PORTELA, M. M., 2000, "Chapter 10 - Economic analysis" *in* RAMOS, H. (ed.) *Guidelines for the design of small hydropower plants*, pp. 167 190, CEHIDRO/WREAN/DED, ISBN 972 96346 4 5, Irlanda.

# 10

# ECONOMIC ANALYSIS Maria Manuela Portela

## 8.1- Introduction. Costs and benefits

The decision on whether or not a small hydropower scheme should be constructed or the choice among alternative design solutions for the same are generally based on the comparison of the expected costs and benefits for the useful life of the project, by means of economic analysis criteria. This analysis should be performed in the first stages of the design (as soon as the feasibility study) as nothing ensures that a project suitable from a technical point of view it is also advantageous from an economic point of view.

It should be pointed out that the choice among alternative solutions having identical benefits is simply accomplished by identifying which one has the lower cost. Only the comparison of alternative projects or design solutions with different costs and benefits requires the application of economic criteria in order to identify the most desirable alternative.

The effectiveness of the economic analysis as a decision tool of the investor depends on the accuracy of the project cost and benefits estimates. These estimates are not easy to reach, especially in the first stages of design where some of the scheme characteristics are only preliminary defined.

The costs of a small hydropower scheme can be grouped in the three following categories, also systematised in Table 8.1:

- The capital cost that may be defined as the sum of all expenditures required to bring the project to completion. These costs occur during the construction period (generally, from one to three years).
- The annual operation costs resulting from the exploitation and maintenance of the scheme during its useful live.
- The reposition costs concerning to the substitution of the equipment having a useful live lesser than the one of the scheme.

Table 8.1 – Costs of a small hydropower scheme

| | |
|---|---|
| Capital costs | Studies and design<br>Supervision during the execution<br>Civil works<br>Equipment<br>Land acquisition<br>Contingencies or unforeseen cost |
| Annual operation costs | Exploitation<br>Maintenance<br>Spare parts<br>Grant of permission |
| Reposition costs | |

The following items should generally be considered within the capital costs – Table 8.1:

- Studies and design.
- Supervision during the execution.
- Civil works (including access roads and building site facilities).
- Equipment (including hydromechanical, electromechanical and electrical equipment and the interconnection to the electrical grid).
- Land acquisition.

It should also be considered an item for contingencies or unforeseen cost. This item represents expenditures that are possible but not certain or yet foreseen. For instances, this item intends to overcome the uncertainty that result from the fact that the characteristics of the site where the scheme is going to be constructed are not totally known, especially in the first design phases and, so, they may be incompletely expressed in the scheme conception. The uncertainty under consideration is mainly related with the civil works and can result, for instances, from excavation or landing works undervalued or from bedrock having characteristics worse than those foreseen in the design.

The studies and design costs and the supervision costs during the scheme execution result from agreements between the investor and consulting firms. If the investor has previous experience in the execution of small hydropower schemes, he should be able to express the costs under consideration as a percentage of the civil works and equipment costs.

The civil work costs are evaluated from the design, by measuring the work quantities relative to the different components of the scheme and affecting them of unit prices, which generally are not difficult to obtain from each country civil work contractors market. To evaluate the equipment costs budget prices from the suppliers should also be obtained.

The cost of the acquisition (or renting) of the land that will be occupied by the scheme (including accesses and the area that will be submerged by the scheme reservoir) depends strictly on the land valorisation in each country.

If possible, the capital costs estimated to the hydropower scheme under study should be compared with the ones of similar schemes, already built or previously characterised. This procedure is more important in what concerns the evaluation of the equipment cost as frequently it is not possible to get budget prices from the suppliers in a period as short as the design one.

The annual operation costs include the following main components – Table 8.1:

- Exploitation.
- Maintenance.
- Spare parts.
- Grant of permission or legal permit.

The exploitation costs represent the charges with the staff responsible for the scheme operation. To reduce these costs the scheme should be made automatic, that is to say, explored in an abandon mode. This kind of exploitation requires additional equipment (for instances, telephone or satellite lines for telemetry and alarm signals).

The maintenance costs include two parcels, related one with the civil works and the other, with the equipment. The former in generally the smallest representing from 0,25% to 0,50% of the capital costs in civil woks, while the latter can reach about 2,50% of the respective capital costs.

The spare parts costs are the costs with the reposition of the material that is necessary to keep in stock in order to perform the maintenance of the hydropower scheme or to execute small repairs in the same. These costs can be assigned to annual costs or to costs without periodicity, occurring whenever it is necessary to restore the stock of the material.

The grant of permission costs occur once the scheme starts to operate and represent the annual payments due for the scheme license and for the water utilisation. Although these costs result from the legislation in force in each country, in terms of economic appraisal they can be treated as fixed percentages of the energy incomes.

From the investor point of view, the only tangible revenue or benefit in a small hydropower scheme is the annual income with the energy production sale. This income depends on the amount of energy produced during the scheme lifetime and on the specific conditions that rule the hydroelectric sector, namely the energy sale contract conditions and the tariffs policy, which are specific in each country.

In the further development of this chapter it will be assumed that the purchase of the energy produced in a small hydropower scheme is ensured, no matter the amount and the characteristics of the production. This scenario should be real as it translates the special rule that the renewable energies are expected to play in the energetic policy, not only of Europe, but also of the world.

The evaluation of the energy production requires accurate hydrological studies based on specific methodologies that overcome the non-existence of basic hydrological data that characterises most of the small hydropower schemes, generally located in small and ungauged watersheds. The results of the hydrological study have to be interpreted taking into account the characteristics of the watershed that condition the water availability and regime at the water intake of the scheme: watershed geology, vegetation covering, land utilisation, water consumption, existing upstream storage reservoirs, ecological requirements.

As the energy production that will result from the future inflows at the scheme water intake can not be specify, the revenues in the economic analysis are considered to be fixed during the lifetime of the project and based on a annual long-term average discharge of the river. By other words, the revenues are generally defined on the basis of an annual production constant and equal to the expected mean one, $\overline{E}$ .

The uncertainty concerning the future inflows and, thus, concerning the future energy productions, can be regard as a hydrologic risk. Based on the statistic analysis of the historic flow series, this risk can be expressed, for instances, in terms of the probability of occurring future periods of dry years or of years with annual flows bellow a limit. This kind of analysis is most important and should be performed in countries, as those of south Europe, characterised by an irregular flow regime where dry periods of several years can occur.

Based on simulation studies, PORTELA and ALMEIDA, 1995, carried out hydrologic risk analysis for several hypothetical small hydropower schemes located in the North of Portugal. This analysis clearly show that the profitability of those schemes could be drastically reduced if periods of dry years occur, specially in the first years of exploitation, when the incomes are crucial for the capital recovery.

Figure 8.1 represents some of the results achieved by those authors. The cost factor, $\lambda$, was defined as the ratio between the income under real flow conditions and the income evaluated on the basis of an annual production constant and equal to the mean annual production. Two exploitation periods where considered: one with 33 years and the other with only 10 years. Based on real flow data, simulation studies were performed in order to evaluate the maximum (best series) and the minimum (worst series) incomes during each of the previous periods. The results thus achieved were represented as a function of the ratio between the design flow, Qmax, and the average mean daily flow, Qave.

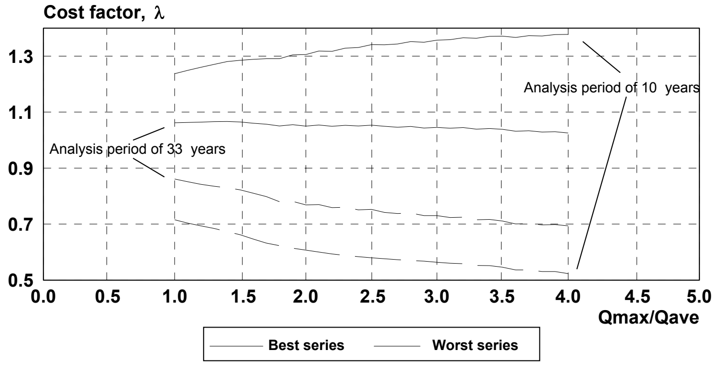


Figure 8.1 – Variation of the income in a hypothetical small hydropower scheme, located in the North of Portugal, due to the natural variability of the flow regime (PORTELA and ALMEIDA, 1995)

## 8.2- Economic analysis

### 8.2.1- Introduction

In this item some concepts necessary to the economic analysis or appraisal of small hydropower schemes are presented in a simple and straight way.

Several literature references are available either in general terms of economic and financial analysis principles and applications (which are far beyond the scope of this Guide) or in specific terms for small hydropower schemes. Among these last ones KUIPER, 1981, ESHA, 1994 and 1997, and JIANDONG *et al.*, 1996, may also have interest in the domain of the present chapter.

### 8.2.2- Constant market prices system concept

Although the design of a small hydropower scheme generally foresees a schedule for the investment costs and revenues, the respective estimates are based on market prices referred to a given year, the one during which the studies were performed. The evolution of the inflation during the project lifetime and its effect on each component of the previous cost estimates is practically impossible to establish.

So, one could say that one of the main problems of the economic analysis in to conceive a scenario for the future evolution of the inflation. To overcome this problem a common and simple economic approach based on a constant market prices system referred to a given year is generally applied in the comparison of costs and benefits either of a project or of alternative design solutions for the same. This approach, which will be adopted in the present chapter, assumes that it is not necessary to account for the inflation, as it will have the same effect in any monetary flux. The future costs and benefits are, then, evaluated at present market prices.

### 8.2.3- Discount rate and present value concept

A same monetary unit (for instances, a pound or a dollar) is more worthy in the present that in the future. By other words, the future value of the monetary flux that has a present value of one unit will be great then one. At the same time, the present value of a future unitary monetary flux will be lesser than one.

Through the years, this situation generates different “appetencies” to transfer money from the present to the future and vice-verse. Theses “appetencies” can be expressed in terms of different **discount rates**, r. The values of these rates depend, among other factors, on the state of the economy, on the risk that involves the investment, the capital availability and on the expected future rate of inflation.

Let n denote a period of n years, from year 1 to year n. According to the discount rate concept and as represented in Figure 8.2, one monetary unit of today will be change in year n by $(1+r)^n$ monetary units and one monetary unit of year n will be change today by $1/(1+r)^n$ units. If r is defined, not on a yearly basis, but for a generic period of time $\alpha$, n will denote the total number of $\alpha$ periods between the two monetary fluxes of Figure 8.2.

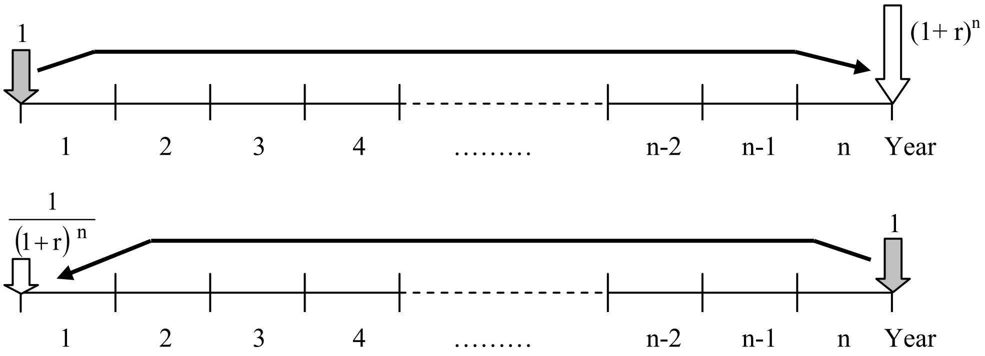


Fig. 8.2 – Transference of unitary monetary fluxes by means of the discount rate, r.

The factor $\frac{1}{(1+r)^n}$ that expresses the depreciation suffered by future monetary fluxes when transferred to the present is call **present worth or value factor**. According to this concept, the **present value**, PV, of a single generic monetary flux occurring in future year i, $C_i$, is given by

$$PV = \frac{1}{(1+r)^i} C_i \qquad (8.1)$$

The present value for the beginning of year 1 of the continuous sequence of annual monetary fluxes represented in Figure 8.3 is given by

$$PV = \frac{1}{(1+r)} C_1 + \frac{1}{(1+r)^2} C_2 + \cdots + \frac{1}{(1+r)^i} C_i + \cdots + \cdots + \frac{1}{(1+r)^{(n-1)}} C_{n-1} + \frac{1}{(1+r)^n} C_n \qquad (8.2)$$

$$PV = \sum_{i=1}^{n} \frac{1}{(1+r)^i} C_i \qquad (8.3)$$

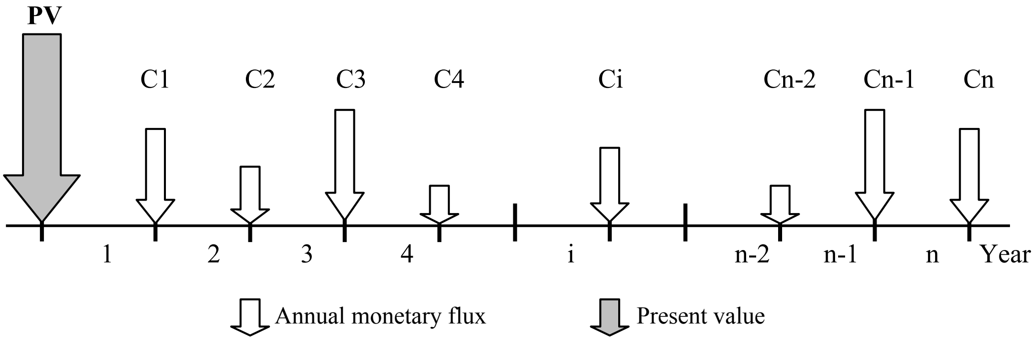


Fig. 8.3 – Continuos sequence of monetary fluxes.

For economical analysis purpose the monetary fluxes are grouped in periods (generally years) and are considered to occur as represented in Figure 8.3, that is to say, concentrated in the end of each of those periods. The present value operations are performed for the beginning of the year adopted as reference (year one in the previous figure).

If the monetary fluxes of Figure 8.3 are constant and equal to an annuity, C, – uniform series of annual monetary fluxes – the following relation is achieved for the respective present value referred to the beginning of year 1:

$$PV = C\sum_{i=1}^{n}\frac{1}{(1+r)^{i}} = C\frac{(1+r)^{n}-1}{(1+r)^{n}\,r} \qquad (8.4)$$

where $\frac{(1+r)^{n}-1}{(1+r)^{n}\,r}$ is the **present worth factor for uniform series**. The inverse of this factor is denoted by capital-recovery factor.

The present worth factor either for a single monetary flux or for a series of uniform monetary fluxes is generally provided by tables as the ones presented in next pages, which can be found in most books dealing with economic analysis concepts.

The factor $(1+r)^n$ represented in the first part of Figure 8.2 is the capitalisation factor or the future value factor. Table 8.2 also includes its value either for a single monetary flux or for an uniform series of monetary fluxes. The formula that provides the future value factor for an uniform series of monetary fluxes is given by $\left[\frac{(1+r)^n - 1}{r}\right]$. The inverse of the previous ratio is the **sinking-fund factor**.

Although the computation of the previous factors does not offer special difficulty it is useful to provide tables as those included herein in order to allow expedite evaluations or to control results of the economic appraisal.

It should be pointed out that the expressions and concepts presented so far, as well as their development and application in the rest of this chapter, assume that the discount rate, r, is constant during the n years period under analysis. If this is not the situation, different sub periods having different discount rates should be considered. However, this is not a common procedure in the economic analysis of small hydropower schemes.

Table 8.2 (1/4) – Values of the present worth factor and of the capitalisation factor for different time periods, n, and discount rates, r

a1) Present worth factor for single monetary fluxes $\left[\dfrac{1}{(1+r)^{n}}\right]$

| Time Period, n | Discount rate, r, of: | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2% | 4% | 6% | 8% | 10% | 12% | 14% |
| 1 | 0,98039 | 0,96154 | 0,94340 | 0,92593 | 0,90909 | 0,89286 | 0,87719 |
| 2 | 0,96117 | 0,92456 | 0,89000 | 0,85734 | 0,82645 | 0,79719 | 0,76947 |
| 3 | 0,94232 | 0,88900 | 0,83962 | 0,79383 | 0,75131 | 0,71178 | 0,67497 |
| 4 | 0,92385 | 0,85480 | 0,79209 | 0,73503 | 0,68301 | 0,63552 | 0,59208 |
| 5 | 0,90573 | 0,82193 | 0,74726 | 0,68058 | 0,62092 | 0,56743 | 0,51937 |
| 6 | 0,88797 | 0,79031 | 0,70496 | 0,63017 | 0,56447 | 0,50663 | 0,45559 |
| 7 | 0,87056 | 0,75992 | 0,66506 | 0,58349 | 0,51316 | 0,45235 | 0,39964 |
| 8 | 0,85349 | 0,73069 | 0,62741 | 0,54027 | 0,46651 | 0,40388 | 0,35056 |
| 9 | 0,83676 | 0,70259 | 0,59190 | 0,50025 | 0,42410 | 0,36061 | 0,30751 |
| 10 | 0,82035 | 0,67556 | 0,55839 | 0,46319 | 0,38554 | 0,32197 | 0,26974 |
| 11 | 0,80426 | 0,64958 | 0,52679 | 0,42888 | 0,35049 | 0,28748 | 0,23662 |
| 12 | 0,78849 | 0,62460 | 0,49697 | 0,39711 | 0,31863 | 0,25668 | 0,20756 |
| 13 | 0,77303 | 0,60057 | 0,46884 | 0,36770 | 0,28966 | 0,22917 | 0,18207 |
| 14 | 0,75788 | 0,57748 | 0,44230 | 0,34046 | 0,26333 | 0,20462 | 0,15971 |
| 15 | 0,74301 | 0,55526 | 0,41727 | 0,31524 | 0,23939 | 0,18270 | 0,14010 |
| 16 | 0,72845 | 0,53391 | 0,39365 | 0,29189 | 0,21763 | 0,16312 | 0,12289 |
| 17 | 0,71416 | 0,51337 | 0,37136 | 0,27027 | 0,19784 | 0,14564 | 0,10780 |
| 18 | 0,70016 | 0,49363 | 0,35034 | 0,25025 | 0,17986 | 0,13004 | 0,09456 |
| 19 | 0,68643 | 0,47464 | 0,33051 | 0,23171 | 0,16351 | 0,11611 | 0,08295 |
| 20 | 0,67297 | 0,45639 | 0,31180 | 0,21455 | 0,14864 | 0,10367 | 0,07276 |
| 21 | 0,65978 | 0,43883 | 0,29416 | 0,19866 | 0,13513 | 0,09256 | 0,06383 |
| 22 | 0,64684 | 0,42196 | 0,27751 | 0,18394 | 0,12285 | 0,08264 | 0,05599 |
| 23 | 0,63416 | 0,40573 | 0,26180 | 0,17032 | 0,11168 | 0,07379 | 0,04911 |
| 24 | 0,62172 | 0,39012 | 0,24698 | 0,15770 | 0,10153 | 0,06588 | 0,04308 |
| 25 | 0,60953 | 0,37512 | 0,23300 | 0,14602 | 0,09230 | 0,05882 | 0,03779 |
| 26 | 0,59758 | 0,36069 | 0,21981 | 0,13520 | 0,08391 | 0,05252 | 0,03315 |
| 27 | 0,58586 | 0,34682 | 0,20737 | 0,12519 | 0,07628 | 0,04689 | 0,02908 |
| 28 | 0,57437 | 0,33348 | 0,19563 | 0,11591 | 0,06934 | 0,04187 | 0,02551 |
| 29 | 0,56311 | 0,32065 | 0,18456 | 0,10733 | 0,06304 | 0,03738 | 0,02237 |
| 30 | 0,55207 | 0,30832 | 0,17411 | 0,09938 | 0,05731 | 0,03338 | 0,01963 |
| 35 | 0,50003 | 0,25342 | 0,13011 | 0,06763 | 0,03558 | 0,01894 | 0,01019 |
| 40 | 0,45289 | 0,20829 | 0,09722 | 0,04603 | 0,02209 | 0,01075 | 0,00529 |
| 45 | 0,41020 | 0,17120 | 0,07265 | 0,03133 | 0,01372 | 0,00610 | 0,00275 |
| 50 | 0,37153 | 0,14071 | 0,05429 | 0,02132 | 0,00852 | 0,00346 | 0,00143 |
| 60 | 0,30478 | 0,09506 | 0,03031 | 0,00988 | 0,00328 | 0,00111 | 0,00039 |
| 70 | 0,25003 | 0,06422 | 0,01693 | 0,00457 | 0,00127 | 0,00036 | 0,00010 |
| 80 | 0,20511 | 0,04338 | 0,00945 | 0,00212 | 0,00049 | 0,00012 | 0,00003 |
| 90 | 0,16826 | 0,02931 | 0,00528 | 0,00098 | 0,00019 | 0,00004 | 0,00001 |
| 100 | 0,13803 | 0,01980 | 0,00295 | 0,00045 | 0,00007 | 0,00001 | 0,00000 |

Table 8.2 (2/4) – Values of the present worth factor and of the capitalisation factor for different time periods, n, and discount rates, r

a2) Present worth factor for uniform monetary fluxes $\left[\dfrac{(1+r)^n - 1}{(1+r)^n\ r}\right]$

| Time period, n | Uniform series of monetary fluxes and discount rate, r, of: | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2% | 4% | 6% | 8% | 10% | 12% | 14% |
| 1 | 0,98039 | 0,96154 | 0,94340 | 0,92593 | 0,90909 | 0,89286 | 0,87719 |
| 2 | 1,94156 | 1,88609 | 1,83339 | 1,78326 | 1,73554 | 1,69005 | 1,64666 |
| 3 | 2,88388 | 2,77509 | 2,67301 | 2,57710 | 2,48685 | 2,40183 | 2,32163 |
| 4 | 3,80773 | 3,62990 | 3,46511 | 3,31213 | 3,16987 | 3,03735 | 2,91371 |
| 5 | 4,71346 | 4,45182 | 4,21236 | 3,99271 | 3,79079 | 3,60478 | 3,43308 |
| 6 | 5,60143 | 5,24214 | 4,91732 | 4,62288 | 4,35526 | 4,11141 | 3,88867 |
| 7 | 6,47199 | 6,00205 | 5,58238 | 5,20637 | 4,86842 | 4,56376 | 4,28830 |
| 8 | 7,32548 | 6,73274 | 6,20979 | 5,74664 | 5,33493 | 4,96764 | 4,63886 |
| 9 | 8,16224 | 7,43533 | 6,80169 | 6,24689 | 5,75902 | 5,32825 | 4,94637 |
| 10 | 8,98259 | 8,11090 | 7,36009 | 6,71008 | 6,14457 | 5,65022 | 5,21612 |
| 11 | 9,78685 | 8,76048 | 7,88687 | 7,13896 | 6,49506 | 5,93770 | 5,45273 |
| 12 | 10,57534 | 9,38507 | 8,38384 | 7,53608 | 6,81369 | 6,19437 | 5,66029 |
| 13 | 11,34837 | 9,98565 | 8,85268 | 7,90378 | 7,10336 | 6,42355 | 5,84236 |
| 14 | 12,10625 | 10,56312 | 9,29498 | 8,24424 | 7,36669 | 6,62817 | 6,00207 |
| 15 | 12,84926 | 11,11839 | 9,71225 | 8,55948 | 7,60608 | 6,81086 | 6,14217 |
| 16 | 13,57771 | 11,65230 | 10,10590 | 8,85137 | 7,82371 | 6,97399 | 6,26506 |
| 17 | 14,29187 | 12,16567 | 10,47726 | 9,12164 | 8,02155 | 7,11963 | 6,37286 |
| 18 | 14,99203 | 12,65930 | 10,82760 | 9,37189 | 8,20141 | 7,24967 | 6,46742 |
| 19 | 15,67846 | 13,13394 | 11,15812 | 9,60360 | 8,36492 | 7,36578 | 6,55037 |
| 20 | 16,35143 | 13,59033 | 11,46992 | 9,81815 | 8,51356 | 7,46944 | 6,62313 |
| 21 | 17,01121 | 14,02916 | 11,76408 | 10,01680 | 8,64869 | 7,56200 | 6,68696 |
| 22 | 17,65805 | 14,45112 | 12,04158 | 10,20074 | 8,77154 | 7,64465 | 6,74294 |
| 23 | 18,29220 | 14,85684 | 12,30338 | 10,37106 | 8,88322 | 7,71843 | 6,79206 |
| 24 | 18,91393 | 15,24696 | 12,55036 | 10,52876 | 8,98474 | 7,78432 | 6,83514 |
| 25 | 19,52346 | 15,62208 | 12,78336 | 10,67478 | 9,07704 | 7,84314 | 6,87293 |
| 26 | 20,12104 | 15,98277 | 13,00317 | 10,80998 | 9,16095 | 7,89566 | 6,90608 |
| 27 | 20,70690 | 16,32959 | 13,21053 | 10,93516 | 9,23722 | 7,94255 | 6,93515 |
| 28 | 21,28127 | 16,66306 | 13,40616 | 11,05108 | 9,30657 | 7,98442 | 6,96066 |
| 29 | 21,84438 | 16,98371 | 13,59072 | 11,15841 | 9,36961 | 8,02181 | 6,98304 |
| 30 | 22,39646 | 17,29203 | 13,76483 | 11,25778 | 9,42691 | 8,05518 | 7,00266 |
| 35 | 24,99862 | 18,66461 | 14,49825 | 11,65457 | 9,64416 | 8,17550 | 7,07005 |
| 40 | 27,35548 | 19,79277 | 15,04630 | 11,92461 | 9,77905 | 8,24378 | 7,10504 |
| 45 | 29,49016 | 20,72004 | 15,45583 | 12,10840 | 9,86281 | 8,28252 | 7,12322 |
| 50 | 31,42361 | 21,48218 | 15,76186 | 12,23348 | 9,91481 | 8,30450 | 7,13266 |
| 60 | 31,72839 | 21,57725 | 15,79217 | 12,24336 | 9,91810 | 8,30561 | 7,13304 |
| 70 | 31,97842 | 21,64146 | 15,80910 | 12,24793 | 9,91936 | 8,30597 | 7,13315 |
| 80 | 32,18353 | 21,68485 | 15,81855 | 12,25005 | 9,91985 | 8,30609 | 7,13317 |
| 90 | 32,35179 | 21,71416 | 15,82383 | 12,25104 | 9,92004 | 8,30612 | 7,13318 |
| 100 | 32,48982 | 21,73396 | 15,82678 | 12,25149 | 9,92011 | 8,30614 | 7,13318 |

Table 8.2 (3/4) – Values of the present worth factor and of the capitalisation factor for different time periods, n, and discount rates, r

b1) Capitalisation factor for single monetary fluxes $\left[(1+r)^{n}\right]$

| Time Period, n | Discount rate, r, of: | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2% | 4% | 6% | 8% | 10% | 12% | 14% |
| 1 | 1,02000 | 1,04000 | 1,06000 | 1,08000 | 1,10000 | 1,12000 | 1,14000 |
| 2 | 1,04040 | 1,08160 | 1,12360 | 1,16640 | 1,21000 | 1,25440 | 1,29960 |
| 3 | 1,06121 | 1,12486 | 1,19102 | 1,25971 | 1,33100 | 1,40493 | 1,48154 |
| 4 | 1,08243 | 1,16986 | 1,26248 | 1,36049 | 1,46410 | 1,57352 | 1,68896 |
| 5 | 1,10408 | 1,21665 | 1,33823 | 1,46933 | 1,61051 | 1,76234 | 1,92541 |
| 6 | 1,12616 | 1,26532 | 1,41852 | 1,58687 | 1,77156 | 1,97382 | 2,19497 |
| 7 | 1,14869 | 1,31593 | 1,50363 | 1,71382 | 1,94872 | 2,21068 | 2,50227 |
| 8 | 1,17166 | 1,36857 | 1,59385 | 1,85093 | 2,14359 | 2,47596 | 2,85259 |
| 9 | 1,19509 | 1,42331 | 1,68948 | 1,99900 | 2,35795 | 2,77308 | 3,25195 |
| 10 | 1,21899 | 1,48024 | 1,79085 | 2,15892 | 2,59374 | 3,10585 | 3,70722 |
| 11 | 1,24337 | 1,53945 | 1,89830 | 2,33164 | 2,85312 | 3,47855 | 4,22623 |
| 12 | 1,26824 | 1,60103 | 2,01220 | 2,51817 | 3,13843 | 3,89598 | 4,81790 |
| 13 | 1,29361 | 1,66507 | 2,13293 | 2,71962 | 3,45227 | 4,36349 | 5,49241 |
| 14 | 1,31948 | 1,73168 | 2,26090 | 2,93719 | 3,79750 | 4,88711 | 6,26135 |
| 15 | 1,34587 | 1,80094 | 2,39656 | 3,17217 | 4,17725 | 5,47357 | 7,13794 |
| 16 | 1,37279 | 1,87298 | 2,54035 | 3,42594 | 4,59497 | 6,13039 | 8,13725 |
| 17 | 1,40024 | 1,94790 | 2,69277 | 3,70002 | 5,05447 | 6,86604 | 9,27646 |
| 18 | 1,42825 | 2,02582 | 2,85434 | 3,99602 | 5,55992 | 7,68997 | 10,57517 |
| 19 | 1,45681 | 2,10685 | 3,02560 | 4,31570 | 6,11591 | 8,61276 | 12,05569 |
| 20 | 1,48595 | 2,19112 | 3,20714 | 4,66096 | 6,72750 | 9,64629 | 13,74349 |
| 21 | 1,51567 | 2,27877 | 3,39956 | 5,03383 | 7,40025 | 10,80385 | 15,66758 |
| 22 | 1,54598 | 2,36992 | 3,60354 | 5,43654 | 8,14027 | 12,10031 | 17,86104 |
| 23 | 1,57690 | 2,46472 | 3,81975 | 5,87146 | 8,95430 | 13,55235 | 20,36158 |
| 24 | 1,60844 | 2,56330 | 4,04893 | 6,34118 | 9,84973 | 15,17863 | 23,21221 |
| 25 | 1,64061 | 2,66584 | 4,29187 | 6,84848 | 10,83471 | 17,00006 | 26,46192 |
| 26 | 1,67342 | 2,77247 | 4,54938 | 7,39635 | 11,91818 | 19,04007 | 30,16658 |
| 27 | 1,70689 | 2,88337 | 4,82235 | 7,98806 | 13,10999 | 21,32488 | 34,38991 |
| 28 | 1,74102 | 2,99870 | 5,11169 | 8,62711 | 14,42099 | 23,88387 | 39,20449 |
| 29 | 1,77584 | 3,11865 | 5,41839 | 9,31727 | 15,86309 | 26,74993 | 44,69312 |
| 30 | 1,81136 | 3,24340 | 5,74349 | 10,06266 | 17,44940 | 29,95992 | 50,95016 |
| 35 | 1,99989 | 3,94609 | 7,68609 | 14,78534 | 28,10244 | 52,79962 | 98,10018 |
| 40 | 2,20804 | 4,80102 | 10,28572 | 21,72452 | 45,25926 | 93,05097 | 188,88351 |
| 45 | 2,43785 | 5,84118 | 13,76461 | 31,92045 | 72,89048 | 163,98760 | 363,67907 |
| 50 | 2,69159 | 7,10668 | 18,42015 | 46,90161 | 117,39085 | 289,00219 | 700,23299 |
| 60 | 3,28103 | 10,51963 | 32,98769 | 101,25706 | 304,48164 | 897,59693 | 2595,91866 |
| 70 | 3,99956 | 15,57162 | 59,07593 | 218,60641 | 789,74696 | 2787,79983 | 9623,64498 |
| 80 | 4,87544 | 23,04980 | 105,79599 | 471,95483 | 2048,40021 | 8658,48310 | 35676,9818 |
| 90 | 5,94313 | 34,11933 | 189,46451 | 1018,91509 | 5313,02261 | 26891,9342 | 132262,467 |
| 100 | 7,24465 | 50,50495 | 339,30208 | 2199,76126 | 13780,6123 | 83522,2657 | 490326,238 |

Table 8.2 (4/4) – Values of the present worth factor and of the capitalisation factor for different time periods, n, and discount rates, r

b2) Capitalisation factor for uniform monetary fluxes $\left[\dfrac{(1+r)^n - 1}{r}\right]$

| Time period, n | Uniform series of monetary fluxes and discount rate, r, of: | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2% | 4% | 6% | 8% | 10% | 12% | 14% |
| 1 | 1,00000 | 1,00000 | 1,00000 | 1,00000 | 1,00000 | 1,00000 | 1,00000 |
| 2 | 2,02000 | 2,04000 | 2,06000 | 2,08000 | 2,10000 | 2,12000 | 2,14000 |
| 3 | 3,06040 | 3,12160 | 3,18360 | 3,24640 | 3,31000 | 3,37440 | 3,43960 |
| 4 | 4,12161 | 4,24646 | 4,37462 | 4,50611 | 4,64100 | 4,77933 | 4,92114 |
| 5 | 5,20404 | 5,41632 | 5,63709 | 5,86660 | 6,10510 | 6,35285 | 6,61010 |
| 6 | 6,30812 | 6,63298 | 6,97532 | 7,33593 | 7,71561 | 8,11519 | 8,53552 |
| 7 | 7,43428 | 7,89829 | 8,39384 | 8,92280 | 9,48717 | 10,08901 | 10,73049 |
| 8 | 8,58297 | 9,21423 | 9,89747 | 10,63663 | 11,43589 | 12,29969 | 13,23276 |
| 9 | 9,75463 | 10,58280 | 11,49132 | 12,48756 | 13,57948 | 14,77566 | 16,08535 |
| 10 | 10,94972 | 12,00611 | 13,18079 | 14,48656 | 15,93742 | 17,54874 | 19,33730 |
| 11 | 12,16872 | 13,48635 | 14,97164 | 16,64549 | 18,53117 | 20,65458 | 23,04452 |
| 12 | 13,41209 | 15,02581 | 16,86994 | 18,97713 | 21,38428 | 24,13313 | 27,27075 |
| 13 | 14,68033 | 16,62684 | 18,88214 | 21,49530 | 24,52271 | 28,02911 | 32,08865 |
| 14 | 15,97394 | 18,29191 | 21,01507 | 24,21492 | 27,97498 | 32,39260 | 37,58107 |
| 15 | 17,29342 | 20,02359 | 23,27597 | 27,15211 | 31,77248 | 37,27971 | 43,84241 |
| 16 | 18,63929 | 21,82453 | 25,67253 | 30,32428 | 35,94973 | 42,75328 | 50,98035 |
| 17 | 20,01207 | 23,69751 | 28,21288 | 33,75023 | 40,54470 | 48,88367 | 59,11760 |
| 18 | 21,41231 | 25,64541 | 30,90565 | 37,45024 | 45,59917 | 55,74971 | 68,39407 |
| 19 | 22,84056 | 27,67123 | 33,75999 | 41,44626 | 51,15909 | 63,43968 | 78,96923 |
| 20 | 24,29737 | 29,77808 | 36,78559 | 45,76196 | 57,27500 | 72,05244 | 91,02493 |
| 21 | 25,78332 | 31,96920 | 39,99273 | 50,42292 | 64,00250 | 81,69874 | 104,76842 |
| 22 | 27,29898 | 34,24797 | 43,39229 | 55,45676 | 71,40275 | 92,50258 | 120,43600 |
| 23 | 28,84496 | 36,61789 | 46,99583 | 60,89330 | 79,54302 | 104,60289 | 138,29704 |
| 24 | 30,42186 | 39,08260 | 50,81558 | 66,76476 | 88,49733 | 118,15524 | 158,65862 |
| 25 | 32,03030 | 41,64591 | 54,86451 | 73,10594 | 98,34706 | 133,33387 | 181,87083 |
| 26 | 33,67091 | 44,31174 | 59,15638 | 79,95442 | 109,18177 | 150,33393 | 208,33274 |
| 27 | 35,34432 | 47,08421 | 63,70577 | 87,35077 | 121,09994 | 169,37401 | 238,49933 |
| 28 | 37,05121 | 49,96758 | 68,52811 | 95,33883 | 134,20994 | 190,69889 | 272,88923 |
| 29 | 38,79223 | 52,96629 | 73,63980 | 103,96594 | 148,63093 | 214,58275 | 312,09373 |
| 30 | 40,56808 | 56,08494 | 79,05819 | 113,28321 | 164,49402 | 241,33268 | 356,78685 |
| 35 | 49,99448 | 73,65222 | 111,43478 | 172,31680 | 271,02437 | 431,66350 | 693,57270 |
| 40 | 60,40198 | 95,02552 | 154,76197 | 259,05652 | 442,59256 | 767,09142 | 1342,02510 |
| 45 | 71,89271 | 121,02939 | 212,74351 | 386,50562 | 718,90484 | 1358,23003 | 2590,56480 |
| 50 | 84,57940 | 152,66708 | 290,33590 | 573,77016 | 1163,90853 | 2400,01825 | 4994,52135 |
| 60 | 114,05154 | 237,99069 | 533,12818 | 1253,21330 | 3034,81640 | 7471,64111 | 18535,1332 |
| 70 | 149,97791 | 364,29046 | 967,93217 | 2720,08007 | 7887,46957 | 23223,3319 | 68733,1784 |
| 80 | 193,77196 | 551,24498 | 1746,59989 | 5886,93543 | 20474,0021 | 72145,6925 | 254828,441 |
| 90 | 247,15666 | 827,98333 | 3141,07519 | 12723,9386 | 53120,2261 | 224091,118 | 944724,767 |
| 100 | 312,23231 | 1237,62370 | 5638,36806 | 27484,5157 | 137796,123 | 696010,547 | 3502323,12 |

## 8.2.4- Economic indexes

### 8.2.4.1- Basic considerations

The evaluation of the profitability of a small hydropower scheme or the comparison of alternative design solutions for the same can be based on economic indexes or parameters. Among these parameters the next five ones will be treated herein: **net present value** (NPV), **benefit/cost ratio** (B/C), **internal rate of return** (IRR), **average price of the kWh** (AP) and **payback period** (T).

The economic parameters do not always identify the same project as being the most economic amongst a number of alternatives. At the same time, the preference of one particular parameter may alter with a change, even small, in the discount rate.

Being the results of the economic analysis so sensitive to the value considered for the discount rate much attention should be paid in the establishment of this value However, in most situation, there is not a well-defined and unique discount rate but, instead, a range of possible discount rates. Although this range is often narrow, it is advisable to perform a sensitivity analysis of the project response to different discount rates. By this way it will be possible to partially overcome the uncertainty related with this rate and, at the same time, to conclude if there is any change in the relative preferences indicated by the economic parameters.

Especially to compare alternative design solutions for a small hydropower it is usual to evaluate, for each of these solutions, the ratio of the total capital cost to the installed capacity, that is to say, the cost per installed kW. Although this index is quite easy to obtain it is poorly informative from an economic point of view, as it does not take into account neither other costs of the project, nor its benefits. However it may be useful in the systematisation of the capital costs required for small hydropower projects or in comparison of alternative projects having similar benefits.

In the next items the following symbols will be utilised:

- n number of the project lifetime periods (generally measured in years and equal to the duration of the legal permits);
- r discount rate (constant along the project useful live);

- Ci capital costs in year i;
- Oj annual operation cost for year j;
- Rj revenues in year j;
- Pm reposition cost foreseen for year m ( $n/2 < m < n$ );
- $\overline{E}$ mean annual production.

The abbreviations C, O, R and P will respectively denote the present values of the costs, Ci, Oj, Rj and Pm. If

- the capital costs occur in the first k years,
- the energy production takes place from year (k+1) until year n,
- the equipment reposition is foreseen for year m,

the following relation are obtained for the beginning of the n years period:

$$C = \sum_{i=1}^{k} \frac{Ci}{(1+r)^i} \qquad (8.5)$$

$$O = \frac{\sum_{j=k+1}^{n} \frac{Oj}{(1+r)^j}}{(1+r)^k} \qquad (8.6)$$

$$R = \frac{\sum_{j=k+1}^{n} \frac{Rj}{(1+r)^j}}{(1+r)^k} \qquad (8.7)$$

$$P = \frac{Pm}{(1+r)^m} \qquad (8.8)$$

The numerator of expressions (8.6) e (8.7) provides the present value (for the beginning of year k+1) of an annuity that will occur during n-k years, from year k+1 until year n. The denominator performs the transference of the previous value from year k to the beginning of year 1 – Figure 8.4.

Expression (8.6) assumes that the parcel of the annual operation costs related with the legal permits will occur only when the scheme starts to operate which is generally a far enough realistic scenario.

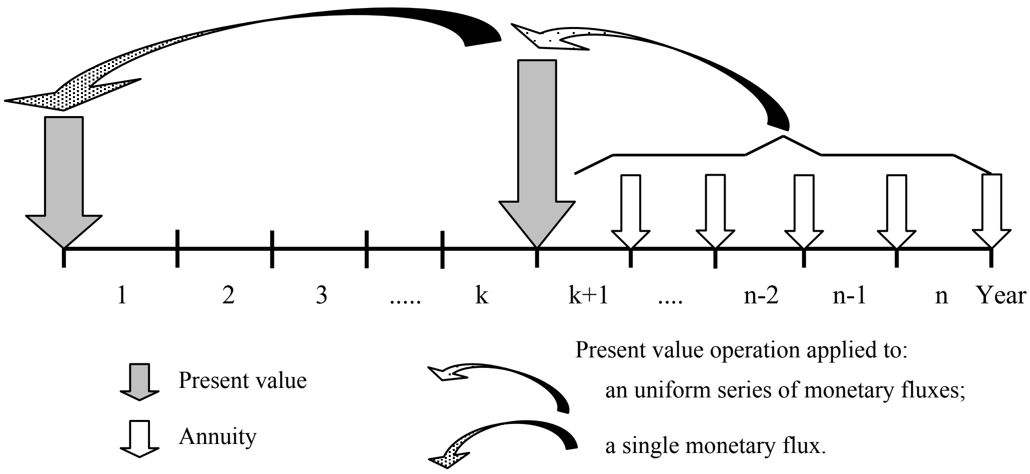


Fig. 8.4 – Compound present values operations.

As the annual benefits in a small hydropower scheme are generally evaluated on a constant annual production basis (the mean annual production, $\overline{E}$), expression (8.7) becomes

$$R = \frac{\overline{R}\,\dfrac{(1+r)^{(n-k)}-1}{(1+r)^{(n-k)}\,r}}{(1+r)^{k}} \qquad (8.9)$$

where $\overline{R}$ is the mean annual benefit obtained by multiplying the $\overline{E}$ by unitary sale price of the energy in the first year of the period under analysis (year 1).

The period for which the economical analysis is performed should be equal to the period foreseen in the legal permit of the hydropower exploitation. However, it is not reasonable to adopt periods greater then twenty five to thirty years, as the present values of the expected costs and benefits in the last years become so small that their contribution to the economic indexes is negligible.

If the lifetime of the equipment is greater than the assumed useful life of the hydropower scheme a residual value of the investment over its lifetime can be considered and jointed to the benefits. As the estimate of this residual quantity is quite subjective and fallible and its present value contribution for the scheme profitability will certainly be very modest, it will not be considered in the further development of this chapter.

### 8.2.4.2- Net Present Value (NPV)

The **net present value**, NPV, represents the cumulative sum of all expected benefits during the lifetime of the project minus the sum of all its cost during the same period, both expressed in terms of present values

$$NPV = R - C - O - P \qquad (8.10)$$

If NPV is negative, the project should be rejected as it is expected that the benefits during its lifetime will be insufficient to cover the project costs. Assuming that there are not any restrictions with respect to the required initial capital availability, among projects or alternative design solutions with positive NPV the best ones will be those with greater NPV.

The net present value can also be evaluated by computing **the discount cumulative cash flow**. This cash flow gives, through each year of the economic analysis period, the value of the cumulative sum of the present values of the costs minus the present values of the benefits. The NPV equals the result provided by the cash flow for the last year of the period under analysis (year n).

### 8.2.4.3- Benefit/cost ratio (B/C)

The **benefit/cost ratio**, B/C, compares the present values of the benefits and costs of the hydropower scheme on a ratio basis. This index can be defined as the ratio between present values of the net annual benefits and of the capital and reposition costs or as the ratio between present values of the benefits and of the total costs, that is to say

$$B/C = \frac{R - O}{C + P} \qquad (8.11)$$

$$B/C = \frac{R}{C + O + P} \qquad (8.12)$$

The first definition seems more coherent as it combines together the annual monetary fluxes that occur during the project lifetime.

The B/C parameter has much popular appeal since it gives an immediate indication of the “degree” of desirability of a project. If the benefit/cost is less than one, the project is evidently undesirable. If it is exactly one the project has a marginal interest and if is greater than one, its implementation would seem justified and as much justified as B/C is higher.

It should be pointed out that the B/C ratio evaluated by expression (8.12) is always equal or greater then the B/C ratio that results from expression (8.11). However, if (8.11) provides a unitary value, the B/C ratio given by (8.12) will also be one. An unitary B/C ratio implies a NPV equal to zero.

#### 8.2.4.4- Internal Rate of Return (IRR)

The **internal rate of return**, IRR, is defined as the discount rate that makes the net present value, NPV, equal to zero.

Let us considered a project having capital costs, Ci, during the first k years and energy revenues, Rj, and annual operation costs, Oj, from year j=(k+1) until year n. A reposition cost is foreseen for year m. In this condition, the project NPV for the beginning of year 1 can be evaluated according to

$$NPV = R - C - O - P = \frac{\sum_{j=k+1}^{n} \frac{1}{(1+r)^{j}} Rj}{(1+r)^{k}} - \sum_{i=1}^{k} \frac{1}{(1+r)^{i}} C_i - \frac{\sum_{j=k+1}^{n} \frac{1}{(1+r)^{j}} Oj}{(1+r)^{k}} - \frac{Pm}{(1+r)^{m}} \qquad (8.13)$$

The respective IRR will be obtained by

$$NPV = \frac{\sum_{j=k+1}^{n} \frac{1}{(1+IRR)^{j}} (Rj - Oj)}{(1+IRR)^{k}} - \sum_{i=1}^{k} \frac{1}{(1+IRR)^{i}} C_i - \frac{Pm}{(1+IRR)^{m}} = 0 \qquad (8.14)$$

A discount rate equal to IRR will imply an unitary B/C ratio and a null NPV.

A process of trial and error can provide the solution of expression (8.14). This process, which is generally simple to carry out with the software available nowadays, begins with an arbitrary discount rate. If the NPV thus obtained is positive, a higher discount rate must be tested; if NPV is negative, the search must proceed with a lower discount rate – Figure 8.5.

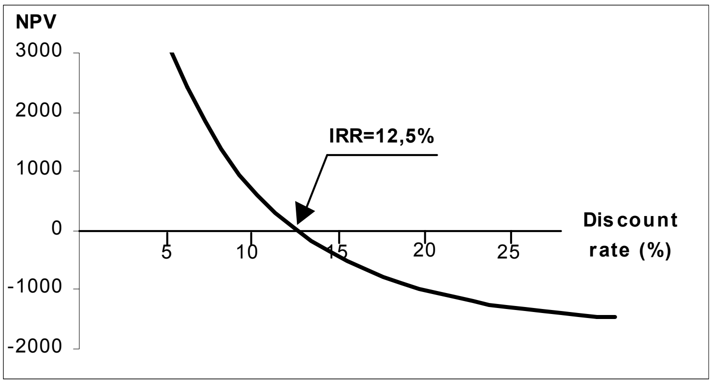


Figure 8.5 – Internal rate of return, IRR

The previous figure assumes that the project is well behaved from an economic point of view. This is a correct assumption for small hydropower projects in which the capital costs occur during a very short period of time (generally, less than three years) while the incomes last during the useful life of the scheme (for saying, more than twenty years).

Among projects or alternative design solutions with different internal rates of return the best ones will be those with greater IRR. If the rates thus achieved are greater than the opportunity costs of the capital, the projects are advantageous from an economic point of view.

### 8.2.4.5- Average price of the kWh (AP)

Although this parameter is not generally referred in the speciality literature, it is an interesting index as it provides economic information in a way very simple to understand. It is also useful in the comparison of alternative design solutions.

According to the abbreviations established, the **average price of the kWh**, AP, is be defined by

$$AP = \frac{\sum_{i=1}^{k} \frac{1}{(1+r)^{i}} Ci + \frac{\sum_{j=k+1}^{n} \frac{1}{(1+r)^{j}} Oj}{(1+r)^{k}} + \frac{Pm}{(1+r)^{m}}}{\frac{(1+r)^{(n-k)} - 1}{(1+r)^{(n-k)}\, r} \overline{E}} =$$

$$= \frac{C + O + P}{\frac{(1+r)^{(n-k)} - 1}{(1+r)^{(n-k)}\, r} \overline{E}} \qquad (8.15)$$

This parameter represents the ratio between the present value of all costs and an "equivalent energy present amount". This last amount is obtained by applying the present worth factor to the mean annual production. By other words, the AP index represents the unitary energy sale price that makes the NPV equal to zero and the B/C ratio equal to one.

If the AP price is lower than the nominal unitary energy-selling price the project is justified from an economic point of view. The best project will be the one with lower AP.

#### 8.2.4.6- Payback period (T)

The **payback period** or recovery period, T, can be defined either on a discounted or without discount basis and represents the number of years it takes before cumulative forecasted cash flows equal the initial investment. Its value is provided by the year when the cumulative cash flow changes from a negative value to a positive value.

### 8.2.5- Sensitivity analysis

A small hydropower scheme project is usually characterised by a lack of certainty about the capital cost estimates, future annual costs and future value of the energy. So a sensitivity analysis should be performed in order to analyse the project response capability to different scenarios. These scenarios can be obtained by increasing the costs and maintaining or decreasing the benefits or, if the cost estimates are considered to be accurate enough, maintaining the costs and decreasing the benefits. Variations from $\pm 10\%$ to $\pm 20\%$ are usually adopted in the previous analysis.

In what concerns the discount rate, at least two values should be considered around the most probable discount rate: a pessimist value higher than the expected one and a optimist value, lower than the expected discount rate.

### 8.2.6- Application example

Table 8.3 provides an application example for a hypothetical hydropower scheme having an installed capacity of 2,2 MW and an average energy production of 8,5 GWh.

The costs were considered to occur during the first two years (execution period) and the benefits during the next twenty-eight years (total duration of the legal licence period of 30 years). No residual costs, reposition costs and spare parts costs were considered. The economic analysis was developed for three discount rates: 10%, 8% and 6%. The first year is adopted for reference year.

The annual operation costs were estimate on the basis of fixed percentages either of the capital costs (exploitation and maintenance costs), or of the incomes (legal permit costs).

As one can concluded from the previous table, if the discount rate is set equal to the internal rate return then the net present value becomes zero, the benefit/cost ratio one, the average price of the kWh the nominal unitary sale price of the energy and the payback period the analysis period.

Table 8.3 – Application example

**COST AND BENEFITS**

| | YEAR 1 | YEAR 2 | YEAR 3 | YEAR 4 | ...... | YEAR 30 |
|---|---|---|---|---|---|---|
| **CAPITAL COSTS** ($10^3$ EURO) | | | | | | |
| **1** - Studies and design | 74000 | 38000 | | | | |
| **2** - Supervision during execution | 25000 | 60000 | | | | |
| **3** - Civil works | | | | | | |
| **3.1** - Weir and water intake | 70000 | 140000 | | | | |
| **3.2** - Channal | 69000 | 265000 | | | | |
| **3.3** - Forebay | __ | 70000 | | | | |
| **3.4** - Penstock | 60000 | 18000 | | | | |
| **3.5** - Powerhouse | 30000 | 70000 | | | | |
| **3.6** - Acess road | 42500 | 17500 | | | | |
| **4** - Equipment | | | | | | |
| **4.1** - Weir and water intake | 30000 | 60000 | | | | |
| **4.2** - Forebay | | 25000 | | | | |
| **4.3** - Penstock | 270000 | 300000 | | | | |
| **4.4** - Powerhouse | 200000 | 750000 | | | | |
| **5** - Connection to the electrical grid | __ | 400000 | | | | |
| **6** - B. site facilities. Contigencies | 99000 | 50000 | | | | |
| **7** - Land acquisition | 55000 | 55000 | | | | |
| **TOTAL ($10^3$ EURO)** | **982000** | **2301000** | | | | |
| **ANNUAL OPERATION COSTS** ($10^3$ EURO) | | | | | | |
| **1** - Exploitation | __ | __ | 14000 | 14000 | ........ | 14000 |
| **2** - Maintenance | | | | | | |
| **2.1** - Civil works | __ | __ | 6500 | 6500 | ........ | 6500 |
| **2.2** - Equipment | __ | __ | 25500 | 25500 | ........ | 25500 |
| **3** - Legal permission | __ | __ | 7500 | 7500 | ........ | 7500 |
| **TOTAL ($10^3$ EURO)** | __ | __ | **53500** | **53500** | ........ | **53500** |
| **ANNUAL BENEFITS** | | | | | | |
| **1** - Mean annual production (GWh) | __ | __ | 8.5 | 8.5 | ........ | 8.5 |
| **2** - Unitary sale price (EURO/1 000 kW | __ | __ | 62.5 | 62.5 | ........ | 62.5 |
| **TOTAL ($10^3$ EURO)** | __ | __ | **531250** | **531250** | ........ | **531250** |

**ECONOMICAL ANALYSIS**

**GENERAL CHARACTERISTICS**

| | |
|---|---|
| Installed capacity (MW) | 2.200 |
| Mean annual production (GWh) | 8.500 |
| Cost per kW (EURO/kW) | 1492273 |

**ECONOMIC ANALYSIS**

| | |
|---|---|
| Analysis period (years) | 30 |
| **IRR(%)** | **13.589** |

| Discount rate (-) | 0.100 | 0.080 | 0.060 | 0.13589 |
|---|---|---|---|---|
| **NPV (EURO)** | **880175.3** | **1644455.4** | **2725947.8** | **0.0** |
| **B/C (-)** | **1.3150** | **1.5706** | **1.9165** | **1.0000** |
| **AP(EURO/1 000 kWh)** | **49.037** | **42.080** | **35.621** | **62.500** |
| **Payback period (years** | **(See discount cumulative cash flow)** | | | |

| Year | **Discount cumulative cash flow (ECU)** | | | |
|---|---|---|---|---|
| 1 | -892727.3 | -909259.3 | -926415.1 | -864518.8 |
| 2 | -2794380.2 | -2881995.9 | -2974296.9 | -2647893.2 |
| 3 | -2435439.5 | -2502742.5 | -2573168.8 | -2321914.2 |
| 4 | -2109129.8 | -2151582.0 | -2194746.0 | -2034933.7 |
| 5 | -1812484.7 | -1826433.4 | -1837743.5 | -1782285.9 |
| 6 | -1542807.3 | -1525369.9 | -1500948.6 | -1559863.5 |
| 7 | -1297646.0 | -1246607.3 | -1183217.5 | -1364050.6 |
| 8 | -1074772.1 | -988493.9 | -883471.3 | -1191663.7 |
| 9 | -872159.4 | -749499.9 | -600691.8 | -1039900.2 |
| 10 | -687966.1 | -528209.2 | -333918.7 | -906292.9 |
| 11 | -520517.7 | -323310.4 | -82245.9 | -788669.6 |
| 12 | -368291.8 | -133589.3 | ⇨ **155181.2** | -685118.2 |
| 13 | -229904.6 | ⇨ **42078.3** | 379169.0 | -593955.1 |
| 14 | -104098.1 | 204733.6 | 590478.3 | -513698.2 |
| 15 | ⇨ **10271.4** | 355340.3 | 789826.7 | -443042.9 |
| 16 | 114243.7 | 494791.0 | 977891.2 | -380840.4 |
| 17 | 208764.0 | 623912.0 | 1155310.6 | -326079.4 |
| 18 | 294691.6 | 743468.5 | 1322687.3 | -277869.8 |
| 19 | 372807.5 | 854168.9 | 1480589.9 | -235427.7 |
| 20 | 443822.0 | 956669.3 | 1629554.6 | -198063.2 |
| 21 | 508380.6 | 1051577.1 | 1770087.4 | -165168.7 |
| 22 | 567070.3 | 1139454.7 | 1902665.4 | -136209.6 |
| 23 | 620424.5 | 1220822.8 | 2027739.1 | -110714.9 |
| 24 | 668928.4 | 1296163.7 | 2145733.1 | -88270.3 |
| 25 | 713022.8 | 1365923.7 | 2257048.2 | -68510.9 |
| 26 | 753108.6 | 1430516.3 | 2362062.4 | -51115.4 |
| 27 | 789550.3 | 1490324.4 | 2461132.4 | -35801.0 |
| 28 | 822679.1 | 1545702.1 | 2554594.7 | -22318.7 |
| 29 | 852796.2 | 1596977.9 | 2642766.7 | -10449.4 |
| 30 | 880175.3 | 1644455.4 | 2725947.8 | 0.0 |

NOTATION

| | |
|---|---|
| AP | average price of the kWh. |
| B/C | benefit/cost ratio. |
| C | present value of the capital costs. |
| Ci | capital costs in year i. |
| $\overline{E}$ | mean annual production. |
| IRR | internal rate of return. |
| n | number of the project lifetime periods (generally measured in years). |
| NPV | net present value. |
| O | present value of the annual operation costs. |
| Oj | annual operation cost for year j. |
| P | present value of the reposition costs. |
| Pm | reposition cost in year m. |
| PV | present value. |
| r | discount rate. |
| R | present value of the revenues. |
| Rj | revenues in year j. |
| $\overline{R}$ | mean annual benefit. |
| T | payback period. |

KUIPER, E. (1981) – *Water resources projects economics*. Butterworths and Co., London.

PORTELA, M. M; ALMEIDA, A. B. (1995) – Production evaluation of small powerplants under variable yearly flow conditions. *Proceedings of the 4 th International Conference HIDROENERGIA 95*. Milan, Italy.

ESHA (1994), *Layman's guidebook on how to develop a small hydro site*. Part I and Part II, Directorate General for Energy (DG XVII), European Small Hydropower Association, Brussels.

ESHA (1998), *Layman's guidebook on how to develop a small hydro site*. Part I and Part II, Directorate General for Energy (DG XVII), European Small Hydropower Association, Brussels.

JIANDONG, T.; NAIBO, Z.; XIANHUAN, W.; JING, H.; JUISHEN, D.(1996) – *Mini hydropower*, John Wiley and Sons, England.