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ENERGY RESOURCES EVALUATION

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Energy resource evaluation on a regional or national scale may be for either one or both of two purposes. The first purpose is an immediate one: to identify (that is, to find and measure) resources that can be economically exploited under present conditions as part of the general economic development of the region or country. Such an activity is a kind of inventory of the natural endowment for immediate development purposes, and is the function of an agency like the Geological Survey or Hydrological Survey. It is of special importance in countries like those of Latin America, where systematic activity of this kind has not been a long-established policy.

The second purpose of energy resource evaluation may encompass the first, but has as its focus the longer-term future. This purpose is now assuming greater importance in all countries of the world, as greater attention is given to long-range planning with the development of improved techniques for undertaking it. It aims to assess the complete resource endowment of the region or country in order that endowment may be measured against future needs or may be used as a basis for estimating future producing capacity. The purpose, in other words, is to make an inventory on which to base national policy in the light of the future as well as the present resource situation.

The emphasis of this paper is on the second purpose. It draws on a recently published study undertaken at Resources for the Future over the past few years on the subject, "Energy in the American Economy: 1850-1975".

The differences in the two approaches to energy resource evaluation are well illustrated by the work of the Economic Commission for Europe in evaluating the hydro power resources of that region. The Commission did not limit itself to an inventory of hydro power sites that are suitable for immediate development. It chose rather to begin at the level of the environment and to consider the potential provided by the total runoff and the gross head for each separable portion of that runoff over the entire area of the region. This concept it termed the "theoretical potential" in recognition of the fact that complete development and utilization of total flow and head is quite impracticable for both technical and economic reasons.

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Within the theoretical potential there was distinguished that portion which could be feasibly developed with current technology, to which was applied the term "technical potential". And within this, in turn, there was further distinguished that portion which would be economically feasible to develop under present conditions - the "economic potential".1/

As concepts, these three levels of hydro power potential are simple and unambiguous, although the technical potential is somewhat imprecise in its relation to costs. (For example, how does one distinguish between true physical impossibility and impracticability because of wholly extravagant costs like the damming of a floodplain 50 miles across or the relocation of a very large city?)2/ The measurement of the potentials, on the other hand, is not a simple matter. Measurement of the theoretical potential requires detailed hydrologic and topographic data for the entire area under consideration. The other two potentials call for a site-by-site survey, the choice of the appropriate limiting criteria, and judgment in each instance as to whether these criteria are or are not met. The measurement itself is a large-scale, expensive effort, and the judgments cannot be wholly objective, but must inevitably contain a substantial subjective element.

Whatever the difficulties of measurement, the concepts themselves constitute an improvement of great value in the evaluation of hydro power resources, and their use offers important advantages. Their value lies in the systematizing of the evaluation and the provision of a frame of reference

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1/ For a detailed exposition of these terms see: Economic Commission for Europe, Committee on Electric Power, Hydro-Electric Potential in Europe and its Gross, Technical and Economic Limits (United Nations, May 1953), p. 51. Additional discussion may be found in other reports of that Commission as well as of the Economic Commission for Asia and the Far East, and in papers presented at the recent sectional and world meetings of the World Power Conference.

2/ See V. M. Yevdjevic, "Some Statistical Methods for Determining Water Power Resources", Paper 165 B/13, Fifth World Power Conference, Vienna, 1956; and S. H. Schurr and B. C. Netschert with Vera F. Eliasberg, Joseph Lerner and Hans H. Landsberg, Energy in the American Economy, 1850-1975: An Economic Study of Its History and Prospects (Baltimore, John Hopkins Press, 1960), pp. 441 et seq.

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on which the evaluation can be made. In the absence of these concepts an estimate of hydro power resources is ambiguous and perhaps misleading. If the resources are estimated (in terms of installed capacity) to be 50 million kilowatts, for example, what does this mean? Does this figure represent only that capacity which could be economically justified at present? Does it include some capacity which could produce power only at twice the present prevailing cost of electricity, or at some higher level? Does it take into account improvements in design, construction and operating technology that are not yet perfected but which give promise of lower cost at some sites in the future? Or does the figure represent the absolute maximum that could ever be developed?

With estimates made according to the concepts of the three potentials these questions are answered at once; perhaps not with complete satisfaction but at least with considerable improvement in clarity. If the figure of 50 million kilowatts is based on current economic conditions, it is obviously not the upper limit on either technical or physical grounds. Over the long term a potential of more (most likely, considerably more) exists. This is especially important if some sizable portion - say, 40 million kilowatts - is already developed. With the figure of 50 million defined as it is, it is clear that development is approaching a limit only under current economic and technical circumstances. The possibility of additional capacity becoming technically and economically feasible in the future is not ignored, or by implication, ruled out.

The advantages offered by this terminology and the concepts behind it are several. It offers, for example, a means of obtaining hydro resource estimates through statistical inference. Considerable progress has been made in deriving empirical relationships between the three levels of potential where direct measurements are available for all of them,[3/] and with further refinement of the technique it will be possible to obtain a first approximation of the economic potential of a region or country if one knows the theoretical potential, and _vice versa_, with obvious savings in time and money.

3/ See Economic Commission for Europe, _op.cit._, and various papers presented at the Fifth World Power Conference.

/Equally helpful

Equally helpful an advantage lies in the different scale of perspective provided by the different levels of potential. If one is interested in the here and now, the economic potential is a suitable measure. If one is interested in the long term, the theoretical potential provides the absolute outer limit to whatever opportunities may become feasible in the future.

In summary, the concepts just described constitute a major contribution to the estimation of hydro power resources by releasing the engineer from his constitutional preoccupation with the present. Consideration of the long-term future is inadequate and inappropriate, and perhaps even dangerously misleading, if no allowance is made for continued technological progress and for economic circumstances other than those currently prevailing. The traditional concern of the technical man with only what is immediately or imminently feasible is here overcome, and the larger possibilities inherent in the future can be given due recognition.

A good demonstration of the advantages of this approach is provided in a negative way by experience in the United States, where it has not yet been adopted. The United States Government, through the Federal Power Commission, has issued periodic estimates of the "hydroelectric power resources" of the United States. These estimates are not limited to the potential that is currently economic to develop, but are carried beyond this level to include sites "which give promise at some time of economic feasibility". The extent to which the current economic limit is exceeded, however, is never made clear, and although the estimates do not purport to cover all possible sites, the term "resources" unfortunately connotes a complete inventory. Actually, the estimates appear to be merely a summation of the sites that have come to the attention of the Commission.

As a result, the "hydroelectric power resources" of the United States (including already developed sites) have been constantly growing. As of 1950 the figure was 104.6 million kW; in 1959 it was 122.1 million kW (48-State basis), an increase of one sixth in the nine years. The change itself is not important, since any estimate should be considered subject to revision; it is what the change signifies that is a matter for criticism. The absence of a clear, logical basis for estimating and expressing the hydro power potential of the United States has contributed to a constant, serious underestimation of the true extent of that potential.

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It is a serious shortcoming because of its consequences, which are of special interest to this meeting. The need for planners in both government and industry to have some idea of the future growth of installed hydro power capacity in the United States has called forth many estimates of that future growth. A survey of all published estimates since 1948 reveals that throughout the period the majority of the estimators were pessimistic in viewing the future. In almost all instances they underestimated the rate of growth that has actually occurred since the time they made their estimate. Even more remarkable, this pessimism has persisted through to the present. The estimates of the past two years assume a marked reduction from current growth rates in the future, just as their predecessors did. The average growth rate over the period 1925-59 was 4.5 per cent per year. From 1946 to 1959 it was 5.5 per cent; and for the period 1959-62 (including planned additions and additions under construction) the rate is 7.7 per cent. Yet the average implied growth rate after 1962 in estimates of installed capacity in 1975 is 2.1 per cent.

The most logical explanation for this expectation of a sharp reduction in the rate of growth is the implied (and sometimes stated) assumption that the development of the United States hydro power potential has proceeded so far that future development will be hindered by the increasing cost and difficulty of using the remaining sites. This assumption was engendered by the "resources" estimates of the Federal Power Commission. It is clear from the Commission's own discussion of their figures that they are aware that 100 per cent of the total could eventually be developed. But the users of the figures have been misled by the term "resources", and apparently regard it as the equivalent of what the new approach would call the theoretical potential. It would be a rash optimist indeed who would carry hydro development past 60 per cent of that potential, especially by 1975. All of this has been to the detriment of good planning, whether by government or by industry, and could have been (and still could be) avoided by the adoption of the concepts and terminology described above.

In the course of the work at Resources for the Future it was found that discussions of the future supply of other conventional energy resources, the mineral fuels, exhibited a similar constant tendency to underestimate the true potential, with equivalent misleading results generating erroneous

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assumptions by those who used them. In order to deal with the problem satisfactorily a new conceptual and terminological approach to the estimation of the natural stocks of the mineral fuels was devised that is in many ways similar to the new approach to hydro power. A complete exposition of this work is available elsewhere;[4/] the emphasis in this paper is on the difference in the results obtained by the old and new approaches.

Crude oil is an excellent example. The industry commonly speaks of "proved recoverable reserves", rigorously defined as the natural stocks of crude oil in place which can be economically recovered with existing wells. These reserves constitute a working inventory and thus tend to be only a fairly small multiple of current annual production. This means that for production to be maintained in the future additional reserves must be discovered, and has led to attempts to estimate the quantity remaining to be discovered.

The difficulties of such estimation are enormous, but these can be passed over here. Of immediate concern is the approach used in the estimating procedure. The crucial element in the approach concerns the quantity of oil in place that can be recovered. At present in the United States this is, on the average, one third - of every three barrels of oil that is actually known to exist in the ground, one barrel is produced and two barrels remain behind. In their approach to the problem the estimators assumed, almost without exception, that this recovery ratio would remain constant in the future, and that whatever the quantity of oil that may be presumed to exist beneath the United States, only one third could be recovered.

Like the pessimism with respect to the future growth rate in United States hydro power capacity, this is oddly contrary to past and current events. The present one third recovery level is higher than it was in the past, due to improvements in recovery methods. It would be logical, in view of this, to expect further advances in recovery capability in the future; yet the assumption of any specific higher recovery level at any given time in the future would be wholly arbitrary. This leaves one in the dilemma of wanting to allow for future improved recovery but having no basis on which to be specific.

4/ Schurr, Netschert _et.al._, _op.cit._, chapter 7.

/The dilemma

The dilemma is solved by going to the absolute limit - the total quantity of oil estimated to exist beneath a country or region. This quantity is termed the "resource base" of oil and is conceptually equivalent to the theoretical hydro power potential. The resource base is the quantity with which both present and future technology can work. Like the theoretical hydro potential its complete "development" (discovery and production) is not to be expected, but it provides a reference mark against which one can assess future possibilities and prospects. In this instance the resource base concept is especially useful because of the current evidence of a developing revolution in recovery technology. Within the past few years an average recovery level of two thirds in the United States by 1975 has become a plausible assumption.

The application of the resource-base concept to the question of the future domestic supply of crude oil in the United States illustrates the change in perspective the new approach provides. Estimates of the amount of oil remaining to be discovered in the United States have been made using the "proved reserve" approach. That is, the estimators have attempted to quantify the remaining undiscovered oil in terms of what could be recovered and produced with today's technology and under present cost-price conditions. This amounts to an assumption that in the future, as at present, only one of every three barrels of oil actually located will be recovered. On this basis, the total potential future supply of oil in the United States, including present proved reserves of 32,000 million barrels (4,200 million metric tons), ranges between 80,000 million and 190,000 million barrels (11,000 million and 25,000 million metric tons) according to the several estimates.

By adjusting these estimates to allow for their assumption that only one third of the oil actually in place could be produced, one obtains a "resource-base equivalent" on the order of 500,000 million barrels (67,000 million metric tons). This is the total crude oil potentially available for future recovery, the quantity against which present and future technology can be applied. Note that this is not based on an independent estimate of the occurrence of oil under the United States but is a figure inferred from estimates made on the proved-reserve basis by experts within the oil industry.

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It is what they imply when one takes into account their own recovery assumption in a manner appropriate for the long-term future. Nor does this figure in any way imply that something like 500,000 million barrels (67,000 million metric tons) of oil actually will be found and produced in the future. It is, on the other hand, a resource measure at the absolute limit and suggests, given the possibilities of improved future technology, a more optimistic potential than does the more limited view. From the resource viewpoint, at least, the entire perspective on the long-term future of the oil industry in the United States is changed as a result. Not the least of these changes is that the figure of 500,000 million barrels (67,000 million metric tons) includes some 200,000 million barrels (27,000 million metric tons) of oil already known to exist, but which is currently unrecoverable.

The moral of all this as it applies to evaluating energy resources is reducible to a single sentence: <u>It is essential, in evaluating resources over the long-term future, to make allowance for future technological progress.</u> This applies equally well to the mature, industrialized countries and to those countries that are still in the early stages of developing their resources; to countries in which resource development is a matter of private initiative, and to those in which it is a matter of Government planning. This does not mean that the resource-base approach will necessarily result in important policy changes, or that submarginal resources will thereby be converted into resources of immediate economic significance. It does mean that decisions, both private and public, can be made in the light of the fullest resource knowledge, that opportunities for the development of specific resources are less likely to slip by, that more complete utilization of the resource endowment is more likely possible, and that the development of previously unutilized resources may occur sooner than would otherwise be true.

There are many examples of instances in the Latin American region where the resource-base approach can be applied at present. In those countries fortunate enough to be endowed with petroleum resources the total quantity of oil known to be in the ground can be ascertained, thus making it possible to obtain a quantitative assessment of the potential impact of the emerging

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new techniques of improved recovery. Where natural gas also occurs, this energy source takes on new significance in the light of the new technique of storage and ocean tanker transport of liquefied gas. The resources of the contained natural gas liquids should also be ascertained in full so that they can be measured against the growing demand for these hydrocarbons as petrochemical and refinery feedstock and against the potentials afforded by the improved techniques of transporting, storing, marketing and using liquefied petroleum gases.

The same can be said for coal of all ranks. An inventory of all coal deposits, however poor in quality and remote in location, means that the information will be on hand with which to assess the potential for in situ combustion and above-ground gasification and liquefaction as improvements in those techniques occur in the future (as they eventually will).

In all this it is necessary to rise above the preoccupation with the immediate present in looking at the long-term future, to abandon the assumption that a resource with no present economic value will never acquire that value. This should be done not with blind faith that somehow, sometime the present worthless resources will become a precious endowment, but with the practical realization that in the technological ferment of today and in the even greater ferment of the future, some of those resources are certain to acquire economic utility as long as there is any demand for the resource in general. For those whose concern is the long-term future, forewarned is twice forearmed.