would be: "How does the value of a certain output parameter (e.g. net present value, pay-back period, internal rate of return) change when one or more of the input parameters (e.g. discount rate, duration of project, product price) deviates by a certain amount (or percentage) from the expected value?"

If all the input parameters are individually reduced or increased by a specific percentage (e.g. 10 %), a comparison of the absolute or percentage changes in the output parameters under examination reveals which input parameters have a particularly sensitive effect on the output parameters (e.g. the net present value). The reliability of this parameter should therefore be given particular attention, since it could seriously affect the success of the project.

In Example 21 the values for the input paramters which specify this project were increased or reduced in turn by 10 % and the net present value re-calculated each time. By comparing the new NPV with that for the original parameters (NPV = 902,400 DM), the effect of an isolated variation in each of the parameters of ± 10 % is established individually.

As is shown by comparing the possible deviation from the original value, the NPV of this project reacts very differently in absolute terms to the variations made. The following table shows the degree of sensitivity in order of rank.

- o Energy volume sold
- o Selling price
- o Assumed discount rate
- o Investment costs

- o Service life time
- o Repair and maintenance costs
- o Manpower costs
- o Administration costs

The most serious change in the NPV of this project arises with a change in the number of kilowatt hours sold and their selling price, and the least serious with a variation in the administration costs.

Of course the comparison of the possible change in the NPV, with a starting value of DM 902,400, shows that a deviation of any parameter by 10 % on the pessimistic side does not in any way endanger the favourability of this project. Therefore, if considerable deviation in the anticipated parameters, i.e. far exceeding 10 %, is not probable, the adoption of the project does not present a financial risk.

Example 21:
Analysis of the sensitivity of the net present value (NPV) of the small hydro-power plant (c.f. case study, Appendix) to a change in specific important parameters by ± 10 %

Net present value of the project given the original assumptions of the value of the individual parameters.

NPV = 902,400 DM

Parameter[1]	Change in the net present value (absolute) after changing the parameter by	
	+ 10 %	- 10 %
01. Assumed discount rate	- 93,575	+ 104,035
04. Service life (25 years)	+ 42,921	- 52,554
1.1 Investment (I_o = 540,000)[2]	- 74,413	+ 73,938
2.1 Manpower costs (16,000 DM per annum)	- 17,317	+ 16,842
2.2 Repair and maintenance costs (18,900 DM per annum)	- 20,413	+ 19,938
2.5 Administration costs (5,000 DM per annum)	- 5,575	+ 5,100
4.1 a) Energy sold (350,000 kWh p. a.)	+ 186,571	- 187,046
b) Selling price (0.50 DM/kWh)	+ 186,571	- 187,046

[1] In brackets - the values originally assumed

[2] Item 2.2 was also altered at the same time by 10 %

Example 22:
Analysis of the sensitivity of the net present value of a diesel unit (c.f. case study, Appendix) to changes of ± 10 % in important parameters

Net present value of the project given the original assumptions of the vlaue of the individual parameters.

NPV = 98,975 DM

Parameter[1]	Change in the net present val (absolute) on changing the parameter by	
	+ 10 %	- 10 %
01. Assumed discount rate (8 %)	- 5,119	+ 5,348
04. Service life (7 years)	+ 12,930	- 13,645
1.1 Investment costs[2] (I_o = 87,000)	- 8,117	+ 8,116
1.2 Residual value/liquidation yield (I_T) = 10,000)	+ 583	- 584
2.1 Manpower costs (16,000 DM per annum)	- 8,330	+ 8,331
2.2 Repair and maintenance costs (14,400 DM per annum)	- 7,497	+ 7,498
2.3 Energy and related costs (105,000 DM per annum)	- 54,666	+ 54,667
2.5 Administration costs (5,000 DM per annum)	- 2,603	+ 2,604
4.1 a) Energy sold[3] (350,000 kWh p. a.)	+ 36,445	- 36,444
b) Selling price (0.50 DM/kWh)	+ 91,112	- 91,111

[1] In brackets, the values originally assumed

[2] The liquidation yield has also been simultaneously altered by 10 %

[3] Item 2.3 has also been simultaneously adjusted to account for additional/lower diesel consumption

In Example 22, as in Example 21, the change in the net present value of the diesel unit project has been calculated in relation to independent changes in the individual input parameters.

By referring to the degree of sensitivity of the NPV to each independent change, the following ranking of the individual paramters results.

- o Selling price
- o Energy and related costs
- o Energy volume sold
- o Service life
- o Manpower costs
- o Investment costs
- o Repair and maintenance costs
- o Administration costs
- o Residual value

It can be seen that the NPV of this project is also very sensitive to a change in the selling price but that otherwise the ranking of the parameters by their risk content is very different from that for the small hydro-power project.

The most important aspect here is that an increase in the energy costs of 10 % would consume more than half of the originally-obtained NPV and a reduction in the selling price would consume nearly all. Seen from the viewpoint of possible parameter deviations it can be concluded that the adoption of this project constitutes a very much higher risk than the small hydro-power project.

The determination of the "critical values" within the context of the sensitivity analysis is of particular interest. If the financial analysis of an investment project is positive, given the expected individual input paramters, one could then use the critical values procedure to determine what range of uncertainty is acceptable without causing the relevant feasibility indicator to fall above or below a required value.

Calculation of the critical values is done by inserting maximum/minimum acceptable values in the respective equation and solving it for the input parameter in question.

If, for example, the viability of an investment project is to be determined by means of the net present value method, this project rates as being favourable when its net present value is not negative (NPV ≥ 0). This means that with the net present value method a NPV of zero represents the minimum acceptable value. A smaller, i.e. a negative, NPV would indicate that this project is not favourable. A check should then be made using the critical values procedure to see which input parameters result in a value of zero. The values calculated in this way for the input parameters are to be regarded as critical values since the NPV would become negative if they were to increase or decrease.

If, for example, the critical value for the investment costs is to be determined, the procedure is as follows:

Net present value equation:

$$NPV = -I_O + R \cdot PF + L_T \cdot q^{-T}$$

Condition: $NPV = O$

If there is no anticipated liquidation yield, it then follows that:

$$O = -I_O + R \cdot PF$$

or $I_O = R \cdot PF$

Example 23:
Calculation of the critical values of the small hydro-power plant (c.f. case study, Appendix)

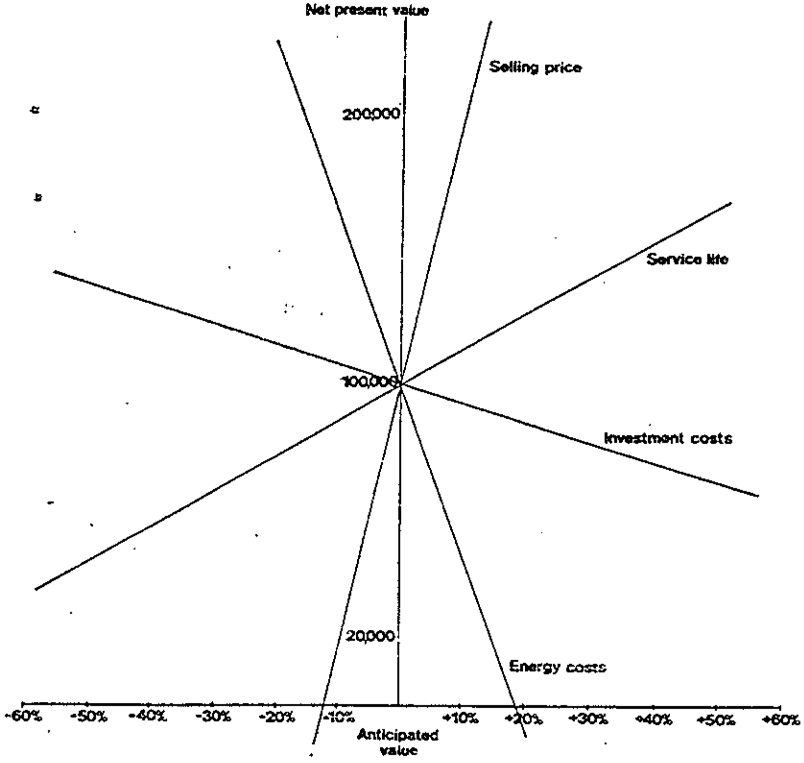
Parameter	NVP=902,400 DM Expected value	NVP=0 DM Critical value
01. Assumed discount rate	8	24.9
04. Service life (years)	25	5
1.1 Investment costs (DM)	540,000	1,442,162
2.1 Manpower costs (DM/annum)	16,000	100,513
2.2 Repair and maintenance costs (DM/annum)	18,900	103,413
2.5 Administration costs (DM/annum)	5,000	89,513
4.1 a) Energy sold (kWh/annum)	350,000	180,974
b) Selling price (DM/kWh)	0.50	0.26

Example 24:
Calculation of the critical values of the diesel unit (c.f. case study, Appendix)

Parameter	NVP=98,975 DM Expected value	NVP=0 DM Critical value
01. Assumed discount rate	8	35.5
04. Service life (years)	7	2.6
1.1 Investment costs (DM)	87,000	185,975
2.1 Manpower costs (DM/annum)	16,000	35,010
2.2 Repair and maintenance costs (DM/annum)	14,400	33,410
2.3 Energy and related costs (DM/annum)	105,000	124,010
2.5 Administration costs (DM/annum)	5,000	24,010
4.1 a) Energy sold (kWh/annum)	350,000	254,950
b) Selling price (DM/kWh)	0.50	0.45

Figure 3:

Sensitivity of the net present value of the diesel unit (c.f. case study, Appendix) to changes in selected parameters by ± 10% [1]



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[1] The figure is based on the numerical values of Example 21

Examples 23 and 24 show the critical values of the individual parameters of the small hydro-power plant and the diesel unit which have been determined by means of the method described above and compares them to their respective anticipated values.

Using the diesel unit as an example, Figure 3 shows that the critical values of the different parameters can also be determined graphically. On the graph the net present value is shown on the ordinate (y-axis) and the average change in the input parameters is shown on the abscissa (x-axis). To start with, the original NPV is marked on the ordinate of the graph, i.e. the NPV which applies if all the parameters maintain their anticipated value. In our figure this is DM 98,975. Each individual present-value-parameter curve must bisect the ordinate at this point. When the relationship between the NPV and a certain parameter is a linear function, one more point is sufficient to determine the slope of the line. This second point can very easily be determined mathematically by referring back to the value given in Example 21. For example, when the "selling price" parameter is changed by + 10 % the NPV changes in absolute terms by + DM 91,112, i.e. a deviation of the selling price by + 10 % from the anticipated price results in a new NPV of DM 190,087 (98,975 + 91,112). The second point on the curve which shows the relation between the NPV and the "selling price" parameter is clearly described by the coordinates of + 10 % and DM 190,087. The point of intersection of the straight line which joins both points and the abscissa indicates the "critical value" of the parameter as a percentage of the original value. Thus one can read off from Figure 3 that the "critical value" of the selling price is about 12 % less than the anticipated value, i.e. 0.50 DM less 12 % = 0.44 DM. The "critical value" determined by purely mathematical means was 0.45 DM (c.f. Example 24).

The procedure just described can also be repeated for the remaining parameters, so that - as shown in Figure 3 - an assortment of curves is obtained. Although these curves all biscet the ordinate at the point which represents the original NPV they have very different slopes. This demonstrates that the NPV is sensitive in varying degrees to changes in the different parameters.

In general, it can be said that the steeper the curve, the more sensitive the NPV is to a change in that parameter and the nearer the "critical value" will lie to the anticipated value.

It must also be said that additional graphs can be constructed in the same fashion in order to illustrate the relationship of the parameter to other financial indicators such as internal rate of return, annuity, pay-back period, etc.

In comparing the "critical values" with the anticipated values and with the critical values of the alternative project, it may come as a surprise to see to what extent - both in absolute and relative terms - the investment costs, for example, in both projects may increase without the project becoming unprofitable (all other conditions remaining constant). In the case of the diesel unit project it would hardly be more serious if the investment costs were to double than if, for example, the annual manpower costs were to double.

It will doubtless also be of interest that the diesel unit with a "critical" energy sales volume of about 255,000 kWh/a or 29.1 % of the installed capacity requires a higher load utilisation to operate economically than the small hydro-power plant with a critical value of about 181,000 kWh/a or 20.7 %. From this it may be concluded that a small hydro-power plant could sometimes be more suitable than a diesel unit for the development of profitable isolated grids within electrification programmes, where the expected capacity utilisation is uncertain.

Furthermore a comparison of the "critical" selling price of both alternatives i.e. 0.26 and 0.45 DM, shows that the small hydro-power plant is in a better position than the diesel unit to stimulate sales by pricing policy. It is possible, beginning with a capacity utilisation of 40 % to reduce the selling price of 0.50 DM by almost 50 % without endangering the minimum acceptable profitability of the small hydro-power plant.

Possibilities for the application of the critical values procedure are particularly interesting in the RE and RUE fields. Here we often meet with technical systems whose installation has not (yet) been evaluated, so that we can now approach this problem from the other direction and ask which minimum or maximum values should the input parameters of a certain system have for it to exceed the profitability threshold. Using the same computing techniques as for the "critical values", we can, for example, determine:

a) what is the target price
b) what must be the minimum possible service life
c) what minimum price should alternative energy sources have
   etc.

in order that a technical system can profitably be installed.

The knowledge gained in this way can make a considerable contribution to the evaluation of the future chances of a technical system and in particular can give clear indications as to its potential for successful further development.

Appendix I

CASE STUDY

Electricity supply for a small town in isolated operation

The case study on "Electricity supply for a small town in isolated operation" which is described below, was designed as the background for the data used in the calculation examples in Section C. The data given are not, therefore, the results of acutal investigations on a definite site, but rather figures which have been derived from relevant experience in various developing countries.

1. THE CONTEXT

A small town situated in a rural area of a developing country has for some time had its electricity generated by means of a diesel unit operated in isolation from regional grids.

A technical survey of the installation showed that wear on the unit has progressed so far that it is urgently necessary to replace the diesel unit within the next 12 months in order to maintain the electricity supply. The local electricity utility wants to collect comprehensive information for the new investment.

The consultants entrusted with this task by the electricity utility first of all establish that, given present planning, connection of the town to the national electricity grid within the next two decades is not to be anticipated. An independent supply in isolated operation will still be required.

In their analysis of previous electricity consumption, the consultants conclude that for the given daily and annual peaks in load, including a necessary reserve, the installation of a plant with an output capacity of 100 kW would be advisable. The generating plant must be in continuous operation since there is, e.g. a hospital connected to the isolated grid. For the first and subsequent years of operation of the new plant an electricity consumption of about 350,000 kWh can be reckoned with, which corresponds to about 40 % of the total capacity of the plant given a 24-hour operation. The selling price of the energy supplied should not be increased from its present price of 0.50 DM/kWh if possible.

After exhaustive research the consultants come to the conclusion that a small hydro-power plant installed near the town (2 km) would also be a possible alternative to a new diesel unit to meet the town's energy demand.

The decision as to which of the two alternative electricity generating systems should finally be adopted is to be preceded by a financial evaluation of the two systems.

2. DATA REVIEW

After evaluating the tenders from contracting and supply companies and carrying out their own data collection, the consultants are left with the following picture of the income and expenditures connected with the two systems.

a) Small hydro-power plant

The cash flows expected from an investment in a small hydro-power plant during its foreseeable service life are given in Table I/1. The following remarks must be made in connection with the figures assumed for the different items.

Re 0.1: It is assumed that the project must be totally financed by external capital. Taking account of the inflation rate anticipated for the country, we start with an actual interest rate for external capital of 8 % which is included in the calculation as the assumed interest rate.

Re 0.2 and 0.3: The general inflation rate has already been taken into account in setting the calculatory interest rate. It is not expected that the price of energy will develop independently of prices in general.

Re 0.4: A lifetime of 25 years is assumed for the machinery, thus a liquidation yield at the level of the salvage value will just cover the dismantling costs.

A maximum service life of 50 years is assumed for the buildings. Given linear depreciation, therefore, a positive residual value of 50 % of the capital resources involved would be calculated at the end of 25 years. However, it is only meaningful to take this residual value into account if it is intended at the end of 25 years to make a new investment for continued similar use. Since it is not yet possible to decide on this, it is assumed that these expenditures will also be written off after 25 years.

Re 1.1: The value given here is the summation of the investment costs listed in Table I/2. It is assumed that in the period 0, i.e. before the first year of operation, the following payments are to be effected:

a) DM 20,000 for planning and supervision of construction
b) DM 240,000 for civil works and buildings
c) DM 40,000 for connecting the plant to the town's electricity grid (medium capacity connection 10 KV,2km)
d) DM 210,000 for machinery

Table I/1: Small hydro-power plant project 100 kW
- data review -
(in 1,000 currency units = 1,000 DM)

	Period		0	1	2 - 24	25
	Item / Year		19	19	19	19
.1 .2 .3 .4	Assumed interest rate General inflation rate Inflation rate of energy Service life of the unit (year)	8 % - % - % 25 years				
.1	Investment costs (total Table I/2)		540			
.2	Residual value of unit (after 25 years use)		-	-	-	0
.1	Manpower costs		-	16.0	16.0	16.0
.2	Repair and maintenance costs		-	18.9	18.9	18.9
.3	Energy and related costs					
.4	Auxiliary materials					
.5	Administration costs (excl. manpower)		-	5	5	5
.1	Taxes and duties not dependent on profit					
.2	Other costs		-			
.3	Total of operating costs (2.1 - 3.2)		-	39.9	39.9	39.9
.1	Energy supplied (MWh) x selling price/unit = revenue from energy sales		- - -	350 0.5 175	350 0.5 175	350 0.5 175
	Energy substituted (units) x buying price/unit = saving on energy costs					
	Energy-related production (units) (e.g. drinking water - m³) x price/unit = operating income					
.2 .3	Other income Subsidies					
.4	Total income (4.1 through 4.3)		-	175.0	175.0	175.0
.1	Return (4.4 minus 3.3)		-	135.1	135.1	135.1
.2	Depreciation		-	21.6	21.6	21.6
.3	Profit (5.1 minus 5.2)		-	113.5	113.5	113.5

e) DM 15,000 for the transport of machinery to the port of arrival
f) DM 5,000 for transport of goods within the country to the site
g) DM 10,000 for assembly and commissioning of the machinery.

It is assumed either that no further expenditures arise or that they can be assimilated by a careful calculation of the other costs.

Table I/2: Small hydro-power plant project
- review of investment costs -
(in 1,000 currency unit = 1,000 DM)

Item	Period / Year	0 19	1 - 25 19
Planning		20	-
Land acquisition/leasing		-	
Civil works			
Buildings and structures		240	-
Connections to water, electricity, gas, sewage and traffic networks		40	-
Machinery (ex works)			
- main equipment		200	-
- additional unit A			
- additional unit B, etc.			
- equipment for workshop		2	-
Transport to port of arrival[1]		15	-
Transport from port of arrival to factory site[1]		5	-
Assembly and commissioning		10	-
Customs, taxes, duties, fees			
Other			
Total of investment costs		540	-

[1] Including insurance

Re 1.2: On the basis of the assumptions made under item 0.4, it is presumed that the total plant will have a residual value of zero after 25 years of use.

Re 2.1: It is assumed that the operation and maintenance of the plant plus administration will require four employees each of whom will be paid DM 4,000 per annum.

Re 2.2: The annual costs for repair and maintenance are estimated at 3.5 % of the investment costs. This amount in-

Re 2.5: Annual costs of DM 5,000 are assumed for administration purposes (office supplies, communications, etc.)

Re 4.1: It is assumed that the electricity utility will sell on average 350,000 kWh at a price of 0.5 DM/kWh during the lifetime of the project, so that an annual income of DM 175,000 can be expected.

Re 5.2: On the basis of the assumptions made above on the service life of the units, an annual depreciation of DM 21,600 is charged, given linear depriciation.

b) Diesel Unit

The figures anticipated for an investment in a diesel unit are to be taken from the data review (Table I/3). The following comments must be made for the individual items:

Re 0.1: The project is to be 100 % externally financed. Taking account of the anticipated inflation rate, an actual rate of 8 % for external capital is thus assumed which is included in the calculation as the applied interest rate.

Re 0.2: The general inflation rate has already been taken into account in setting the calculatory interest rate.

Re 0.3: It is not expected that the price of energy will develop differently from prices in general.

Re 0.4: In view of the necessity for uninterrupted operation, a service life of about 7 years is assumed for the plant equipment.

Re 1.1: The value of DM 87,000 given here is calculated as the sum of all the investment costs estimated in Table I/4. It is assumed that in the time period 0, i.e. before the first year of operation, the following costs are to be effected.

a) DM 2,000 for planning and supervision of construction
b) DM 75,000 for the purchase of necessary equipment parts (ex works)
c) DM 6,000 for the transport of the unit to the port of arrival
d) DM 1,000 for further transport of the unit to the site
e) DM 3,000 for assembly and commissioning of the diesel unit.

Re 1.2: It is assumed that various component parts will realise a liquidation yield of DM 10,000 altogether at the end of the planned 7-year service life.

Re 2.1: Annual manpower costs of DM 16,000 are estimated. This amount includes the costs for the required operating and administrative staff (3 employees) plus the labour costs for the necessary inspection and maintenance work.

Re 2.2: DM 14,400 per annum can be expected for repair and maintenance costs (materials only). This amount already includes the costs for auxiliary materials (item 2.4).

Re 2.3: Because of the reduced efficiency due to the probability of reduced load operation of the plant, we can expect a diesel fuel consumption of about 0.3 ltr. per kilowatt hour generated. Assuming a diesel price of DM 1.00/ ltr. (including the cost of the necessary contingency storage tanks), energy related costs of DM 105,000/annum are calculated for an anticipated electrical output of 350,000 kWh per annum.

Re 2.5: The administration costs (excl. manpower) for this investment are also expected to be DM 5,000.

Re 4.1: It is anticipated that the electricity utility will sell on an average 350,000 kWh per annum at a price of 0.50 DM/kWh during the lifetime of the project, so that the foreseeable income can be estimated at DM 175,000.

Re 5.2: On the basis of the assumptions made above on the service life of the units, an annual depreciation of DM 21,600 is charged, given linear depriciation.

Table I/1: 100 kW diesel unit project
– data review –
(in 1,000 currency units = 1,000 DM)

No.	Item	Period	0	1	2 - 6	7
		Year	19	19	19	19
0.1 0.2 0.3 0.4	Assumed interest rate General inflation rate Inflation rate of energy Service life of the unit	8 % – % – % 7 years				
1.1	Investment costs (total Table I/4)		87,0	–	–	–
1.2	Residual value of unit (after 7 years use)		–	–	–	10.0
2.1	Manpower costs		–	16.0	16.0	16.0
2.2	Repair and maintenance costs		–	14.4	14.4	14.4
2.3	Energy and related costs		–	105.0	105.0	105.0
2.4	Auxiliary materials		–	–	–	–
2.5	Administration costs (excl. manpower)		–	5.0	5.0	5.0
3.1	Taxes and duties not dependent on profit		–	–	–	–
3.2	Other costs		–	–	–	–
3.3	Total of operating costs (2.1 - 3.2)		–	140.4	140,4	140,4
4.1	Energy supplied (MWh) x selling price/unit = revenue from energy sales		– – –	350 0.5 175.0	350 0.5 175.0	350 0.5 175.0
	Energy substituted (units) x buying price/unit = saving on energy costs					
	Energy-related production (units) (e. g. drinking water - m³) x price/unit = operating income					
4.2	Other income		–	–	–	–
4.3	Subsidies		–	–	–	–
4.4	Total income (4.1 through 4.3)		–	175.0	175.0	175.0
5.1	Return (4.4 minus 3.3)		–	34.6	34.6	34,6
5.2	Depreciation		–	11.0	11.0	11,0
5.3	Profit (5.1 minus 5.2)		–	23.6	23.6	23.6

Table I/4: 100 kW diesel unit prject
- review of investment costs -
(in 1,000 currency units = DM 1,000)

Item	Period	0	1	2	3	4	5	6	7
	Year	19	19	19	19	19	19	19	19
Planning		2	-	-	-	-	-	-	-
Land acquisition/leasing		-	-	-	-	-	-	-	-
Civil works		-	-	-	-	-	-	-	-
Buildings and structures		-	-	-	-	-	-	-	-
Connection to water, electricity, gas, sewage and traffic networks									
Machinery (ex works)		75	-	-	-	-	-	-	-
- equipment for workshop		-	-	-	-	-	-	-	-
Transport to port of arrival[1)]		6	-	-	-	-	-	-	-
Transport from port of arrival to factory site[1)]		1	-	-	-	-	-	-	-
Assembly and commissioning		3	-	-	-	-	-	-	-
Customs, taxes, duties, fees									
Other									
Total of investment costs		87	-	-	-	-	-	-	-

[1)] Including insurance

3. Results of the financial analysis

On the basis of the data established above, a first analysis shows that both investment projects are not only technically feasible but are also favourable from the economic viewpoint.

The consultants appointed by the electricity utility are then faced with the question of the relative favourability of the two projects. However, they cannot immediately answer the question as to which of the two technical systems will be more advantageous for the utility. Of course the costs per annum and per kilowatt hour calculated for the small hydro-power plant are considerably lower and the net present value is very much greater; however the capital to be invested for the diesel unit, given the assumptions made, will gain considerably more interest than the capital required for the small hydro-power plant. In order to be able to solve the selection problem as outlined here, the planners are first forced to clarify some further questions.

a) From their experience the planners know that investment decisions are very often made not only from the point of view of profitability but also from that of financing. Since the small hydro-power plant at DM 540,000 requires more than six times the capital input of the diesel unit, the question of financing could kill the idea for the small hydro-power plant.

b) Furthermore the planners know that a selection made solely on the basis of a simple comparison of "return on investment" rates or of the internal rate of return can very often be false if the investment alternatives, as is the case here, have very different capital requirements and lifetimes and it cannot be assumed that financial resources in any desired quantity can be invested elsewhere at an interest rate of 36 % (the internal rate of return of the diesel unit).

c) The planners are aware of the fact that the amounts entered for the anticipated income and expenditures during the service life of the technical systems are, of necessity based on uncertain assumptions, since to some extent they reach far into an uncertain future. It would therefore be important for them to know which maximum or minimum values the individual parameters might assume without endangering the favourability of the two alternatives: they would thereby gain an impression of the risk connected with each of the projects.

Re a: Preliminary discussions between the electricity utility and the local banks show that the higher investment costs for the small hydro-power plant could be financed under the

Table I/5: Summary of the data and indicators for the feasibility of the small hydro-power plant and diesel unit projects

	Small hydro-power plant	Diesel unit
Project data:		
Investment costs (DM)	540,000	87,000
Residual value (DM)	-	10,000
Service life (years)	25	7
Assumed interest rate (%)	8	8
Operating costs (DM/annum)	39,900	140,400
Total income (DM/annum)	175,000	175,000
Return (DM/annum)	135,100	34,600
Indicators for the feasibility (static):		
Costs per annum (DM) (cost comparison calculation)	83,100	155,280
Costs per kWh (DM) (cost comparison calculation)	0.24	0.44
Cost annuity (DM/annum)	90,487	155,990
Cost annuity (DM/kWh)	0.26	0.45
ROI (%)	42	49
Pay-back period (years)	4	2.5
Indicators for the feasibility (dynamic):		
Net present value NPV (DM)	902,400	98,958
Internal rate of return (%)	25.3	36
Annuity (DM/annum)	84,534	19,007
Cost annuity (DM/kWh)	0.26	0.45
Pay-back period (years)	5	3

anticipated conditions since, on the basis of the calculations submitted, this project shows promise of being very attractive and there is no doubt of the standing of the electricity utility as a creditor.

Re b: The planners now have to try to solve the problem of choosing between the two projects which differ greatly both in their duraton and also in their capital requirement. This is done by comparing the annuities of the two projects rather than their net present value. It is hoped that this will avoid the falsification of the comparison which results when the competitive advantage due to unequal lifetimes, which is enjoyed by the plant with the longer life, is included. As the comparison of the annuities shows, the small hydro-power plant has a considerably higher annuity at DM 84,534 than the diesel unit at DM 19,007. Although the interest on the capital invested is less with the small hydro-power plant than with the alternative plant, the capital on which interest is to be paid is considerably higher.

In a second stage the planners try to clarify the question of whether the considerable difference between the investment costs for each of the two projects could not, in the event of adopting the diesel unit alternative, be applied to other equally profitable investments. A discussion on this point with the representatives of the electricity utility quickly reveals that such investments are not possible for the utility in its role as a community energy supplier. It becomes clear that a decision in favour of the diesel unit would be a wrong decision. Furthermore it becomes clear that the electricity utility, because of its statutory obligation, is not so much interested in maximum profits as in supplying the town with electricity at a reasonable, cost-covering tariff. In this respect, the management of the utility appears very pleased that the lower costs per kWh of the small hydro-power plant would enable the utility to inaugurate a policy of variable tariffs which could be an additional stimulus for the further economic development of the town.

One final point, which had been problematic for the management of the electricity utility in the past was the rising price of diesel fuel and irregular deliveries, forcing them to keep large contingency stores which in turn further increase enery-related costs. It is highly probable that this situation would continue in the future, while the probability of being able to pass on the increased production costs to the consumer is uncertain.

Re c: In order to estimate the economic risk connected with each of the two projects, the planners finally calculate the "critical values" of the parameters of both projects for a net present value NPV = 0: that is the values of the individual parameters at which, when they are altered independently, the NPV will become zero. On comparing the calculated "critical values" with the respective anticipated values of the individual input parameters (see Section C.IV, Example 23 and 24), the consultants come to the conclusion that the small hydro-power plant has a lower risk factor than the diesel unit. This is justified by the fact that the net present value of the diesel unit project reacts very sensitively to variations in operating costs and income. Furthermore, these items are often so close to the "critical values" e.g. the anticipated selling price and particularly the energy costs, that their future trends must be viewed with great concern.

Appendix II

GLOSSARY OF SPECIAL TERMS

Actual interest rate:
The market interest rate corrected by the inflation rate. (For the calculation see B.0.2).

Amortisation:
1) In banking, repayment of debts.
2) In investment calculation, the recovery of investment expenditure by means of annual returns.

Amortisation period (dynamic):
The period needed to recover the capital invested in an investment project from the returns discounted at an appropriate rate. Also pay-back period.

Amortisation period (static):
The period needed to recover the capital invested from returns in an investment project. Also pay-back period.

Assumed interest (or discount) rate:
In the dynamic methods of analysis, that interest (discount) rate which is assumed or required as the minimum acceptable on the capital investment for the duration of the project. Also cut-off discount rate.

Averaging-method:
A method for calculating the static pay-back period.

Capital recovery factor:
Factor used to calculate amount of regular payments needed to recover a present value at a given interest rate over a specified time period.

Capital servicing:
Interest and principal on credits.

Cash flow:
The flow of capital from turnover. Here the balance of cash inflows and outflows during a specified period within the service life of an investment project.

Compounding:
Increase in the value of a past payment by regularly compounded interest to establish its present value.

Continuous amortisation:
Repayment of a debt in equal periodic amounts.

Credit duration:
A period agreed with the lender as to the time during which a certain debt is to be repaid.

Cumulative method:
A method of calculating pay-back period.

Depreciation:
Periodic reduction in the value of the capital goods assets connected with an investment.

Discounting:
Reduction in the value of a future payment calculated at a given interest (discount) rate to establish its present value.

Discounting factor:
Factor for calculating the present value of a single future payment accounting for the time and at a given interest (discount) rate.

Dynamic procedures:
Methods of investment calculation.

External financing:
Securing of financial resources from outside a company to cover its capital requirement e.g. for investment projects.

Inflation:
The process of general price expansion.

Inflation rate:
Increase of the general price level as a percentage of the previous year's prices.

Internal financing:
Provision of financial resources within a company to permit the adoption of an investment project.

Internal rate of return:
(IRR) Profitability (%) of an investment calculated from the net present value.

Lifetime:
Maximum period during which an investment facility can be used either for production or other purposes.

Linear depreciation:
The initial equipment costs, minus the amount anticipated as the liquidation yield, are divided by the number of years of foreseeable service life. This gives a constant annual depreciation charge. In other words, the book value of the plant decreases linearly.

Liquidation yield:
The income expected by the sale of assets at a fixed point in time, usually at the end of the service life.

Loss of purchasing power:
Reduction in value of a certain captial sum due to inflation.

Loss of value:
Depreciation in the value of assets due to utilization.

Market interest rate:
The normal rate of interest on the current capital market for the investment of internal capital or the loan of external capital, taking account of duration and risk aspects.

Maximum acceptable pay-back period:
The maximum period within which an investment should pay itself off.

Minimum acceptable profitability:
The minimum profitability required by the investor on the average capital tied-up.

Net present value:
Sum of the present values of all cash flows connected with particular investment project over its lifetime.

Opportunity costs:
Fictitious costs which correspond to the income which might be expected from an alternative application of scarce resources. They are sometimes also referred to as "shadow prices".

Pay-back period:
Amortisation period. Also pay-off or pay-out period.

Payments:
1) Payments by the investor to third parties in connection with an investment project.
2) Payments in connection with an investment project on the part of third parties to the benefit of the investor.

Planning period:
The period between the initiation of an investment project and its conclusion. The planning period is equal to or longer than the service life.

Present value:
Value of a future amount discounted or a past amount compounded over a specified time period at a specified interest rate.

Present value factor:
(PF) Factor used to calculate the present value of a sequence of equal payments or cash flows occuring at regular intervals over a specified time period and at a given interest rate.

Profitability:
Return on investment.

Profitability threshold:
This describes a profit/loss situation from which point onwards an investment project is economically favourable. Indicators e.g. the cut-off ROI or the break-even point.

Recovery factor: RF
See Capital recovery factor

RE plant:
Plant for the utilisation of renewable energies.

RE technologies:
Technologies for the utilisation of renewable energies.

Remaining service life:
Difference between the planned or actual service life of the plant and its technical lifetime. If the service life and the technical lifetime are equal then the remaining service is zero.

Residual value:
The residual value of material assets connected with an investment project consists of their initial investment costs minus the depreciation up to a certain point in time (usually the service life).

Return:
Excess of the income in a period (usually one calendar year) over the running costs.

Risk supplement:
Increase in the interest rate to be used to take account of any particular risk of loss.

Sensitivity analysis:
Investigation during an investment evaluation with the aim of determining the sensitivity in a financial indicator following from a given variation in a project input parameter.

Service life:
Period during which an investment facility should or will be used economically. The service life can be shorter than the technical lifetime, however it is usually assumed that technical lifetime and service life are equal.

Servicing of debt:
= Capital servicing or financial costs.

Static procedure:
Method of investment calculation.

Technical lifetime:
Maximum period during which plants or components are technically operational.

Appendix III

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Appendix IV

Interest tables

Table 1: Discounting factors: $q - t$

Table 2: Recovery factors: RF (i, t)

$$RF = \frac{q^t (q - 1)}{q^t - 1}$$

Table 3: Present value factor: PF (i, t)

$$PF = \frac{q^t - 1}{q^t (q - 1)}$$

Table 4: Compounding factors: q^t

Table 1: Discounting factors $(1+\frac{i}{100})^{-t} = q^{-t}$

i t	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	.990	.980	.971	.962	.952	.943	.935	.926	.917	.909	.901	.893	.885	.877	.870
2	.980	.961	.943	.925	.907	.890	.873	.857	.842	.826	.812	.797	.783	.769	.756
3	.971	.942	.915	.889	.864	.840	.816	.794	.772	.751	.731	.712	.693	.675	.658
4	.961	.924	.888	.855	.823	.792	.763	.735	.708	.683	.659	.636	.613	.592	.572
5	.951	.906	.863	.822	.784	.747	.713	.681	.650	.621	.593	.567	.543	.519	.497
6	.942	.888	.837	.790	.746	.705	.666	.630	.596	.564	.535	.507	.480	.456	.432
7	.933	.871	.813	.760	.711	.665	.623	.583	.547	.513	.482	.452	.425	.400	.376
8	.923	.853	.789	.731	.677	.627	.582	.540	.502	.467	.434	.404	.376	.351	.327
9	.914	.837	.766	.703	.645	.592	.544	.500	.460	.424	.391	.361	.333	.308	.284
10	.905	.820	.744	.676	.614	.558	.508	.463	.422	.386	.352	.322	.295	.270	.247
11	.896	.804	.722	.650	.585	.527	.475	.429	.388	.350	.317	.287	.261	.237	.215
12	.887	.788	.701	.625	.557	.497	.444	.397	.356	.319	.286	.257	.231	.208	.187
13	.879	.773	.681	.601	.530	.469	.415	.368	.326	.290	.258	.229	.204	.182	.163
14	.870	.758	.661	.577	.505	.442	.388	.340	.299	.263	.232	.205	.181	.160	.141
15	.861	.743	.642	.555	.481	.417	.362	.315	.275	.239	.209	.183	.160	.140	.123
16	.853	.728	.623	.534	.458	.394	.339	.292	.252	.218	.188	.163	.141	.123	.107
17	.844	.714	.605	.513	.436	.371	.317	.270	.231	.198	.170	.146	.125	.108	.093
18	.836	.700	.587	.494	.416	.350	.296	.250	.212	.180	.153	.130	.111	.095	.081
19	.828	.686	.570	.475	.396	.331	.277	.232	.194	.164	.138	.116	.098	.083	.070
20	.820	.673	.554	.456	.377	.312	.258	.215	.178	.149	.124	.104	.087	.073	.061
21	.811	.660	.538	.439	.359	.294	.242	.199	.164	.135	.112	.093	.077	.064	.053
22	.803	.647	.522	.422	.342	.278	.822	.184	.150	.123	.101	.083	.606	.056	.046
23	.795	.634	.507	.406	.326	.262	.211	.170	.138	.112	.091	.074	.060	.049	.040
24	.788	.622	.492	.390	.310	.247	.197	.158	.126	.102	.082	.066	.053	.043	.035
25	.780	.610	.478	.375	.295	.233	.184	.146	.116	.092	.074	.059	.047	.038	.030
26	.772	.598	.464	.836	.281	.220	.172	.135	.106	.084	.066	.053	.042	.033	.026
27	.764	.586	.450	.347	.268	.207	.161	.125	.098	.076	.060	.047	.037	.029	.023
28	.757	.574	.437	.333	.255	.196	.150	.116	.090	.069	.054	.042	.033	.026	.020
29	.749	.563	.424	.321	.243	.818	.141	.107	.082	.063	.048	.037	.029	.022	.017
30	.742	.552	.412	.308	.231	.174	.131	.099	.075	.057	.044	.033	.026	.020	.015

Discounting factors

i t	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	.862	.855	.847	.840	.833	.826	.820	.813	.806	.800	.794	.787	.781	.775	.769
2	.743	.731	.718	.706	.694	.683	.672	.661	.650	.640	.630	.620	.610	.601	.592
3	.641	.624	.609	.593	.579	.564	.551	.537	.524	.512	.500	.488	.477	.466	.455
4	.552	.534	.516	.499	.482	.467	.451	.437	.423	.410	.397	.384	.373	.361	.350
5	.476	.456	.437	.419	.402	.386	.370	.355	.341	.328	.315	.303	.291	.280	.269
6	.410	.390	.370	.352	.335	.319	.303	.289	.275	.262	.250	.238	.227	.217	.207
7	.354	.333	.314	.296	2791	.263	.249	.235	.222	.210	.198	.188	.178	.168	.159
8	.305	.285	.266	.249	.233	.218	.204	.191	.179	.168	.157	.148	.139	.130	.123
9	.263	.243	.225	.209	.194	.180	.167	.155	.144	.134	.125	.116	.108	.101	.094
10	.227	.208	.191	.176	.162	.149	.137	.126	.116	.107	.099	.092	.085	.078	.073
11	.195	.178	.162	.148	.135	.123	.112	.103	.094	.086	.079	.072	.066	.061	.056
12	.168	.152	.137	.124	.112	.102	.092	.083	.076	.069	.062	.057	.052	.047	.043
13	.145	.130	.116	.104	.093	.084	.075	.068	.061	.055	.050	.045	.040	.037	.033
14	.125	.111	.099	.088	.078	.069	.062	.055	.049	.044	.039	.035	.032	.028	.025
15	.108	.095	.084	.074	.065	.057	.051	.045	.040	.035	.031	.028	.025	.022	.020
16	.093	.081	.071	.062	.054	.047	.042	.036	.032	.028	.025	.022	.019	.017	.015
17	.080	.069	.060	.052	.045	.039	.034	.030	.026	.023	.020	.017	.015	.013	.012
18	.069	.059	.051	.044	.038	.032	.028	.024	.021	.018	.016	.014	.012	.010	.009
19	.060	.051	.043	.037	.031	.027	.023	.020	.017	.014	.012	.011	.009	.008	.007
20	.051	.043	.037	.031	.026	.022	.019	.016	.014	.012	.010	.008	.007	.006	.005
21	.044	.037	.031	.026	.022	.018	.015	.013	.011	.009	.008	.007	.006	.005	.004
22	.038	.032	.026	.022	.018	.015	.013	.011	.009	.007	.006	.005	.004	.004	.003
23	.033	.027	.022	.018	.015	.012	.010	.009	.007	.006	.005	.004	.003	.003	.002
24	.028	.023	.019	.015	.013	.010	.008	.007	.006	.005	.004	.003	.003	.002	.002
25	.024	.020	.016	.013	.010	.009	.007	.006	.005	.004	.003	.003	.002	.002	.001
26	.021	.017	.014	.011	.009	.007	.006	.005	.004	.003	.002	.002	.002	.001	.001
27	.018	.014	.011	.009	.007	.006	.005	.004	.003	.002	.002	.002	.001	.001	.001
28	.016	.012	.010	.008	.006	.005	.004	.003	.002	.002	.002	.001	.001	.001	.001
29	.014	.011	.008	.006	.005	.004	.003	.002	.002	.002	.001	.001	.001	.001	.000
30	.012	.009	.007	.005	.004	.003	.003	.002	.002	.001	.001	.001	.001	.000	.000

Table 2: Recovery factors – RF (i,t) = $\frac{q^t (q-1)}{q^t - 1}$; $q = 1 + \frac{i}{100}$

i t	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.010	1.020	1.030	1.040	1.050	1.060	1.070	1.080	1.090	1.100	1.110	1.120	1.130	1.140	1.150
2	.508	.515	.523	.530	.538	.545	.553	.561	.568	.576	.584	.592	.599	.607	.615
3	.340	.347	.354	.360	.367	.374	.381	.388	.952	.402	.409	.416	.424	.431	.438
4	.256	.263	.269	.275	.282	.289	.295	.302	.309	.315	.322	.329	.336	.334	.350
5	.206	.212	.218	.225	.231	.237	.244	.250	.257	.264	.271	.277	.284	.291	.298
6	.173	.179	.185	.191	.197	.203	.210	.216	.223	.230	.236	.243	.250	.247	.264
7	.149	.155	.161	.167	2173	.179	.186	.192	.199	.205	.212	.219	.226	.233	.240
8	.131	.137	.142	.149	.155	.161	.167	.174	.181	.187	.194	.201	.208	.216	.223
9	.117	.123	.128	.213	.141	.147	.153	.160	.167	.174	.181	.188	.195	.202	.210
10	.106	.111	.117	.123	.130	.136	.142	.149	.156	.163	.170	.177	.184	.192	.199
11	.096	.102	.108	.114	.120	.127	.133	.140	.147	.154	.161	.168	.176	.183	.191
12	.089	.095	.100	.107	.113	.119	.126	.133	.140	.147	.154	.161	.169	.177	.184
13	.082	.088	.094	.100	.106	.113	.120	.127	.134	.141	.148	.156	.163	.171	.179
14	.077	.083	.089	.095	.101	.108	.114	.121	.128	.136	.143	.151	.159	.167	.175
15	.072	.078	.084	.090	.096	.103	.110	.117	.124	.131	.139	.147	.155	.163	.171
16	.068	.074	.080	.086	.092	.099	.106	.113	.120	.128	.136	.143	.151	.160	.168
17	.064	.070	.076	.082	.089	.095	.102	.110	.117	.125	.132	.140	.149	.157	.165
18	.061	.067	.073	.079	.086	.092	.099	.107	.114	.122	.130	.138	.146	.155	.163
19	.058	.064	.070	.076	.083	.090	.097	.104	.112	.120	.128	.136	.144	.153	.161
20	.055	.061	.067	.074	.080	.087	.094	.102	.110	.117	.126	.134	.142	.151	.160
21	.053	.059	.065	.071	.078	.085	.092	.100	.108	.116	.124	.132	.141	.150	.158
22	.051	.057	.063	.069	.076	.083	.090	.098	.106	.114	.122	.131	.139	.148	.157
23	.049	.055	.061	.067	.074	.081	.089	.096	.104	.113	.121	.130	.138	.147	.156
24	.047	.053	.059	.066	.072	.080	.087	.095	.103	.111	.120	.128	.137	.146	.155
25	.045	.051	.057	.064	.071	.078	.086	.094	.102	.110	.119	.127	.136	.145	.155
26	.044	.050	.056	.063	.070	.077	.085	.093	.101	.109	.118	.127	.136	.145	.154
27	.042	.048	.055	.061	.068	.076	.083	.091	.100	.108	.117	.126	.135	.144	.154
28	.041	.047	.053	.060	.067	.075	.082	.090	.099	.107	.116	.125	.134	.144	.153
29	.040	.046	.052	.059	.066	.074	.081	.090	.098	.107	.116	.125	.134	.143	.153
30	.039	.045	.051	.058	.065	.073	.081	.089	.097	.106	.115	.124	.133	.143	.152

Recovery factors

i t	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	1.160	1.170	1.180	1.190	1.200	1.210	1.220	1.230	1.240	1.250	1.260	1.270	1.280	1.290	1.300
2	.623	.631	.639	.647	.655	.662	.670	.678	.686	.694	.702	.711	.719	.727	.735
3	.445	.453	.460	.467	.475	.482	.490	.497	.505	.512	.520	.528	.535	.543	.551
4	.357	.365	.372	.379	.386	.394	.401	.408	.416	.423	.431	.439	.446	.454	.462
5	.305	.313	.320	.327	.334	.342	.349	.357	.364	.372	.379	.387	.395	.403	.411
6	.271	.279	.286	.293	.301	.308	.316	.323	.331	.339	.347	.354	.362	.370	.378
7	.248	.255	.262	.270	.277	.285	.293	.301	.308	.316	.324	.332	.340	.349	.357
8	.230	.238	.245	.253	.261	.268	.276	.284	.292	.300	.309	.317	.325	.333	.342
9	.217	.225	.232	.240	.248	.256	.264	.272	.280	.289	.297	.306	.314	.323	.331
10	.207	.215	.223	.230	.239	.247	.255	.263	.272	.280	.289	.297	.306	.315	.323
11	.199	.207	.215	.223	.231	.239	.248	.256	.265	.273	.282	.291	.300	.309	.318
12	.192	.200	.209	.217	.225	.234	.242	.251	.260	.268	.277	.286	.295	.304	.313
13	.187	.195	.204	.212	.221	.229	.238	.247	.256	.265	.274	.283	.292	.301	.310
14	.183	.191	.200	.208	.217	.226	.234	.243	.252	.262	.271	.280	.289	.289	.308
15	.179	.188	.196	.205	.214	.223	.232	.241	.250	.259	.268	.278	.287	.297	.306
16	.176	.185	.194	.203	.211	.220	.230	.239	.248	.257	.267	.276	.285	.295	.305
17	.174	.183	.191	.200	.209	.219	.228	.237	.246	.256	.265	.275	.284	.294	.304
18	.172	.181	.190	.199	.208	.217	.226	.236	.245	.255	.264	.274	.283	.293	.303
19	.170	.179	.188	.197	.206	.216	.225	.235	.244	.254	.263	.273	.283	.292	.302
20	.169	.178	.187	.196	.205	.215	.224	.234	.243	.253	.263	.272	.282	.292	.302
21	.167	.177	.186	.195	.204	.214	.223	.233	.243	.252	.262	.272	.282	.291	.301
22	.166	.176	.185	.194	.204	.213	.223	.232	.242	.252	.262	.271	.281	.291	.301
23	.165	.175	.184	.194	.203	.213	.222	.232	.242	.251	.261	.271	.281	.291	.301
24	.165	.174	.183	.193	.203	.212	.222	.232	.241	.251	.261	.271	.281	.291	.301
25	.164	.173	.183	.192	.202	.212	.222	.231	.241	.251	.261	.271	.281	.290	.300
26	.163	.173	.182	.192	.202	.211	.221	.231	.241	.251	.261	.271	.280	.290	.300
27	.163	.172	.182	.192	.201	.211	.221	.231	.241	.251	.261	.270	.280	.290	.300
28	.163	.172	.182	.191	.201	.211	.221	.231	.241	.250	.260	.270	.280	.290	.300
29	.162	.172	.181	.191	.201	.211	.221	.231	.240	.250	.260	.270	.280	.290	.300
30	.162	.172	.181	.191	.201	.211	.221	.230	.240	.250	.260	.270	.280	.290	.300

Table 3: Present value factors – PF (i, t) = $\frac{q^t-1}{q^t(q-1)}$; $q = 1 + \frac{i}{100}$

i t	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	.990	.980	.971	.962	.952	.943	.935	.926	.917	.909	.901	.893	.885	.877	.870
2	1.970	1.942	1.913	1.886	1.859	1.833	1.808	1.783	1.759	1.736	1.713	1.690	1.668	1.647	1.626
3	2.941	2.884	2.829	2.775	2.723	2.673	2.624	2.577	2.531	2.487	2.444	2.402	2.361	2.322	2.283
4	3.902	3.808	3.717	3.630	3.546	3.465	3.387	3.312	3.240	3.170	3.102	3.037	3.974	3.914	2.855
5	4.853	4.713	4.580	4.452	4.329	4.212	4.100	3.993	3.890	3.791	3.696	3.605	3.517	3.433	3.352
6	5.795	5.601	5.417	5.242	5.076	4.917	4.767	4.623	4.486	4.355	4.231	4.111	03.998	3.889	3.784
7	6.728	6.472	6.230	6.002	5.786	5.582	5.389	5.206	5.033	4.868	4.712	4.564	4.423	4.288	4.160
8	7.652	7.325	7.020	6.463	6.210	5.971	5.747	5.535	5.146	4.968	4.799	4.639	4.799	4.639	4.487
9	8.566	8.162	7.786	7.435	7.108	6.802	6.515	6.247	5.995	5.759	5.537	5.328	5.132	4.946	4.772
10	9.471	8.983	8.530	8.111	7.722	7.360	7.024	6.710	6.418	6.145	5.889	5.650	5.426	5.216	5.019
11	10.368	9.787	9.253	8.760	8.306	7.887	7.499	7.139	6.805	6.495	6.207	5.938	5.687	5.453	5.234
12	11.255	10.575	9.954	9.385	8.863	8.384	7.943	7.536	7.161	6.814	6.492	6.194	5.918	5.660	5.421
13	12.134	11.348	10.635	9.986	9.394	8.853	8.358	7.904	7.487	7.103	6.750	6.424	6.122	5.842	5.583
14	13.004	12.106	11.296	10.563	9.899	9.295	8.745	8.244	7.786	7.367	6.982	6.628	6.302	6.002	5.724
15	13.865	12.849	11.938	11.118	10.380	9.712	9.108	8.559	8.061	7.606	7.191	6.811	6.462	6.142	5.847
16	14.718	13.578	12.561	11.652	10.838	10.106	09.447	8.851	8.313	7.824	7.379	6.974	6.604	6.265	5.954
17	15.562	14.292	13.166	12.166	11.274	10.477	9.763	9.122	8.544	8.022	7.549	7.120	6.729	6.373	6.047
18	16.398	14.992	13.754	12.659	11.690	10.059	9.372	8.756	8.201	8.201	7.702	7.250	6.840	6.467	6.128
19	17.226	15.678	14.324	13.134	12.085	11.158	10.336	9.604	8.950	8.365	7.839	7.366	6.938	6.550	6.198
20	18.046	16.351	14.877	13.590	12.462	11.470	10.594	9.818	9.129	8.514	7.963	7.469	7.025	6.623	6.259
21	18.857	17.011	15.415	14.029	12.821	11.764	10.836	10.017	9.292	8.649	8.075	7.562	7.102	6.687	6.312
22	19.660	17.658	15.937	14.451	13.163	12.042	11.061	10.201	9.442	8.772	8.176	7.645	7.170	6.743	6.359
23	20.456	18.292	16.444	14.857	13.489	12.303	11.272	10.371	9.580	8.883	8.266	7.718	7.230	6.792	6.399
24	21.243	18.914	16.936	15.247	13.799	12.550	11.469	10.529	9.707	8.985	8.348	7.784	7.283	6.835	6.434
25	22.023	19.523	17.413	15.622	14.094	12.783	11.654	10.675	9.823	9.077	8.422	7.843	7.330	6.873	6.464
26	22.795	20.121	17.877	15.983	14.375	13.003	11.826	10.810	9.929	9.161	8.488	7.896	7.372	6.906	6.491
27	23.560	20.707	18.327	16.330	14.643	13.211	11.987	10.935	10.027	9.237	8.548	7.943	7.409	6.935	6.514
28	24.316	21.281	18.764	16.663	14.898	13.406	12.137	11.051	10.116	9.307	8.602	7.984	7.441	6.961	6.534
29	25.066	21.844	19.188	16.984	15.141	13.591	12.278	11.158	10.198	9.370	8.650	8.022	7.470	6.983	6.551
30	25.808	22.396	19.600	17.292	15.372	13.372	12.409	11.258	10.274	9.427	8.694	8.055	7.496	7.003	6.566

Present value factors

i t	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	.862	.855	.847	.840	.833	.826	.820	.813	.806	.800	.794	.787	.781	.775	.769
2	1.605	1.585	1.566	1.547	1.528	1.509	1.492	1.474	1.457	1.440	1.424	1.407	1.392	1.376	1.361
3	2.246	2.210	2.174	2.140	2.106	2.074	2.042	2.011	1.981	1.952	1.923	1.896	1.868	1.842	1.816
4	2.798	2.743	2.690	2.639	2.589	2.540	2.494	2.448	2.404	2.362	2.320	2.280	2.241	2.203	2.166
5	3.274	3.199	3.127	3.058	2.991	2.926	2.864	2.803	2.745	2.689	2.635	2.583	2.532	2.483	2.436
6	3.685	3.589	3.498	3.410	3.326	3.245	3.167	3.092	3.020	2.951	2.885	2.821	2.759	2.700	2.643
7	4.039	3.922	3.812	3.706	3.605	3.508	3.416	3.327	3.242	3.161	3.083	3.009	2.937	2.868	2.802
8	4.344	4.207	4.078	3.954	3.837	3.726	3.619	3.518	3.421	3.329	3.241	3.156	3.076	2.999	2.925
9	4.607	4.451	4.303	4.163	4.031	3.905	3.786	3.673	3.566	3.463	3.366	3.273	3.184	3.100	3.019
10	4.833	4.659	4.494	4.339	4.192	4.054	3.923	3.799	3.682	3.571	3.465	3.364	3.269	3.178	3.092
11	5.029	4.836	4.656	4.486	4.327	4.177	4.035	3.902	3.776	3.656	3.543	3.437	3.335	3.239	3.147
12	5.197	4.988	4.793	4.611	4.439	4.278	4.127	3.985	3.851	3.725	3.606	3.493	3.387	3.286	3.190
13	5.342	5.118	4.910	4.715	4.533	4.362	4.203	4.053	3.912	3.780	3.656	3.538	3.427	3.322	3.223
14	5.468	5.229	5.008	4.802	4.611	4.432	4.265	4.108	3.962	3.824	3.695	3.573	3.459	3.351	3.249
15	5.575	5.324	5.092	4.876	4.675	4.489	4.315	4.153	4.001	3.859	3.726	3.601	3.483	3.373	3.268
16	5.668	5.405	5.162	4.938	4.730	4.536	4.357	4.189	4.033	3.887	3.761	3.623	3.503	3.390	3.283
17	5.749	5.475	5.222	4.990	4.775	4.676	4.391	4.219	4.059	3.910	3.771	3.640	3.518	3.403	3.295
18	5.818	5.534	5.273	5.033	4.812	4.608	4.419	4.243	4.080	3.928	3.786	3.654	3.529	3.413	3.304
19	5.877	5.584	5.316	5.070	4.843	4.635	4.442	4.263	4.097	3.942	3.799	3.664	3.539	3.421	3.311
20	5.925	5.628	5.353	5.101	4.870	4.657	4.460	4.279	4.110	3.954	3.808	3.673	3.546	3.427	3.316
21	5.973	5.665	5.384	5.127	4.891	4.675	4.476	4.292	4.121	3.963	3.816	3.679	3.551	3.432	3.320
22	6.011	5.696	5.410	5.149	4.909	4.690	4.488	4.302	4.130	3.970	3.822	3.684	3.556	3.436	3.323
23	6.044	5.723	5.432	5.167	4.925	4.703	4.499	4.311	4.137	3.976	3.827	3.689	3.559	3.438	3.325
24	6.073	5.746	5.451	5.182	4.937	4.713	4.507	4.318	4.143	3.981	3.831	3.692	3.562	3.441	3.327
25	6.097	5.766	5.467	5.195	4.948	4.721	4.514	4.323	4.147	3.985	3.834	3.694	3.564	3.442	3.329
26	6.118	5.783	5.480	5.206	4.956	4.728	4.520	4.328	4.151	3.988	3.837	3.696	3.566	3.444	3.330
27	6.136	5.798	5.492	5.215	4.964	4.734	4.524	4.332	4.154	3.990	3.839	3.698	3.567	3.445	3.331
28	6.152	5.810	5.502	5.223	4.970	4.739	4.528	4.335	4.157	3.992	3.840	3.699	3.568	3.446	3.331
29	6.166	5.820	5.510	5.229	4.975	4.743	4.531	4.337	4.159	3.994	3.841	3.700	3.569	3.446	3.332
30	6.177	5.829	5.517	5.235	4.979	4.746	4.534	4.339	4.160	3.995	3.842	3.701	3.569	3.447	3.332

Table 4: Compounding factors $(1+\frac{i}{100})^t = q^t$

t	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.01	1.02	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12	1.13	1.14	1.15
2	1.02	1.04	1.06	1.08	1.10	1.12	1.14	1.17	1.19	1.21	1.23	1.25	1.28	1.30	1.32
3	1.03	1.06	1.09	1.12	1.16	1.19	1.23	1.26	1.30	1.33	1.37	1.40	1.44	1.48	1.52
4	1.04	1.08	1.13	1.17	1.22	1.26	1.31	1.36	1.41	1.46	1.52	1.57	1.63	1.69	1.75
5	1.05	1.10	1.16	1.22	1.28	1.34	1.40	1.47	1.54	1.61	1.69	1.76	1.84	1.93	2.01
6	1.06	1.13	1.19	1.27	1.34	1.42	1.50	1.59	1.68	1.77	1.87	1.97	2.08	2.19	2.31
7	1.07	1.15	1.23	1.32	1.41	1.50	1.61	1.71	1.83	1.95	2.08	2.21	2.35	2.50	2.66
8	1.08	1.17	1.27	1.37	1.48	1.59	1.72	1.85	1.99	2.14	2.30	2.48	2.66	2.85	3.06
9	1.09	1.20	1.30	1.42	1.55	1.69	1.84	2.00	2.17	2.36	2.56	2.77	3.00	3.25	3.52
10	1.10	1.22	1.34	1.48	1.63	1.79	1.97	2.16	2.37	2.59	2.84	3.11	3.39	3.71	4.05
11	1.12	1.24	1.38	1.54	1.71	1.90	2.10	2.33	2.58	2.85	3.15	3.48	3.84	4.23	4.65
12	1.13	1.27	1.43	1.60	1.80	2.01	2.25	2.52	2.81	3.14	3.50	3.90	4.33	4.82	5.35
13	1.14	1.29	1.47	1.67	1.89	2.13	2.41	2.72	3.07	3.45	3.88	4.36	4.90	5.49	6.15
14	1.15	1.32	1.51	1.73	1.98	2.26	2.58	2.94	3.34	3.80	4.31	4.89	5.53	6.26	7.08
15	1.16	1.35	1.56	1.80	2.08	2.40	2.76	3.17	3.64	4.18	4.78	5.47	6.25	7.14	8.14
16	1.17	1.37	1.60	1.87	2.18	2.54	2.95	3.43	3.97	4.59	5.31	6.13	7.07	8.14	9.36
17	1.18	1.40	1.65	1.95	2.29	2.69	3.16	3.70	4.33	5.05	5.90	6.87	7.99	9.28	10.76
18	1.20	1.43	1.70	2.03	2.41	2.85	3.38	4.00	4.72	5.56	6.54	7.69	9.02	10.58	12.38
19	1.21	1.46	1.75	2.11	2.53	3.03	3.62	4.32	5.14	6.12	7.26	8.61	10.20	12.06	14.23
20	1.22	1.49	1.81	2.19	2.65	3.21	3.87	4.66	5.60	6.73	8.06	9.65	11.52	13.74	16.37
21	1.23	1.52	1.86	2.28	2.79	3.40	4.14	5.03	6.11	7.40	8.95	10.80	13.02	15.67	18.82
22	1.24	1.55	1.92	2.37	2.93	3.60	4.43	5.44	6.66	8.14	9.93	12.10	14.71	17.86	21.64
23	1.26	1.58	1.97	2.46	3.07	3.82	4.74	5.87	7.26	8.95	11.03	13.55	16.63	20.36	24.89
24	1.27	1.61	2.03	2.56	3.23	4.05	5.07	6.34	7.91	9.85	12.24	15.18	18.79	23.21	28.63
25	1.28	1.64	2.09	2.67	3.39	4.29	5.43	6.85	8.62	10.83	13.59	17.00	21.23	26.46	32.92
26	1.30	1.67	2.16	2.77	3.56	4.55	5.81	7.40	9.40	11.92	15.08	19.04	23.99	30.17	37.86
27	1.31	1.71	2.22	2.88	3.73	4.82	6.21	7.99	10.25	13.11	16.74	21.32	27.11	34.39	43.54
28	1.32	1.74	2.29	3.00	3.92	5.11	6.65	8.63	11.17	14.42	18.58	23.88	30.63	39.20	50.07
29	1.33	1.78	2.36	3.12	4.12	5.42	7.11	9.32	12.17	15.86	20.62	26.75	34.62	44.69	57.58
30	1.35	1.81	2.43	3.24	4.32	5.74	7.61	10.06	13.27	17.45	22.89	29.96	39.12	50.95	66.21

Compounding factors

t \ i	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	1.16	1.17	1.18	1.19	1.20	1.2	1.2	1.2	1.2	1.3	1.3	1.3	1.3	1.3	1.3
2	1.35	1.37	1.39	1.42	1.44	1.5	1.5	1.5	1.5	1.6	1.6	1.6	1.6	1.7	1.7
3	1.56	1.60	1.64	1.69	1.73	1.8	1.8	1.9	1.9	2.0	2.0	2.0	2.1	2.1	2.2
4	1.81	1.87	1.94	2.01	2.07	2.1	2.2	2.3	2.4	2.4	2.5	2.6	2.7	2.8	2.9
5	2.10	2.19	2.29	2.39	2.49	2.6	2.7	2.8	2.9	3.1	3.2	3.3	3.4	3.6	3.7
6	2.44	2.57	2.70	2.84	2.99	3.1	3.3	3.5	3.6	3.8	4.0	4.2	4.4	4.6	4.8
7	2.83	3.00	3.19	3.38	3.58	3.8	4.0	4.3	4.5	4.8	5.0	5.3	5.6	5.9	6.3
8	3.28	3.51	3.76	4.02	4.30	4.6	4.9	5.2	5.6	6.0	6.4	6.8	7.2	7.7	8.2
9	3.80	4.11	4.44	4.79	5.16	5.6	6.0	6.4	6.9	7.5	8.0	8.6	9.2	9.9	10.6
10	4.41	4.81	5.23	5.69	6.19	6.7	7.3	7.9	8.6	9.3	10.1	10.9	11.8	12.8	13.8
11	5.12	5.62	6.18	6.78	7.43	8.1	8.9	9.7	10.7	11.6	12.7	13.9	15.1	16.5	17.9
12	5.94	6.58	7.29	8.06	8.92	9.8	10.9	12.0	13.2	14.6	16.0	17.6	19.3	21.2	23.3
13	6.89	7.70	8.60	9.60	10.70	11.9	13.3	14.7	16.4	18.2	20.2	22.4	24.8	27.4	30.3
14	7.99	9.01	10.15	11.42	12.84	14.4	16.2	18.1	20.3	22.7	25.4	28.4	31.7	35.3	39.4
15	9.27	10.54	11.97	13.59	15.41	17.4	19.7	22.3	25.2	28.4	32.0	36.1	40.6	45.6	51.2
16	10.75	12.33	14.13	16.17	18.49	21.1	24.1	27.4	31.2	35.5	40.4	45.8	51.9	58.8	66.5
17	12.47	14.43	16.67	19.24	22.19	25.5	29.4	33.8	38.7	44.4	50.9	58.2	66.5	75.9	86.5
18	14.46	16.88	19.67	22.90	26.62	30.9	35.8	41.5	48.0	55.5	64.1	73.9	85.1	97.9	112.5
19	16.78	19.75	23.21	27.25	31.95	37.4	43.7	51.1	59.6	69.4	80.7	93.8	108.9	126.2	146.2
20	19.46	23.11	27.39	32.43	38.34	45.3	53.4	62.8	73.9	86.7	101.7	119.1	139.4	162.9	190.0
21	22.57	27.03	32.32	38.59	46.01	54.8	65.1	77.3	91.6	108.4	128.2	151.3	178.4	210.1	247.1
22	26.19	31.63	38.14	45.92	55.21	66.3	79.4	95.0	113.6	135.5	161.5	192.2	228.4	271.0	321.2
23	30.38	37.01	45.01	54.65	66.25	80.2	96.9	116.9	140.8	169.4	203.5	244.1	292.3	349.6	417.5
24	35.24	43.30	53.11	65.03	79.50	97.0	118.2	143.8	174.6	211.8	256.4	309.9	374.1	451.0	542.8
25	40.87	50.66	62.67	77.39	95.40	117.4	144.2	176.9	216.5	264.7	323.0	393.6	478.9	581.8	705.6
26	47.41	59.27	73.95	92.09	114.48	142.0	175.9	217.5	268.5	330.9	407.0	499.9	613.0	750.6	917.3
27	55.00	69.35	87.26	109.59	137.37	171.9	214.6	267.6	333.0	413.6	512.9	634.9	784.6	968.1	1192.5
28	63.80	81.13	102.97	130.41	164.84	208.0	261.9	329.1	412.9	517.0	646.2	806.3	1004.3	1248.9	1550.3
29	74.01	94.93	121.50	155.19	197.81	251.6	319.5	404.8	512.0	646.2	814.2	1024.0	1285.6	[illegible]	[illegible]
30	85.85	111.06	143.37	184.68	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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