ECONOMIC EFFICIENCY OF SMALL-SCALE HYDROPLANTS

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ABSTRACT:

The economic efficiency of small-scale hydroplants may be assessed from the entrepreneur's viewpoint as well as in terms of political economy.

The following examples will describe several evaluation techniques, also including other possibilities of energy generation. Furthermore, the possibilities of a decision on grounds of economic efficiency, in the face of insufficient data, viz. uncertainty, will be discussed.

In conclusion of this contribution, there follows an interesting projection and realization of multipurpose projects, under consideration of multiple evaluation as well as qualification of costs and benefits.

14.1 INTRODUCTION

In determining the economic efficiency, various economic activities, like investment, have to be evaluated. This implies that the initial situation is known, that the feasable set, i.e. all possible alternatives, is determinable, that one or several targets are given, and it necessitates a scale for measuring the efficiency of the various alternatives.

As, in reality, each of these conditions will be satisfied to a certain degree only, this analysis of economic efficiency will frequently be restricted to special cases.

The target of this analysis is a definite evaluation of the alternatives, in order to choose the most favourable one. As is shown by means of the following techniques, definiteness is well possible here, if and when the viewpoint has accurately been determined. This means that, irrespectively of the technique applied, the same result will ensue.

A changed viewpoint will, in most cases, effect a change in the evaluation. That means that an investment, which is unprofitable for the entrepreneur, may be of interest in terms of political economy. The differences are rooted in the additional consideration given to influencing factors like energy imports, trade balance and secondary effects.

The next sections will discuss simple decisions. With the cash flow accurately given, economic efficiency of an investment will be examined by means of various methods. Following this, uncertainty of data will also be included.

This discussion will also extend to decisions to be made in the case of multiple targets.

14.2 CLASSIC ANALYSIS OF ECONOMIC EFFICIENCY

With each investment two cash flows have to be taken into account. Both, income (or benefits) and costs are characterized by amount and point of time of the cash flow item, which in a simplified way, is demonstrated in figure 14.1. The diagram in this figure exhibits the series of payments during the construction of a small-scale hydroplant, where relatively high investment costs are followed by low operation costs. In the income flow, petty fluctuations, in correspondence to the slightly varying annual energy generation, may be registered.

For the purpose of determining the economic efficiency of an investment, the classic evaluation techniques are most suitable:

- o Present Worth Method
- o Annual Costs Method
- o Benefit-Cost Ratio Method
- o Rate of Return Method

JAMES et. al. (1971) comprises, inter alia, a short description of the listed methods.

Before expanding on the description of the methods, we shall briefly discuss some basic notions by means of a payment, X_t. If a payment, X_t, is brought into relation to a point of time, $T > t$, the worth, X_t, due to interest yield, will rise to a future worth, E.

$$E = X_t \cdot d_{T-t} \qquad d_{T-t} = (1+i)^{T-t} \qquad (1)$$

If brought into relation to the initial point of time, t=0, the present worth, B, of a payment, X_t, is to be determined by means of deduction of un-accrued interest or discounting.

$$B = X_t \cdot \frac{1}{d_t} \qquad d_t = (1+i)^t \qquad (2)$$

X_t	payment at a point of time, t
B	present worth
E	future worth
i	market interest rate
$1/d_t$	discounting factor
t	point of time
T	end of the period covered

Both calculation processes, addition and deduction of unaccrued interest are determined by the period of time and the market interest rate. In case of a high interest rate, future payments will only trivially effect the cash value. This will be demonstrated by comparing the present values of payments made at the point of time t = 0, t = 10 and t = 20 years in table 14.1.

i (%)	t = 0	t = 10	t = 20
6	B	0.53 B	0.28 B
8	B	0.46 B	0.21 B

Table 14.1 Discounting in relation to the interest rate

If there are cash flows, each factor of a series must refer to the same point of time, which, in most cases, is placed in the beginning. If payments are the same each year, this will essentially simplify the calculation process. In the following we shall assume that assessment should be made for a project only. This means that we may choose between at least two alternatives: Implementation of the project or no implementation.

Furthermore, we shall presuppose exact knowledge of income and costs during the whole covered period, T, with the market interest rate, i, being definitely given.

14.2.1 Present Worth Method

The present worth is the sum of a series of payments, which fall due during the economic life, T, of a project, in relation to an initial point of time.

$$B_N = \sum_{t=1}^{T} \frac{N_t}{d_t}$$

$$B_K = \sum_{t=1}^{T} \frac{K_t}{d_t} \qquad (3)$$

$$KW = B_N - B_K$$

N_t benefits at a point of time, t
K_t costs at a point of time, t
B_N present value of benefits
B_K present value of costs
KW present worth

Equality of payments, e.g. N_t, simplifies the calculation, as the capital recovery factor, WF,

$$B_N = \frac{N_t}{WF}$$

$$WF = \frac{i \cdot (1+i)^T}{(1+i)^T - 1} \qquad (4)$$

may speedily be calculated.

If the project exhibits a positive present worth, realization is justified.

14.2.2 Annual Costs Method

Payments, whose sequence may frequently vary, are transformed into an equivalent series with constant intervals.

$$K' \Sigma \frac{1}{d_t} = \Sigma \frac{K_t}{d_t}$$
$$N' \Sigma \frac{1}{d_t} = \Sigma \frac{N_t}{d_t} \qquad (5)$$

If the annual benefit, N', exceeds the annual costs, K', realization of the project ist justified. Close relation to the Present Worth Method can be seen from (5).

14.2.3 Benefit-Cost Ratio Method

The quantities B_N, B_K viz. N' and K', which were derived in the above methods, yield the benefit - cost ratio NKF, which is frequently used for economic evaluation of investments.

$$NKF = \frac{B_N}{B_K} = \frac{N'}{K'}$$

As the benefits should exceed costs, the benefit-cost ratio must exceed one in order to justify an investment.

14.2.4 Rate of Return

As the choice of the interest rate entails some uncertainties, the present worth, in the case of the Rate of Return Method, is calculated by means of various interest rates, until the present worth comes down to zero.

If the market interest is lower, realization of the project is recommendable.

The calculation process of this technique is somewhat extensive, uncertainty regarding the interest rate, however, is almost excluded.

14.2.5 Application of the classic methods

The four methods will be demonstrated by means of a simple example. The economic efficiency of a small-scale hydroplant with a capacity of L = 500 KW is to be examined. We suppose an underestimated life time of 25 years and an interest rate of 7 %. Further data are indicated in table 14.2.

	small-scale hydroplant KW 1
capacity (KW)	500
specific costs (S/KW)	28 000
investment costs (mio. S)	14.0
interest rate (%)	7
income (mio. S/a)	1.83
operation and maintenance costs (% of investment)	2.5
operation and maintenance costs (mio. S/a)	0.35
capital recovery factor WF(i=7%, T=25 years)	0.0858
present value of benefit (mio. S)	21.32
present value of costs (mio. S)	18.06
present worth (mio. S)	3.26
annual benefits (mio. S/a)	1.83
annual costs (mio. S/a)	1.55
net annual benefits (mio. S/a)	0.28
benefit-cost ratio	1.18
rate of return (%)	9.8

Table 14.2 Evaluation criteria for KW 1

14.2.6 Evaluation of the Discounting Techniques

If thoroughly implemented, each of the four methods yields the same result, which means that preference is given to the same alternative.

The Methods of Present Worth and Annual Costs are easily accomplished and closely interrelated. The former one yields large numerical values, which, sometimes, lack a certain perspicuity, while the annual benefits and costs are easily comprehensible.

Many governmental authorities would prefer the Benefit-Cost Method, especially for projects ~~of~~ hydraulic engineering. Problems in the assessment of several alternatives will be discussed in detail later on.

The Rate of Return method is a good evaluation instrument in the presence of uncertainties. In order to avoid mistakes, one should stick to accurate performance in cases of complex formulation.

14.3 ECONOMIC EFFICIENCY UNDER UNCERTAINTY

Up to here, the interest rate, investments, as well as income and costs were considered given quantities. This supposition is not applicable to long-term projects. Furthermore, especially on the energy sector, price development is uncertain, which makes an evaluation of the future development inevitable.

Two methods are frequently applied. The first one, the Sensitivity Analysis, examines the effects on the evaluation criterion.

The second method, the Risk Analysis replaces the fixed quantities by probable quantities, which also yields, of course, a result based on probability only.

14.3.1 Sensitivity Analysis

The sensitivity analysis would examine the admissable fluctuation margin of the individual influencing quantities. Here, by turns, each quantity which had been considered a given quantity during the previous section, is replaced by a variable one, in order to examine its effects on the result. Thus the sensitivity degree of the result in relation to each variable quantity, or also "influencing quantity", is being determined.

As regards the previous example, there are uncertainties concerning investments, income and costs, interest rate, and economic life of the plant. In order to evaluate the effects of a variable quantity, the change in the present worth is examined in the previous instance.

Table 14.3 expresses the effects of the modified variable quantities on the present worth in percentages of the modifications.

	Investm. (mio.S)	Benefits (mio. S/a)	Operation Costs (mio.S/a)	Economic Life Time (years)	Interest Rate %	Present Worth (mio.S)	Change in Present Worth
Initial Situation	14	1.83	0.35	25	7	3.26	
+ 10 % Investm.	15.4	1.83	0.35	25	7	1.86	-42 %
- 10 % Investm.	12.6	1.83	0.35	25	7	4.66	+42 %
+ 10 % Benefits	14	2.01	0.35	25	7	5.40	+65 %
- 10 % Benefits	14	1.64	0.35	25	7	1.12	-65 %
+ 10 % Oper.Costs	14	1.83	0.385	25	7	2.85	-12 %
- 10 % Oper.Costs	14	1.83	0.315	25	7	3.66	+12 %
+ 10 % Ec.lifetime	14	1.83	0.35	27.5	7	3.85	+18 %
- 10 % Ec.lifetime	14	1.83	0.35	22.5	7	2.13	-34 %
+ 10 % Interest R.	14	1.83	0.35	25	7.7	2.21	-32 %
- 10 % Interest R.	14	1.83	0.35	25	6.3	4.39	+34 %

Tab. 14.3 Sensitivity Analysis

From this table one may see that a change in the income has the greatest effect on the present worth. Due to the present energy situation one may expect that the energy price will be on the increase during the following decades, which would result in an intensified growth of the present worth. Economic life time and operation costs exert the least important influence, while benefits, investment and the interest rate are more important. At the same time these data serve as a support for decision-making, as they would indicate, for which influencing quantities an accurate evaluation is possible and for which variable quantities, in the course of simple evaluation, satisfactory results would be available. Finally there is the possibility to determine admissible limits for each variable quantity, up to which the project would still be justified in terms of economic efficiency. In special cases, even a pessimistic evaluation of the influencing quantities will still advocate a realization of the project.

14.3.2 Risk Analysis

During the discussion of the sensitivity analysis, the various quantities, e.g., the interest rate or income were variates, while supposing, implicitly that within the variation margin, all values would exhibit the same probability distribution to the variable quantities. These degrees indicate, how much probability should be attributed, for instance to a certain interest rate. The argument that this probability may not be determined objectively, is justified to a certain extent, but one must point out that the realization probability of a fixed given rate or income flow is zero. By means of evaluations, which are based on longterm observation of sequences, e.g. of the interest rate, or which take into consideration projects which have already been realized, the probability distribution of the influencing quantities may be determined in a simple way. An approximative characterization of the variable quantity by means of the most favourable value as well as fluctuation or distribution will do. If a constant exceeding or failing to come up to the estimate is admissible, the application of a standard distribution will be most favourable. If the probability of exceeding or failing to come up to the estimate is irregular, skewed distributions are recommendable. There are examples for two variable quantities in table 14.3.

The result will also exhibit the probability degree for the investment criterion. From the diagram one may find out the degrees of probability, for which realization of the project is justified in terms of economic efficiency.

Calculation of the final distribution function, however, involves a lot of calculation work and may be implemented by means of simulation, bearing in mind, at the same time, several influencing quantities, which were only statistically determined. Here, according to the probability distribution of the variable quantities, a great number of possibilities may be figured out, and the frequency of the results is determined.

Calculation of the interest rate depending on the probability distribution of the individual variable quantities constitute an important means for assessing the project as well as for a comparison of several alternatives.

Distribution as charted in table 14.4 allows a determination of the probability of exceeding a limit, as well as a risk-estimate which is expressed in the confidence interval of distribution.

In conclusion we shall mention some mistakes which may occur in the course of the procedure. The most probable total result ought not to be considered the logical result of the most probable individual data. This assertion holds especially for skewed distributions.

Furthermore one must heed the fact that many variable quantities, in terms of statistics, are not independent from each other. There is, for instance, a relation between the expenses which comprises the interest payments and the interest rate. When determining this relation in a mathematic way, one may also apply correlative statements or conditional probability distributions.

Although, admittedly, this procedure is a rather lengthy one, it allows a far better description of all factual data than the previously treated methods.

Inflationary trends stay unheeded, if benefits and costs are equally subject to increases. In case of irregular developments regarding income and costs, additional corrections will have to be made. This attitude leads us to the dynamic methods. For time reasons, the application of the dynamic method will not be discussed here.

14.4 ECONOMIC EFFICIENCY IN CASE OF SEVERAL ALTERNATIVES

Up to here, decision bases for the evaluation of a project had been worked out. When looking at the matter more closely, however, one shall find several alternatives, some of which would exclude each other. Let us discuss here, as an example, utilization of certain water resources, with, on the one hand, installation of a few big-scale plants carried on quickly, and, on the other hand, gradual installation of small plants with realization timing adapted to the growing demand. Although the number of alternatives exceeds two here, it will, even after having taken into account various combination possibilities, stay a limited one. Plant dimensioning possibilities, however, exhibit a lot of alternatives. Variation of the rated discharge and the fall head at a certain project site, may bring forth an immense number of possibilities. As, at said site, both quantities may constantly be varied, there results a - theoretically - unlimited number of alternatives. Due to the turbine producers' standard programmes, however, reduction to a low number is possible. As both instances require similar treatment, they are comprised and discussed in this chapter. In the same order, the four classic methods will be, for supplementary purposes, briefly discussed here.

14.4.1 Present Worth Method

As payments may be considered equivalent only, if the amounts, in relation to a joint reference point, are the same, one must also fix a joint reference point, e.g. the year 1980, in case there are several alternatives.

These requirements have to be satisfied, even if the alternatives are to be realized at different points of time.

Furthermore, a joint interest rate, as well as a uniform economic life, have to be applied to all alternatives. This economic life shall be a medium period. Alternatives with a longer economic life will, therefore, at the end of the evaluation period, avail of a rest value which has to be included into the analysis on economic efficiency. The present worth of all alternatives has to be figured out and those, exhibiting a positive present worth, will be chosen. In case of projects excluding each other, the one exhibiting the highest present worth will have to be favoured, with its costs being exactly known . If the evaluation criterion is known, the alternative accompanied by the lowest costs is to be favoured.

14.4.2 Annual Costs Method

The same conditions as in the afore mentioned techniques will apply here. In the case of several alternatives excluding each other, the one yielded the best annual net benefit will be the most favourable one in terms of economic efficiency.

14.4.3 Benefit-Cost Method

Having in mind the conditions which, also in future, will apply to the interest rate, evaluation period, and reference point, those projects with their benefit-cost ratio exceeding one, have to be determined. Additional analysis will become necessary for those alternatives, which are mutually exclusive. The group will be arranged in a series according to the cost increases, and, starting from the cheapest alternative, the incremental cost-benefit ratio has to be determined. This procedure is to be determined until the value of the cost-benefit factor sinks below one. The alternative added last, therefore, is to be considered unprofitable, while the last but one is the most favourable one.

14.4.4 Rate of Return Method

After having chosen a joint evaluation period and reference point, the values of the rate of return have to be figured out for all projects. On the basis of a comparison with the minimum value, a preliminary choice will be made. Thereafter, in case of the alternatives excluding each other, the rates of return of the incremental benefit-cost ratio will be the determining factors. As soon as the interest rate of the increments falls below the admissible minimum limit, the most profitable alternative will be established. Depending on the market interest rate, different evaluation results may be expected from this method, as can be seen from figure 14.5.

14.4.5 Example of Application

The above explanation will now be domonstrated in a simplified way by means of an example: A gradual utilization variant will be added to the project discussed in 14.2.5. So, there are the following alternatives now.

In the first case there is a project for the installation of a 500 KW plant. The second alternative envisages the installation of a 350 KW plant, which will generate sufficient energy for some years, and to which, after 10 years, the second small-scale 200 KW hydroplant will be added. The economic life of the plant is fixed at 25 years. For simplification purposes, the present worth of the plants at the end of the period covered by the analysis will not be considered.

	alternative I	alternative II	
capacity (KW)	500	350	200
specific costs	28000	31000	36000
investment costs (mio. S)	14	10.8	7.2
interest rate (%)	7	7	7
income (mio. S)	1.83	1.45	0.95
operation- and maintenance-costs (mio. S/a)	0.35	0.25	0.10
start of operation after n years	0	0	10
economic life (in years)	25	25	25
present value of the benefit (mio. S)	21.3	16.9	4.4
present value of costs (mio. S)	18.1	13.8	4.1
present worth (mio. S)	3.2	3.1	o.3
annual benefits (mio. S)	1.83	1.45	o.38
annual costs (mio. S)	1.55	1.18	o.35
benefit increments (mio. S)	o.o2		——
costs increments (mio. S)	o.2o		——
benefit-cost ratio	1.18		1.19
incremental benefit-cost ratio	< 1		——
rate of return	9.5		9.7

Table 14.4 Evaluation example with various alternatives

All evaluation techniques advocate the gradual utilization of water resources. In applying the Cost-Benefit Method, the incremental benefit-cost ratio would constitute a value below zero, which means that this additional investment is no more justified.

The next instance poses the question for the most economic dimensioning of a small-scale hydroplant. Economic criteria of energy, which refer to reliable energy, to summer and winter output as well as various tariff periods, will not be discussed in detail. They would partially show in the income.

Regarding the project site, there are estimates for the investment and operation costs, as well as for income from energy generation, as is charted in figure 14.6. By increasing the net head as well as the rated discharge, one may effect a rise of the annual output. Following this, only the capacity values of a small scale plant will be used for reference purposes. Regarding figure 14.6 one ought to mention that such diagrams would, still, frequently exhibit inconsistencies in the investment function which are due to the transition, for technical reasons, to more expensive construction methods, which become necessary as soon as, for instance, marginal limits of rated discharge or fall head are exceeded.

capa. (KW)	spec.co. (S/KW)	invest. (mio.S)	maint.& op.costs (mio.S)	in-come (mio)	pr.val. of benef. (mio.S)	ben. incr. (mio.S)	pr.val. of co. (mio.S)	costs incr. (mio.S)	NKF	NKF of growth
380	35260	13.4	0.35	2.0	23.3		17.48		1.33	
510	31600	16.1	0.36	2.4	27.96	4.66	20.29	2.81	1.38	1.65
640	27800	17.8	0.38	2.65	30.87	2.91	22.22	1.93	1.39	1.50
760	25520	19.4	0.40	2.85	33.20	2.33	24.05	1.83	1.38	1.27
890	23250	20.7	0.44	2.98	34.71	1.51	25.81	1.76	1.34	0.85

Table 14.5 Determination of the optimum plant factor

As becomes evident from table 14.5 the incremental benefit-cost ratio between 760 KW and 890 KW falls below one. This means that the plant factor for proportioning is to be found within this margin. The demand for an optimum factor may also be satisfied by an equivalence of the marginal benefits and costs.

In the above analyses, benefits and costs were considered given values without having their components discussed in detail.

There follows a brief on the benefit-cost structure as well as on the latter's influence on hydroplant efficiency.

14.5 STRUCTURES OF BENEFITS AND COSTS

This section provides a survey on the structure of benefits and costs of small-scale hydroplants. Here, special attention is attributed to the reference scope, as, depending on the extent of the analysis, different criteria will be applied.

Previous evaluation of economic efficiency was based on micro-economic analysis, which compared energy generation, expressed by the latter's price, to capital utilization and maintenance costs.

However, different evaluation criteria will be decisive, if evaluation of small-scale hydroplants is implemented on a regional or national level. Before proceeding to evaluation on a broadened basis, the structure of benefits and costs will be discussed on a micro-economic basis.

14.5.1 Micro-economic benefit structures

In the case of a micro-economic analysis of small-scale hydroplants, energy generation constitutes the benefit of small-scale hydroplants. A monetary assessment of energy depends on several aspects, with the form of energy utilization and temporal coincidence of consumption and generation being the most important ones.

Satisfaction of the private demand by means of the energy generated, deserves highest assessment. In this case delivery from elsewhere is substituted, and the energy generated may, approximatively, be adapted to the energy purchase price. Deviations may occur due to a potential restriction on the sector of supply-reliability.

Assessment for the same energy generated would, however, be lower, if the total amount is fed into the grid, that is, if producer and consumer are not identical. In this case, the tariff system with its tariff periods, which are subject to the seasons, as well as the tariff hours, which cover the demand fluctuations during the day, will be applied.

In Austria, tariff arrangements are up to the electricity-generating enterprises, which on their part, would obtain their guidelines from the tariff system of the Österreichische Verbundgesellschaft (Austrian National Grid Company). Assessment of electric energy from small-scale hydroplants by the Niederösterreichische Elektrizitätswerke AG (NEWAG,1980) (Electricity Supply Company of Lower Austria), will serve as an example here.

The number of feeding hours during high-tariff periods and hours, i.e. during week days between 6^{00} and 22^{00} hours, including, from April to September, Saturdays between 6^{00} and 13^{00} hours, will be decisive. Feeding hours result from the quotient of the active output fed during high-tariff periods and hours, and the established nominal capacity of the plant's generator.

high-tariff feeding hours	percentage of the grid working price
1200	50 %
2000	65 %
2500	80 %
3000	90 %
3000	100 %

Table 14.6 Assessment of the hydroplant feeding.

From this table one may see that special consideration is given to continual feeding. Nevertheless, preference is given to low plant factors which make constant feeding possible.

Due to the rising energy consumption, however, one should aim at a complete economic utilization of water-power (OBERLEITNER, 1981), which is feasible by means of increasing the plant factor.

For the assessment of the energy-generation of small-scale hydroplants, therefore, both aspects, efficient utilization of the water power as well as feeding reliability will be considered. Besides, the total contribution of small-scale hydroplants with consideration to the load duration curve of a grid shall be included into the assessment.

Observation of the total energy is advantageous, as fluctuations in discharge and, consequently, in energy generation of the individual plants may be compensated.

In considering very large regions one may realize a certain positive supplementation in the discharge conditions of the various catchment areas, which screws down the seasonal dependence of energy generation.

Utilization of the hydroplant, as well as availability of the established capacity, constitute a further important aspect of energy valency. The higher the plant factor, the more efficient is the utilization of the water resources. At the same time, availability of the capacity is restricted, which means a reduction of the energy valency. A measure to accomplish both targets is the temporary use of reservoirs, which makes an adaption to the day's fluctuations in energy demand possible. For long-term discharge balancing, large reservoirs are recommendable, such as have been built for irrigation purposes. Multipurpose utilization does not only allow an intensified reservoir utilization, but it also effects an essential rise in energy generation.

14.5.2 Micro-economic cost structures

Tables 14.2 and 14.4 show that the investment costs play a dominating role in the cost structure.

Investment costs consist of

- estate costs, water title costs and any potential redemption costs
- initial development costs at the project site, which means an additional burden
- costs for planning and installation management for the hydroplant and the supply grid
- transportation costs, which, in the case of remote project sites have to be considered at any rate, including sea freight, transportation, insurance, etc.
- installation costs for the whole plant
- costs for electric engineering equipment, including the local supply grid
- dues to the public authorities (customs duties, fees, etc.)
- interest coming due during the installation period
- Incidence costs to cover any unforeseen expenses

A generally applicable, quantitative determination of the various shares is extraordinarily difficult, as the specific situation at the project site and the latter's location within the project area influences the costs to a high degree. In this connection, reference is made to the Nepal case study sion (contribution No.16), where the transportation costs are responsible for a high share.

On the basis of several Austrian small-scale hydroplant projects as well as the ITG (1979) and MAYO (1980) data, the following may be considered to hold true:

electric engineering equipment	40-60 %
installation costs	40-50 %
planning and management	5-15 %
preliminary costs, interests, dues	5-10 %

Installation costs for energy distribution constitute an additional share, with a wide scope (10-35 %). The above shares show that, by means of standardizing electric engineering equipment, a significant reduction of the total costs may be achieved.

Object of this standardization is a well-graded type program, similar to that of manufacture units, which entails a good utilization of the water resources.

The generation costs consists of the following shares:

- o interest rate for the capital invested
- o depriciation for plant parts according to their economic life. In line with the LAWA Working Group's guidelines, the average economic life would be

for structural plant parts	60 years
for engineering parts of the plant	40 years
for electric plant parts	30 years
for estates	100 years

- o salaries for staff in charge of operation and supervision
- o costs for repairs and spare parts
- o costs for consumption material
- o current dues and administrational costs

As saving is possible especially with regard to the expenses for salaries and administration, a stepped-up plant automatization will be aimed at in case of new plant installations. Further cost reductions may be achieved by a joint operation and maintenance of small-scale hydroplants or by means of a combination of small-scale plants and small-scale industrial plants. The latter one is a most promising form of energy generation, as the energy generated is to be substituted for the financial expenses for supply from elsewhere and distribution costs as well as salary expenses would be low.

Bearing in mind these individual items as well as the specific circumstances in each country concerned, the production costs may now be assessed, to which the plant factor α has to be added.

$$\alpha = \frac{\text{kWh per year}}{8760 \cdot L} \qquad \text{(L installed capacity)}$$

Starting with the investment costs, we shall attempt to make a rough estimate of the annual cost shares. Interest payment accounts for the main share and is determined by the interest rate, i, and the amortization duration, T. In table 14.7 the annual rate is expressed in percentages of the investment costs.

	T = 50 years	T = 25 years
i = 6 %	6.3 %	7.8 %
i = 8 %	8.2 %	9.4 %
i = 10 %	10.1 %	11.0 %

Table 14.7 Annual payments in percentage of the investment costs

Annual costs for wages, operation and repairs are estimated at 1.5-2.0 %, while those for administration and other dues are 0.5-1.0 %. Interest payment, therefore, amounts to at least two thirds of the annual expenses.

With an accurate understanding for the cost structure, one may proceed to a comparison with caloric plants now. In the following we shall present an example in simplified form: Two small-scale plants with the same capacity and annual output, but with different economic life are to be compared on the basis of the Annual Costs Method, under consideration of the fuel costs.

	hydroplant	caloric plant
capacity	L	L
annual output	A	A
investment costs	I_w	I_k
specific costs	$i_w = I_w/L$	$i_k = I_k/L$
economic life	T_1	T_2
evaluation period	T_2	T_2
rest value	R_w	-
capital recovery factor (i, T)	WF	WF
modified capital recovery factor	WF_w	WF
maintenance and operation costs	$c_w \cdot A$	$c_k \cdot A$
fuel costs	-	e.K.A
duration of utilization	t_a	t_a

Table 14.8 Comparison of hydroelectric and caloric energy generation

The modified capital recovery factor comprises the rest value of the plant after T_2 years, K denotes the specific fuel costs and e accounts for the specific consumption. Suppose, the maintenance costs, c, are approximately the same, which will hold true to a limited degree only, the following will apply:

$$I_w.WF_w + c_w.A \leq I_k.WF + c_k.A + e.K.A$$

$$i_w.WF_w + c_w.t_a \leq i_k.WF + c_k.t_a + e.K.t_a \qquad (6)$$

$$i_w.WF_w \leq i_k.WF + e.K.t_a$$

14.5.3 Macro-economic costs structure

In the above assessment benefits and costs were expressed in monetary terms, with quantification according to the market situation. That is, all actions T (investments) influence the environment through the market and, on the analogy of this, prices are oriented at the market.

Additional effects, which were not comprised in the assessment form the entrepreneur's viewpoint, will be included in this chapter.

Evaluation bases, therefore, will change, and, in special cases, yield evaluation findings which are different from those of the micro-economic evaluation.

We must also differentiate between an analysis on the regional or national level. For illustration purposes, we shall describe both forms by means of a few catchwords.

On a regional level, the following criteria are of significance:

- o share of the investment costs brought to bear in that region
- o number of jobs created by the installation and operation of the plants
- o number of jobs created in consequence, e.g. by the installation of small-scale industrial plants
- o energy share to be utilized in that region, substituting energy from elsewhere
- o improvement of the infrastructure
- o improvement and balancing of the income and social structure within that region

Some of the quoted items may be quantified and explained by means of the multiplier effect of investments. Others, like improvement of infrastructure or the modified social structure, whose evaluation is described by BARTELS, are hard to quantify, or may be characterized in a qualitative way only.

On a national level, other aspects are in the foreground, as are briefly enumerated here:

- o For political economy, the multiplier effect of small-scale hydroplant construction

- o Relief of the trade balance by means of substitution of energy imports
- o Increased national supply reliability by means of utilization of domestic resources
- o Compensation of interregional differences in development and income
- o Improvement of the infrastructure
- o Improvement or consolidation of environmental quality

These items show evidently that one should not necessarily strive for a maximization of output, but that the general benefit, namely social welfare, ought to be the considered the main target of governmental undertakings.

According to comprehensive literature, reference is made to the studies of HOWE (1971) and DOE (1979), where special consideration is given to measures of water resources policy.

14.5.4 Macro-economic costs structure

For a regional as well as national assessment, costs are equally treated and consist of the following shares:

- o Design costs and other preliminary expenses include all costs, falling due before the project proper. Appointment of design groups, training of operation and maintenance staff as well as any potential measures concerning infrastructure, etc, would rank among these costs.
- o Construction and equipment costs. Here, major attention must be paid to financing by means of domestic or foreign capital, exchange rates and long-term interest levels, (shadow exchange-rates, shadow interest rates)
- o Operation and maintenance costs. Frequently, the current wage statements would fail to reflect the production factor of labour in a correct way. If, primarily, unemployed people and parttime workers are used for the implementation of a project, this will cause only small production losses on other production sectors of national economy, or none at all.
- o Opportunity costs, which make allowances for the slipped benefit in case of alternative use of the applied means.
- o Social and consequent costs cover the costs for the installation and operation of social utilities and improvements on the infrastructure sector, additionally caused by the project.
- o Allocated costs must be envisaged in case of multipurpose plants. As this item is of high significance for small-scale hydroplants, whose installation, in combination with projects of river engineering or water economy is highly recommendable, a simple example will be presented in 14.5.5.

Further cost shares may be caused on the grounds of encroachments or damages to the environment, which, however, is to be considered rather negligible in the case of small-scale power plants. This comparison of micro- and macro-economic factors clearly brings to the foreground the different decision bases. On the analogy of this, other techniques of decision finding, too, are being applied, which are discussed in 14.6.

14.5.5 Costs allocation in multipurpose projects

From an economic point of view, the use of multipurpose projects of water economy is highly promising, as cost sharing is possible with regard to planning, installation and further maintenance. This viewpoint bears high significance for Austria, where said combination of flood control measures (reservoirs, regulating devices) and small-scale hydroplants may be applied, as well as for non-European countries, which may, additionally, include irrigation projects, fish breeding, supply reservoirs, etc. As such a kind of planning would frequently affect different institutions and ministerial divisions, allocation of costs, according to their targets, will become necessary. LOUGHIN (1978) provides a description and analysis of the individual allocation techniques.

One of the above techniques will be presented by means of a simplified example, where flood control, an irrigation project and a small-scale hydroplant have their shares in the total project costs.

The Alternative Justifiable Expenditure Method at first compares the total project with the individual projects and, thereafter, allocates the individual shares to each project. These shares consist of the specific costs and the allocated costs, which are calculated in proportion to the individual share in the total benefit.

A water-related project has three objectives:

- o A, to improve flood control in that region
- o B, to irrigate a cultivated area
- o C, to generate energy for supplying an adjacent village

All values, transformed into annual payments, are figured in tab. 14.8.

	OBJECTIVES			
	A	B	C	Σ
1 Benefits from the objectives	o.8	5.8	4.2	1o.8
2 Alternative costs at the individual project	1.o	4.6	3.7	9.3
3 Justifiable costs	o.8	4.6	3.7	9.1
4 Specific costs	o.4	1.9	1.8	4.1
5 Remaining benefits (3-4)	o.4	2.7	1.9	5.o
6 Adjoint costs of the targets	o.19	1.3	o.91	2.4
7 Total costs of the targets (4+6)	o.59	3.2	2.71	6.5
8 Cost savings in percentage	8 %	54 %	38 %	1oo %

Table 14.9 Cost allocation in multipurpose projects in million Schillings per year

The benefits for the objectives A, B and C may be quantified, as are the total costs of the multipurpose project and the alternative costs in case of realization as an individual project. The costs shares (line 4) definitely reflect the cost shares to be allocated, while the rest, corresponding to the remaining benefit (line 5) is distributed to the targets.

14.6 ECONOMIC EFFICIENCY IN CASE OF AN EXTENDED EVALUATION SCOPE

Innumerous techniques are suitable for decision finding, which means the selection of one project from various other projects or the determination of the economic efficiency of a certain project. The hitherto described techniques, the Present Worth Method, the Annual Costs Method, Benefit-Costs Method, as well as the Rate of Return Method are applicable, if benefits and costs may be determined in monetary terms. Sensitivity and Risk Analysis offer extended opportunities.

14.6.1 Extended Benefit-Cost Analysis

If one can manage, even in the face of an extended assessment scope, to quantify all effects a measure has on national economy and, additionally to assess them in monetary terms, the cost-benefit analysis will be applicable also in future. This technique will solely assess the benefit of an investment for national economy.

Even if the analysis is carried out most thoroughly, government objectives like "general welfare" may, only to a limited extent, be assessed in monetary terms. Thus the application limits for this method are set.

14.6.2 Evaluation and decision in view of several objectives

Assessment of a project requires an accurate definition of the target aimed at. Thereafter one may find out, to what degree the various alternatives would come up to the set target. The degree to which a target would be accomplished, will be the basis for decision.

In case of a large-scale water-economy project, i.e. utilization of an extensive river system for energy production, several targets have to be accomplished, which, according to the design principles of the WRC (1973) may be classified into four main groups.

If "general welfare" is the objective, the

- o national economic development
- o regional structure and development
- o social situation
- o environmental situation

must be included into the evaluation. With each large-scale project the objectives, in correspondence to the above categories, are to be formulated in detail, and, if possible, quantified. If the measuring systems are irreconcilable, the effects of the project alternatives on the individual targets are to be examined. Eventually, the criteria for an accomplishment of the objective may be determined and balanced against each other.

Benefit Value Analysis and Cost Efficiency Analysis are suitable techniques, which are recommendable if benefit is hard to quantify. These analyses provide an extensive objectivation of the assessment and decision process, without anticipating the latter. It is merely possible to indicate the interaction of the objectives, and to exclude any unfavourable alternatives. Only by means of establishing a preference structure or a hierarchical classification of the targets, a selection of the individual alternatives is possible.

Even if these methods will still be discussed in detail and new techniques introduced, the above instruments offer designers the opportunity to arrive, in an operational way, at an assessment, which does not only take into account economic efficiency but also other, additional aspects of a measure.

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14 ECONOMIC EFFICIENCY
WIRTSCHAFTLICHKEIT

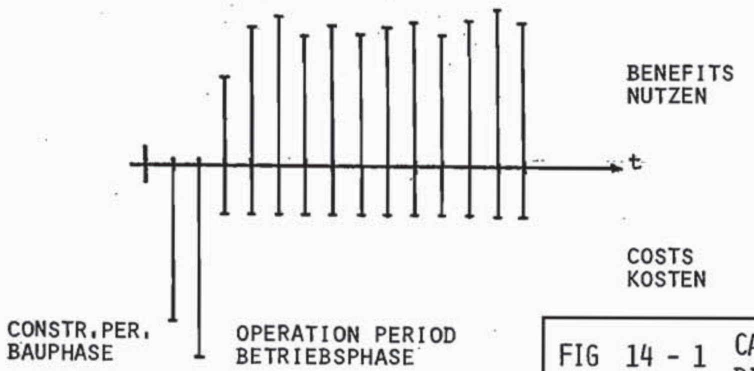

FIG 14 - 1 CASH FLOW DIAGRAM
DIAGRAMM DER ZAHLUNGSSTRÖME

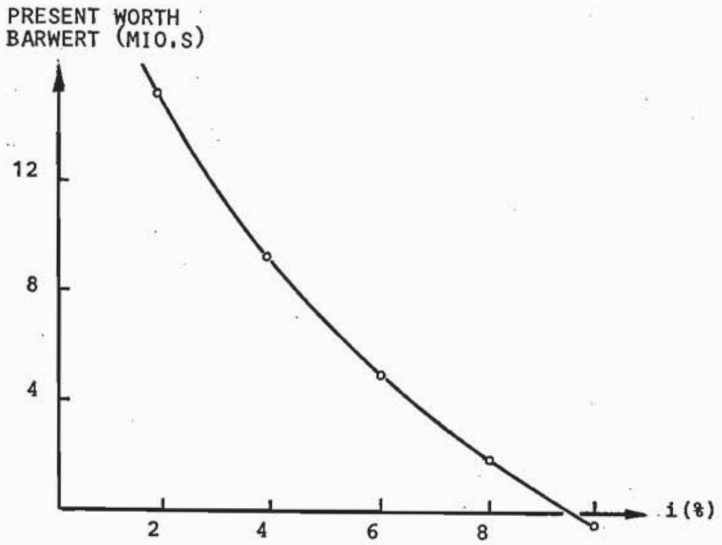

FIG 14 - 2 RATE OF RETURN METHOD
METHODE DES INT.ZINSFUSSES

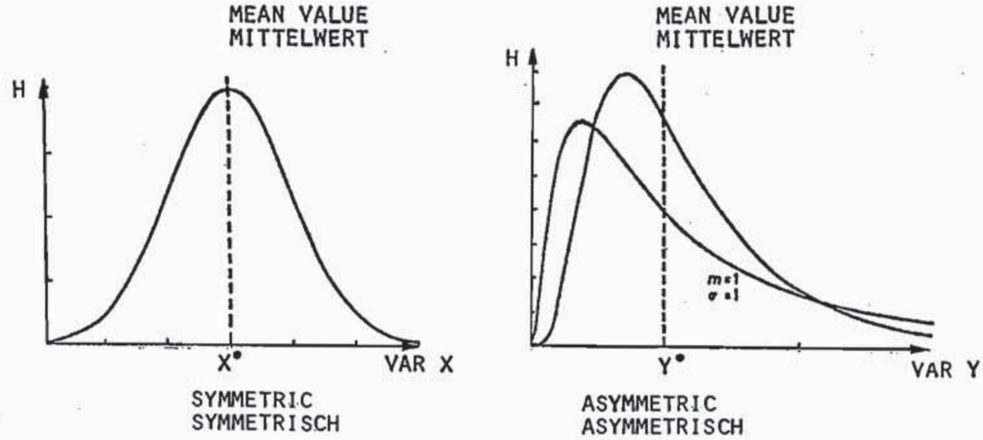

FIG 14 - 3 PROBABILITY DENSITY FUNCTION
WAHRSCHEINLICHKEITSDICHTE

14 ECONOMIC EFFICIENCY
WIRTSCHAFTLICHKEIT

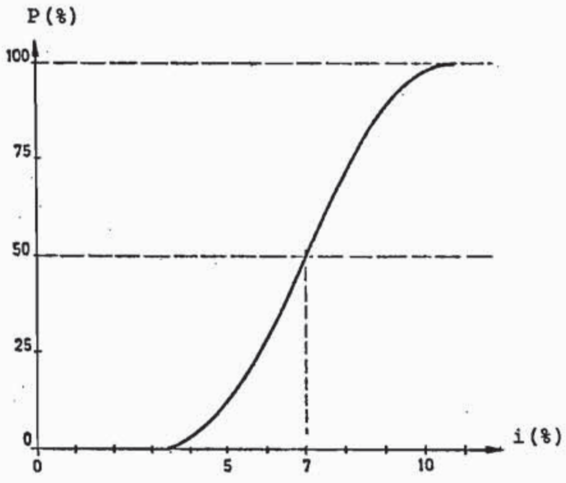

FIG 14 - 4 PROBABILITY OF INT.DISCOUNT RATES
WAHRSCHEINLICHKEIT INT. ZINSSÄTZE

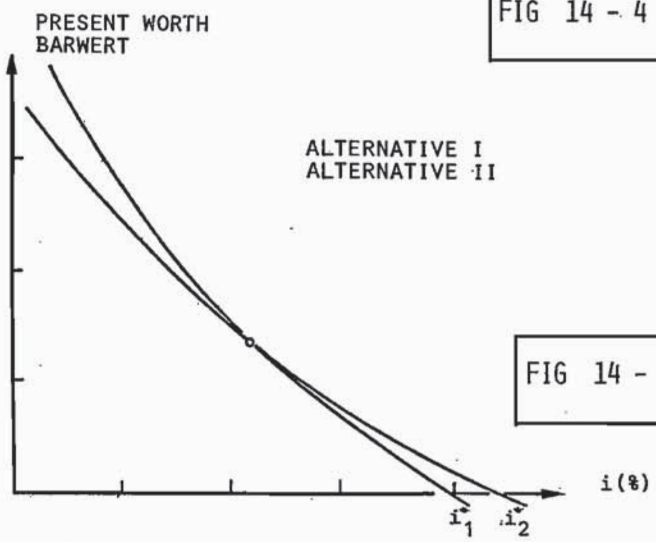

FIG 14 - 5 PRESENT WORTH VS. INTEREST RATE
BARWERT VS. ZINSSATZ

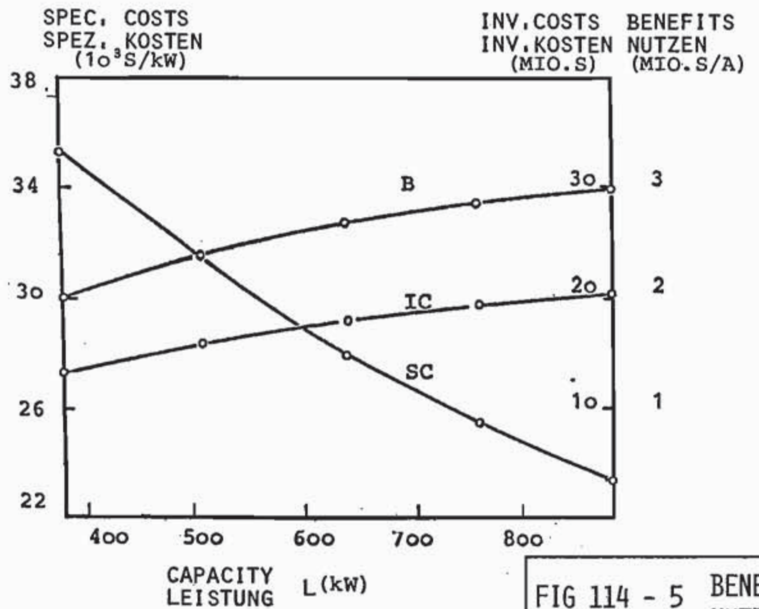

FIG 114 - 5 BENEFITS AND COSTS VS.CAPACITY
NUTZEN UND KOSTEN VS.LEISTUNG