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Σ ECONOMIC ANALYSIS OF PROPOSED  
HYDROELECTRIC PROJECTS

by Frank L. Weaver

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ECONOMIC ANALYSIS OF PROPOSED  
HYDROELECTRIC PROJECTS

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by - Frank L. Weaver 1/

This paper has been prepared within the United States Federal Power Commission at the request of the United Nations Economic Commission for Latin America. It is based upon the more than 20 years of experience of the writer in the field of river basin development as a member of the staff of the Federal Power Commission.

In the preparation of the paper considerable reliance has been placed upon the Federal Power Commission's Bureau of Power Technical Memorandum No. 1, entitled "Instructions For Estimating Electric Power Costs and Values", as revised March 1960. Much reliance has been placed also upon the May 1958 Report to the Inter-Agency Committee on Water Resources, entitled "Proposed Practices for Economic Analysis of River Basin Projects", commonly known as the "Green Book", prepared by the Subcommittee on Evaluation Standards, successor to the Subcommittee on Benefits and Costs which prepared an earlier report on that subject in 1950. The writer has been a member of these subcommittees since first establishment more than 15 years ago and has been the sometime chairman thereof. Material has been lifted freely from both of these documents where so doing appeared to facilitate the presentation of the paper's subject.

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1/ Chief, Division of River Basins, Bureau of Power, Federal Power Commission, Washington, D. C. The Federal Power Commission, as a matter of policy, disclaims responsibility for material published unofficially by any of its employees. The views expressed herein are those of the author and not necessarily those of the Commission.

This paper approaches the subject of economic analysis of proposed hydroelectric projects from the standpoint of development by federal and by non-federal interests, public or private. It considers first the general problems of economic analysis and project formulation as applicable to all types of water resources projects. It then presents a more detailed discussion of these problems as related to hydroelectric power projects. A concluding section covers the matter of cost allocation for multiple-purpose projects.

#### Objectives of Economic Analysis

As set forth in the "Green Book", the objective of economic analysis in planning hydroelectric projects, as well as other types of river basin development, is to provide a guide for the effective use of the required economic resources such as land, labor, and materials. Thus, economic analysis provides a mechanism for the proper formulation and for the selection of proposed hydroelectric developments. This is true whether the power development is a single-purpose project or a part of a multiple-purpose undertaking including also such purposes as flood control, navigation, irrigation, and water supply.

While economic analysis serves a valuable and necessary purpose by showing the extent to which costs must be incurred to accomplish expected results, it must be recognized, of course, that policies governing the development of a nation's natural resources, including hydroelectric power, are not necessarily determined solely on the basis of economic considerations.

### Setting and Viewpoint for Economic Analysis

Fundamental in the consideration of economic factors affecting water resources projects is the economic environment in which the projects will operate. It is believed that the appropriate general setting is one in which, over the long run, an expanding economy will require increasing amounts of goods and services to satisfy increasing needs. In this setting there is competition for the goods and services needed to establish projects. Thus, the beneficial effects accruing from a particular project are for the usual case at the expense of beneficial effects foregone by not using the required goods and services for some other project or use.

The proper point of view for economic analysis affecting a water resources project is that the public interest is paramount. Such a viewpoint would include consideration of all effects, beneficial or adverse, short-range or long-range, that can be expected to be felt by all persons or groups in the project's range.

### Concepts of Benefits and Costs

In making an economic analysis the physical effects of a project must be translated into benefits and costs. This involves estimates of the values of the increases and decreases in goods and services under future conditions with and without the project. The benefits and costs should be measured from the same viewpoint, to a comparable degree, and on comparable bases for time of occurrence and other factors. Usually it is most convenient to express benefits and costs in terms of their equivalent average annual value over the selected period of analysis.

Despite the limitation of the market price system in reflecting values from a public viewpoint, there is no other suitable framework for evaluating the benefits and costs of water resources projects in common terms. Accordingly, the market price system is the starting point in making benefit-cost evaluations.

#### Measurement Standards

The use of benefits and costs in economic analysis requires measurement in common terms. The placing of benefits and costs on a sound and comparable basis necessitates the establishment of measurement standards. Important among such standards are those relating to price levels, interest rates and risk allowances, and period of analysis.

In theory, prices reasonably expected to prevail at the time project costs are incurred and at the time benefits are realized, in terms of a constant general price level, should be used in benefit-cost analyses. This would require the use of long-term projected prices as the basis for evaluating benefits, as well as all costs of operation, maintenance, replacements, and deferred construction and installation. However, Commission experience with projected prices raised a number of questions as to application and as to the reasonableness of results thus obtained, and the Federal Power Commission practice is to use current prices for all estimates of benefits and costs made for project evaluation.

The values attached to benefits and costs at their time of accrual can be made comparable only after conversion to an equivalent basis for time and degree of certainty of occurrence. Interest or discount rates

and risk allowances used in such conversion may be combined in a single rate or handled separately. The current practice, insofar as federal projects in the United States are concerned, is to exclude risks either by deducting them from benefits or adding them to project costs. Risk-free interest rates are then derived on the basis of the interest rates on long-term government bonds.

The upper limit of the economic life of a project is reached when such factors as depreciation and obsolescence cause the costs of continuing the project to exceed the additional benefits expected from continuation. Thus, the economic life is generally less, and never more, than the physical life of a project. The difficulties and uncertainties associated with estimating the value of remote effects lead to limitations on the length of the period of analysis. Even though the character of the basic structures, such as a dam, may allow an extended economic life, the limitations on the reliability of estimates of benefits projected into the distant future and their small present value when discounted provide reasons for conservatism in selecting an evaluation period. For evaluating hydroelectric power projects, it is the present general practice in the United States to use a maximum period of analysis of 50 years.

#### Project Formulation Procedures

Broadly speaking, the process of project and program formulation from beginning to end is largely a matter of weighing alternatives. Throughout the process the physical effects of each plan or proposal

must be measured and translated into benefits for comparison with the costs of the plan. At various stages of formulation, the program, project, or segment of a project under consideration should also satisfy the criterion that it would be more economical than any other actual or potential means of accomplishing the specific purposes involved.

An essential step in river basin studies is the analysis of the existing and potential needs or demands for the useful purposes which can be served by improvement and development of the resources of the river basins. Important in this regard are the Federal Power Commission's power market surveys which show estimates of the future need for, and value of, power for areas or regions in which proposed hydroelectric projects are under consideration. Another essential step in river basin study is the examination and the analysis of the physical possibilities for improvement or development of the basin's resources to meet the needs or objectives.

#### Establishing Scale of Development

As a starting point for the analysis of the possibilities for river basin development to meet any given objective, it is usually necessary to analyze a specific initial proposal. This is usually a nucleus of development which may be selected on the basis of judgment through the consideration of the initial data available and which appears to offer possibilities of meeting the objective wholly or partly. After the initial proposal or nucleus of development has been selected for analysis and its benefits and costs measured, consideration can be given to scales of development greater or less than the selected nucleus. This applies

to (1) variations in scope of each purpose of a single project, (2) additions or omissions of projects from a program, and (3) inclusion or exclusion of specific purposes from a project or program.

The optimum scale of development is that at which the net benefits are at a maximum. Net benefits are maximized if the scale of development is extended to the point where the benefits added by the last increment of scale or scope are equal to the costs of adding that increment. The increments to be considered in this way are the smallest increments on which there is a practical choice as to inclusion in or omission from the project. The same principle applies when selecting a number of projects to form a program or system of projects to meet a given objective. To be justified for inclusion in a plan, each project in a group, each purpose of a project, and each separable segment of a project should add as much or more benefits than it adds costs.

#### Analysis of Justification

A project is properly formulated and economically justified if: (1) project benefits exceed project costs; (2) each separable segment or purpose provides benefits at least equal to its costs; (3) the scale of development is such as to provide the maximum net benefits; and (4) there are no more economical means, of accomplishing the same purpose, which would be precluded from development if the project were undertaken. If all effects of projects could be evaluated in comparable monetary terms, further analysis of justification would be unnecessary. In some cases, however, the intangibles, that is, effects which cannot be adequately expressed as benefits or costs in monetary terms, may be



of sufficient importance to warrant consideration in the formulation and selection of projects. In such cases, if the scale of development is extended or curtailed as compared with the scale indicated on the basis of tangible benefits and costs or if purposes are included or excluded because of intangible or other considerations, the effects of such action in terms of increasing or reducing costs or benefits should be clearly understood. This will indicate the extent of departure of the final project recommendations from those that would have been made if based solely on tangible factors, evaluated in monetary terms.

#### Derivation of Power Benefits

The benefits of power produced by a hydroelectric project are the value of the power to the users as measured by the amount that they would be willing to pay for such power. For most areas of the United States it may be assumed that power to meet most power demands could be obtained from alternative sources. Normally, therefore, the cost of power from the most likely alternative source provides a measure of the value of the power creditable to the project. In view of the predominance of new steam-electric capacity being installed in most sections of the country, it is generally appropriate to evaluate the output of hydroelectric projects on the basis of the cost of equivalent amounts of capacity and energy from modern steam-electric plants, giving due consideration to such differences as transmission losses and annual transmission costs.

As explained in Technical Memorandum No. 1, previously referred to, the value of hydroelectric power is normally expressed in terms of two components: (1) a capacity value, which corresponds to the fixed elements

of the cost of power supply from alternative new steam-electric plants; and (2) an energy value, which corresponds to the variable elements of the cost of power supply from such alternative plants. These capacity and energy components of power value are usually expressed in terms of dollars per kilowatt per year of dependable capacity and mills per kilowatt-hour of average annual energy, respectively.

In special situations, such as the use of power by aluminum plants in the Pacific Northwest region of the United States, power might not be purchased at prices as high as the cost of power from the expected alternative source but would be utilized because of the low cost of the project power. Since such power loads would not develop with power costs at the level of the cost of alternative power sources, but would develop with the low-cost project power, it is likely that they would develop with power costs at some point between these two extremes. When adequate data for such loads are available, the value of the power to the users should be measured directly. In the absence of adequate data, the value of the power should be measured as the midpoint of power costs between the two extremes indicated above. It may be noted, incidentally, that with development of many of the best power sites in the Pacific Northwest being completed or under way, the situation outlined in the foregoing is rapidly coming to a close.

#### Dependable Capacity of a Hydroelectric Plant

The capability of a hydroelectric plant to which capacity values are assignable is its dependable capacity. The dependable capacity of a generating station is defined as the load-carrying ability for the

time interval and period specified when related to the characteristics of the load to be supplied. It is determined by such factors as capability under adverse water conditions, operating power factor, and portion of the load which the station is to supply. For a hydroelectric plant having power storage the dependable capacity may vary over the life of the project as a result of changing use of the available storage. Studies indicate that in many instances the average dependable capacity of a storage hydroelectric project over a 50-year period could conservatively be estimated as the capability at the originally selected maximum drawdown, plus one-half of the difference between that capability and the installed capacity.

#### Hydro-Steam Capacity Value Adjustment

In estimating the value of dependable capacity available from a potential hydroelectric plant, as measured by the cost of capacity from alternative steam-electric plants, consideration should be given to the relative system reserve requirements, operating flexibility, service availability, and other factors relating to the two types of plants. Some hydroelectric plants are particularly well adapted for serving peak loads and operating as synchronous condensers or as spinning reserve. Under favorable water conditions they may supply capacity in excess of their dependable capacity, making possible savings in overall system costs. Also, in contrast to the relatively simple hydroelectric plant involving rugged machinery operating at low speeds and temperatures, the modern steam-electric plant is an intricate and complex mechanism involving high-pressure, high-speed, and high-temperature

equipment, and it is subject to more equipment outages for maintenance and repair. These considerations and others less tangible are difficult to evaluate, and so are matters which must be determined largely on the basis of judgment. Frequently, consideration of these factors will indicate that a credit to the hydroelectric project is warranted. The hydro-steam capacity value adjustment may range up to the equivalent of ten percent of the at-market cost of steam-electric capacity, but is normally equivalent to about five percent of such cost. The adjustment would be zero, however, in any case where transmission facilities included in the hydroelectric plant development program would not provide service as dependable as those contemplated for the alternative steam-electric plants. When a hydro-steam capacity value adjustment is warranted it should be applied to the at-market capacity cost of the alternative steam-electric power. The adjusted cost would be the at-market value of the hydroelectric power capacity.

#### Hydro-Steam Energy Value Adjustment

When using the incremental cost of energy from alternative steam-electric plants in computing hydroelectric energy values, attention should be given to the energy cost differential that may exist if the average annual plant factor of the proposed hydroelectric plant is different from that at which the alternative steam-electric plant would be expected to operate. As the annual plant factor of the alternative steam-electric plant is likely to decrease with time, it is necessary to use a plant factor averaged over the service life of the steam-electric

plant rather than the plant factor at which such plant would operate initially. When the average annual plant factor of a hydroelectric plant is less than that at which an alternative steam-electric plant would operate over its lifetime, system operating studies will usually show that the older and less efficient steam-electric units in the system would operate at higher capacity factors than would be the case if the alternative steam-electric plant were constructed. This would result in an increase in average steam-electric energy production costs which should be considered when computing the value of hydroelectric energy. If, as occasionally happens, the average lifetime plant factor of the hydroelectric plant is greater than that of the alternative steam-electric plant, then the effect of constructing the hydroelectric plant would be to decrease the average production cost of steam-electric energy. To compensate for such differences in the average incremental energy cost of system steam-electric plants, an adjustment should be made, when necessary, to the hydroelectric energy value. The effect of this adjustment is to decrease the hydroelectric energy value when the annual plant factor of the hydroelectric plant is less than that of the alternative steam-electric plant. When the reverse is true, as is less likely, the effect is to increase the hydroelectric energy value. For convenience in computations the adjustment is usually applied to the at-market cost of the steam-electric energy. The adjusted cost would be the at-market value of the hydroelectric energy.

### Transmission Facilities

The transmission facilities selected to transmit power to the market from a hydroelectric project, or from an alternative steam-electric plant, should have sufficient capacity to carry the maximum output of the plant. For purposes of estimating the investment cost of transmission facilities for steam-electric power plants considered to be alternative to hydroelectric plants, as much attention should be given, in making the estimates, to the location and arrangement of such facilities as is given to those for the hydroelectric plants. This is to assure that a reasonable circuit layout is provided to supply power to comparable delivery points. Many of the newly constructed steam-electric plants are located at some distance from load centers to take advantage of low cost sites, ample water supply, economical fuel supply sources, and areas not likely to have smoke-nuisance ordinances. It has been found in a number of cases that the unit investment for transmission facilities of such plants is comparable in magnitude to that for many hydroelectric plants.

In computing at-site power values for a proposed hydroelectric plant, the first step is to derive the alternative steam-electric plant costs which are then modified by the costs of transmission and power losses to arrive at the cost of steam-electric power at the market. Through the application of the hydro-steam capacity and energy value adjustments, the cost of steam-electric power at the market is converted to the value of hydroelectric power at the market. Finally, these values are reduced by the cost of the hydroelectric transmission facilities and power losses to obtain the unit at-site capacity and energy values of the hydroelectric power.

Hydroelectric Power Costs

The investment in hydroelectric projects per kilowatt of installed capacity varies greatly according to the type of project, its size, location, amount and cost of land required, and the cost of relocation of facilities within or adjacent to reservoir areas, such as railroads, roads, bridges, and communities. The total annual cost of a hydroelectric project consists of fixed charges on the project investment; production expenses, consisting of operation and maintenance costs; and the allocated administrative and general expense.

The components of fixed charges are cost of money or interest; depreciation or amortization; interim replacements; insurance; and federal, state and local taxes where applicable. These items are all related to the project investment and may be expressed as a percentage of this investment. The annual fixed charges for privately-financed and for federally-financed hydroelectric projects as currently used in Federal Power Commission studies in the United States are summarized as follows:

	<u>Percent of Investment</u>	
	<u>Privately</u>	<u>Federally</u>
	<u>Financed</u>	<u>Financed</u>
Cost of Money or Interest	6.75	2.625
Depreciation or Amortization	0.27	0.99
Interim Replacements (Straight Line)	0.20	0.20
Insurance or In Lieu of	0.10	0.10
Federal Income Taxes	3.40 <u>1/</u>	-
Federal Miscellaneous Taxes	0.10	-
State and Local Taxes or In Lieu of	<u>2.35</u> <u>1/</u>	<u>2/</u>
Totals	13.17	3.915

1/ These are national average percentages.

2/ Included only when provided for specifically by federal enabling legislation.

Annual operation and maintenance costs for hydroelectric plants vary somewhat inversely with the size of plant installation as indicated in the following tabulation of selected currently used amounts applicable to both privately-owned and publicly-owned plants:

<u>Plant Installed Capacity, Kilowatts</u>	<u>Annual Cost of Operation and Maintenance Per Kilowatt of Installed Capacity</u>
5,000	\$9.60
10,000	6.40
20,000	4.40
50,000	2.85
100,000	2.15
500,000	1.74
1,000,000	1.68
1,500,000	1.42

Annual administrative and general expenses are normally equivalent to about 35 percent of the total operation and maintenance costs of a hydroelectric project.

Taxes Foregone

As indicated previously, the capacity and energy values of hydroelectric power are usually determined on the basis of the cost of power from the alternative source, federal, private, or other, most likely to be utilized in the absence of the hydroelectric project. In most areas of the United States this alternative source would be a privately-financed steam-electric plant. When utilizing these values in the economic analysis of a proposed federal hydroelectric project, the result would be the inclusion of an element of taxes in the benefits, but not in the hydroelectric project costs since taxes are not paid normally for federal projects. The United States federal agencies concerned,



including the Federal Power Commission, agreed, on March 12, 1954, to include an item of "taxes foregone" in federal hydroelectric costs for purposes of project formulation and evaluation studies. Such taxes foregone are derived from the taxes included in the fixed charges on the alternative steam-electric plant plus the taxes included in the fixed charges on the transmission facilities required to deliver the steam-electric power to market, less the taxes included in the fixed charges on the transmission facilities required to deliver the hydroelectric power to market. Any payments in lieu of state and local taxes made by the federal project under the requirements of enabling legislation would be deducted to obtain the net taxes foregone.

#### Benefit-Cost Relationships

In formulation and evaluation studies for a single-purpose hydroelectric development, the total project benefits and costs would be used. For a multiple-purpose development, however the incremental, or separable, costs of including power in the project would be used in considering whether or not to include power as a purpose. Such incremental costs would include those for the power house and equipment as well as those for any additions to the dam and reservoir resulting from the inclusion of power. However, these costs would not, except in the case of projects of marginal economic feasibility, represent the amount that should properly be assigned to power for rate and repayment purposes. Power costs for those purposes would be determined by means of a cost allocation, as discussed in the following section.

Cost Allocation for Multiple-Purpose Projects

The objective of cost allocation is to distribute multiple-purpose project costs equitably among the purposes served. Equitable distribution may be obtained by preventing costs allocated to any purpose from exceeding corresponding benefits; by requiring each purpose to carry at least its incremental, or separable, cost; and, within these maximum and minimum limits, by providing for proportional sharing of the savings resulting from multiple-purpose development. Allocation of project costs is necessary when charges for all of certain products or services of the project are to be based upon the costs incurred therefor. Power rates are normally established on the basis of repayment of costs.

By the agreement of March 12, 1954, the affected federal agencies of the United States adopted as preferable for general application the Separable-Costs Remaining Benefits method of cost allocation. That method was developed by the predecessor of the present inter-agency Subcommittee on Evaluation Standards and is described in the "Green Book" referred to previously. Briefly, it provides for: (1) assigning to each purpose its separable costs, i.e. the added costs of including the purpose in the project; (2) assigning to each purpose a share of the residual or remaining joint costs in proportion to the remaining benefits, i.e., the benefits (as limited by alternative costs) less the separable costs. Thus, the method provides for an equitable sharing among the purposes in the saving resulting from multiple-purpose development.

### Conclusion

The criteria and procedures outlined herein for the economic analysis of proposed hydroelectric projects provide a sound basis for considering power development either in single-purpose power projects or in conjunction with other uses in properly formulated multiple-purpose undertakings. This is especially true in an existing and expanding economy where there is competition for goods and services and other sources of power are available as alternatives. The economic studies are valuable also in making selections between possible alternative hydroelectric developments.

It should be observed, of course, that rigid adherence in all cases to these procedures for economic justification may not always be indicated as necessary or desirable. Sufficient data are often unavailable for the full and complete application of the procedures and criteria outlined. At best, the problems involved are not susceptible to a laboratory-type approach to their solutions. Nevertheless, economic analyses prepared on as rigorous a basis as possible serve a necessary purpose in considering proposed hydroelectric projects, and departures from rigid rules for economic justification should be made only with full knowledge and consideration of all facts available and pertinent to decisions.

In closing I would like to mention the contribution made by one of my principal assistants, Mr. George G. Adkins, in the preparation of this paper.