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FORECASTING FUTURE ELECTRIC POWER REQUIREMENTS,

submitted by the American Public Power Association

NOTE: This text is subject to editorial revision.

CONTENTS

Introduction

The forecasting of future demands for electricity requires making assumptions about the basic policies governing the electric power industry. This is especially true because the demand for electricity depends so heavily upon the degree to which it is available and the price at which it is offered for sale. For example, a farmer located many miles from the nearest power line represents zero future "demand" for power regardless of how much he could use if he could obtain it, unless there is a definite plan for the extension of power service to the farmer and his neighbors at a price they can afford to pay.

Likewise, the future power requirements of a given population will be less if a policy of high rates is assumed than if a more enlightened policy of relatively low rates and vigorous power use promotion is anticipated.

The extent to which a low-rate philosophy can be adopted depends in part upon the prospect for an abundant supply of low-cost power, and this prospect depends not only upon the availability of fossil fuels and hydro energy but upon the future organization of the power industry. For example, an industry consisting of numerous, small, isolated plants will produce power, generally speaking, at unit costs higher than a power supply organization consisting of relatively large and efficient plants tied together with high voltage transmission.

The interrelationships among forecasting, rate policies and power system organization were emphasized with clarity and force on frequent occasions by the late Ieland Olds, former Chairman of the Federal Power Commission (FPC). In a paper presented at the national convention of the American Public Power Association in 1959, Mr. Olds urged power officials to "base your rates on your future business". He said, "First set your goals...Second, find out what price or rate is necessary to reach that sales objective...Third, use modern technology to adjust costs to make the rates economically feasible with an increasing volume of sales..." 1/

1/ Ieland Olds, "A New Concept in Residential Electric Rates", 1959 Convention Proceedings, American Public Power Association, P. 102 ff.

/The process

The process of forecasting, in short, involves the consideration of many factors in addition to the statistical record of past experience, and can help to shape and to express the future goals, spirit and philosophy of the power industry.

This paper discusses power forecasting in the United States but leaves to the reader the task of deciding what lessons this experience may hold for the forecasting of power needs in other countries.

Forecasts of future national electric power requirements in the United States characteristically have underestimated the rate of growth of power consumption. This habitual conservatism by the forecasting agencies has been in part a reflection of an attitude within much of the U.S. power industry which in earlier years did not comprehend the needs and market for power in the small towns and rural areas of the U.S. and which still is slow to adopt progressive rate philosophies and the concepts of efficient wholesale power supply systems.

1. Forecasts of future power requirements

A complete census of past predictions of future United States electric power requirements has not been attempted in this paper. Principal attention has been given to the estimates of the United States Federal Power Commission, since these are the only "official" periodic forecasts, with some reference also to those of a leading trade journal, Electrical World. In both cases, there has been a constant tendency to underestimate the nation's future power requirements, with FPC being the more conservative.

(a) Federal Power Commission predictions

In 1935, for example, the Federal Power Commission in its "National Power Survey - Interim Report" showed that United States power production had fallen from 71,400 million kilowatt-hours in 1929 to about 63,000 million kWh in 1933, and estimated that an additional 20 per cent of the 1929 production figure would be needed upon "resumption of predepression industrial activity", for a total exceeding 85,000 million kWh.[2/] However, in the same

2/ Federal Power Commission, "National Power Survey - Interim Report, Power Series #1", Government Printing Office, 1935, table 14, p. 33.

/year (1935),

year (1935), power generation by the electric utility industry totalled more than 95,000 million kWh. In terms of consumption (somewhat less than generation due to transmission and other losses) it would appear that the projected 20 per cent increment over the 1929 level had been reached or surpassed by the time the 1935 estimate was published.

In this same 1935 report, the FPC estimate of total United States hydro potential - projected at that time at 52.6 million kilowatts - likewise was clearly too conservative. It was much less than half the potential hydro capacity presently estimated for the United States by the Federal Power Commission.

In a 1940 report, the FPC was itself highly critical of 1940 load forecasts made by private power systems. The Commission remarked that:

> "The demand for power is growing more rapidly than the utility systems expected. Their December, 1940 demand of 27,752,856 kilowatts exceeded their September, 1940 demand by 2,609,154 kilowatts. This increase exceeded by 472,440 kilowatts or 22 per cent the estimates in the September report of the utilities". 3/

The FPC then pointed out that nine "important war material areas underestimated needs by 53 per cent; in some areas, increases were approximately double those anticipated." Such miscalculations, the Commission cautioned, "would mean serious power shortages such as threatened the defense effort in 1918".

In 1955, the FPC pointed out that "Of the numerous long-range estimates made by various authorities just prior to the Korean war, one was far above the others, predicting that the nation's electric utility energy requirements would reach 657 billion kilowatts-hours in 1960", a figure the FPC said would probably be surpassed by 100 to 150,000 million kWh. 4/

This tendency to underestimate reappeared during the Korean conflict. In its 1952 report on "Resources for Freedom", the capable President's Materials Policy Commission predicted a total (utility and non-utility)

3/ Federal Power Commission, "Electric Power Requirements and Supply in the United States", 1940, p.1.

4/ Federal Power Commission, "Estimated Future Power Requirements of the United States by Regions - 1955-1980", 1956, p. 4.

1975 production of 1,400,000 million kWh. This figure now is clearly low, compared with other, more recent estimates.

Recent years have witnessed periodic Commission increases over its own projections made one, two or three years earlier. Figure I shows four of the projections made by FPC since the Korean war, illustrating the inherent conservatism of the Commission's forecasting of power needs.

The figure compares the FPC's forward estimates published in 1954, 1956, 1958 and 1959. Each shows the preceding one to have undershot. Its 1959 forecast for 1975, for example, is more than 300,000 million kWh greater than that predicted four years earlier. This represents about a 23 per cent change in judgement.

The FPC predictions published in 1959 postulate a 33.3 per cent increase from 1960 to 1965; 26.9 per cent from 1965 to 1970; 23.3 per cent from 1970 to 1975; and 20.6 per cent from 1975 to 1980. At the October, 1959, hearings of the Subcommittee on Automation and Energy Resources of the Joint Economic Committee (United States Congress), the FPC spokesman acknowledge that its projections were more conservative than some by the industry itself, and noted one reason for Commission conservatism:

> "The forecasts of the electric power industry appear to be in the nature of goals that the industry feels may be reached through intensive sales efforts. Sales goals are often higher than actual accomplishments, although in the case of electric power, actual loads have generally been higher than the estimates of the Federal Power Commission as well as those of other parties."

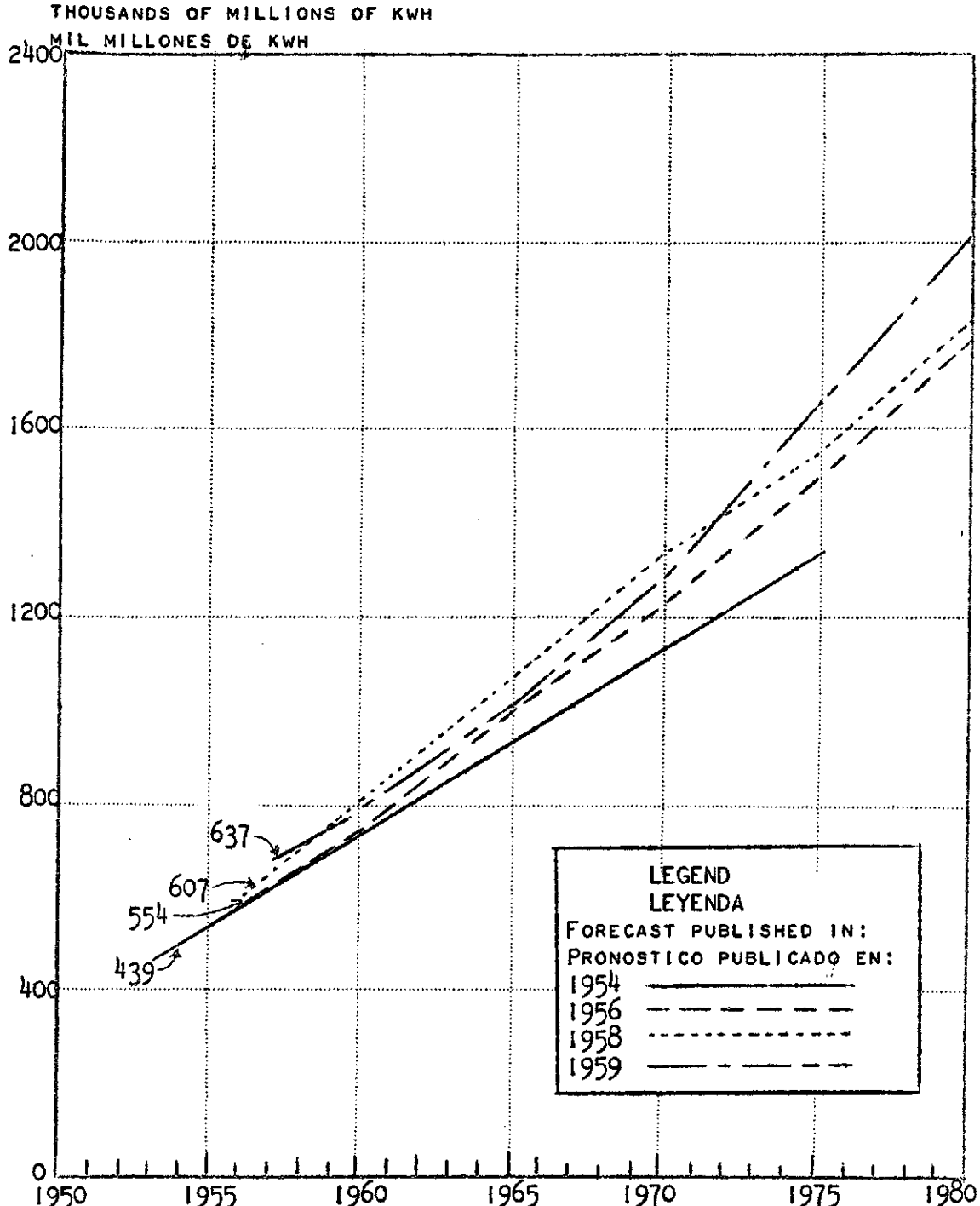
(b) Recent projections

Tabulated below are forecasts of total energy by the Federal Power Commission (August 1960) and Electrical World (19 September 1960), with the latter projecting a far more rapid growth in electric utility generation than does the FPC. This has been the usual pattern.

FIGURE 1
GRAFICO 1

FEDERAL POWER COMMISSION: FORECASTS OF FUTURE UNITED STATES POWER NEEDS

COMISION FEDERAL DE ENERGIA: PRONOSTICO DE LAS NECESIDADES FUTURAS DE ENERGIA EN LOS ESTADOS UNIDOS



SOURCE ; FPC, "ESTIMATED FUTURE POWER REQUIREMENTS: 1953-1975", JUNE 1954; "ESTIMATED FUTURE POWER REQUIREMENTS: 1955-1980", DECEMBER 1956; "ELECTRIC POWER REQUIREMENTS AND SUPPLY AT THE UNITED STATES", APRIL 1958; PRESS RELEASE Nº. 10,480, 17 JUNE 1959.

FUENTE : COMISION FEDERAL DE ENERGÍA, ESTIMATED FUTURE POWER REQUIREMENTS: 1953-1975 JUNIO DE 1954; ESTIMATED FUTURE POWER REQUIREMENTS: 1955-1980 DICIEMBRE DE 1956; ELECTRIC POWER REQUIREMENTS AND SUPPLY IN THE UNITED STATES ABRIL DE 1958; PRESS RELEASE Nº 10,480, 17 DE JUNIO DE 1959.

ELECTRIC UTILITY ENERGY OUTPUT PROJECTIONS
(Thousands of millions of kilowatt-hours)

	Federal Power Commission	Electrical World
Year	Estimated output	Estimated output
1965	1,075	1,138
1970	1,379	1,672.5
1975	1,716	2,422.8
1980	2,084	3,184.4

If the two forecasts are analyzed in terms of the annual rates of growth which each reflects, it is evident that both assume that the growth rate of 9 to 9.5 per cent experienced during the 1946-58 period will not be sustained. Moreover, in both projections there is a clear tendency to assume slower growth rates for the more distant periods covered by the forecasts, although no reasons are given for making such assumptions. The table below shows the annual rates of growth predicted for successive periods of time in each forecast, and these are illustrated in Figure II.

FORECAST ANNUAL RATES OF GROWTH IN ELECTRIC UTILITY ENERGY OUTPUT

Period	Federal Power Commission	Electrical World
1959-1965	7%	8.5%
1965-1970	5.25%	8.0%
1970-1975	4.5%	7.5-8.0%
1975-1980	4%	5.75%

In terms of installed utility capability, Electrical World forecasts a 1975 figure of 479 million kW, and the FPC predicts 360 million kW of capacity by that date.

(c) Past growth

Figure III outlines the magnitude of the growth in power generation in the United States since 1902. It includes production by both privately owned and publicly owned utilities, together with the relatively slight industrial production. Table 1 is included to show the numerical equivalents of the two growth curves for certain years.

/Table I

Table 1

UNITED STATES: ELECTRICITY GENERATION, 1902-58[a/]

Year	Generation (Thousands of millions of kWh)
1902	6.0
1907	14.1
1912	24.8
1917	43.4
1922	61.2
1925	84.7
1927	101.4
1930	114.6
1932	99.4
1935	118.9
1937	146.5
1940	179.9
1942	233.1
1945	271.3
1947	307.4
1950	388.7
1952	463.0
1955	629.0
1957	716.4
1958	724.8

Source: Federal Power Commission reports (see also Bureau of the Census, Historical Statistics, series G171-190, pg. 156.

a/ Utilities and industrial.

/Table II

FIGURE II
GRAFICO II

FUTURE ELECTRIC UTILITY GENERATION FORECASTS

PRONOSTICOS DE LA GENERACION FUTURA DE LAS EMPRESAS ELECTRICAS DE SERVICIO PUBLICO

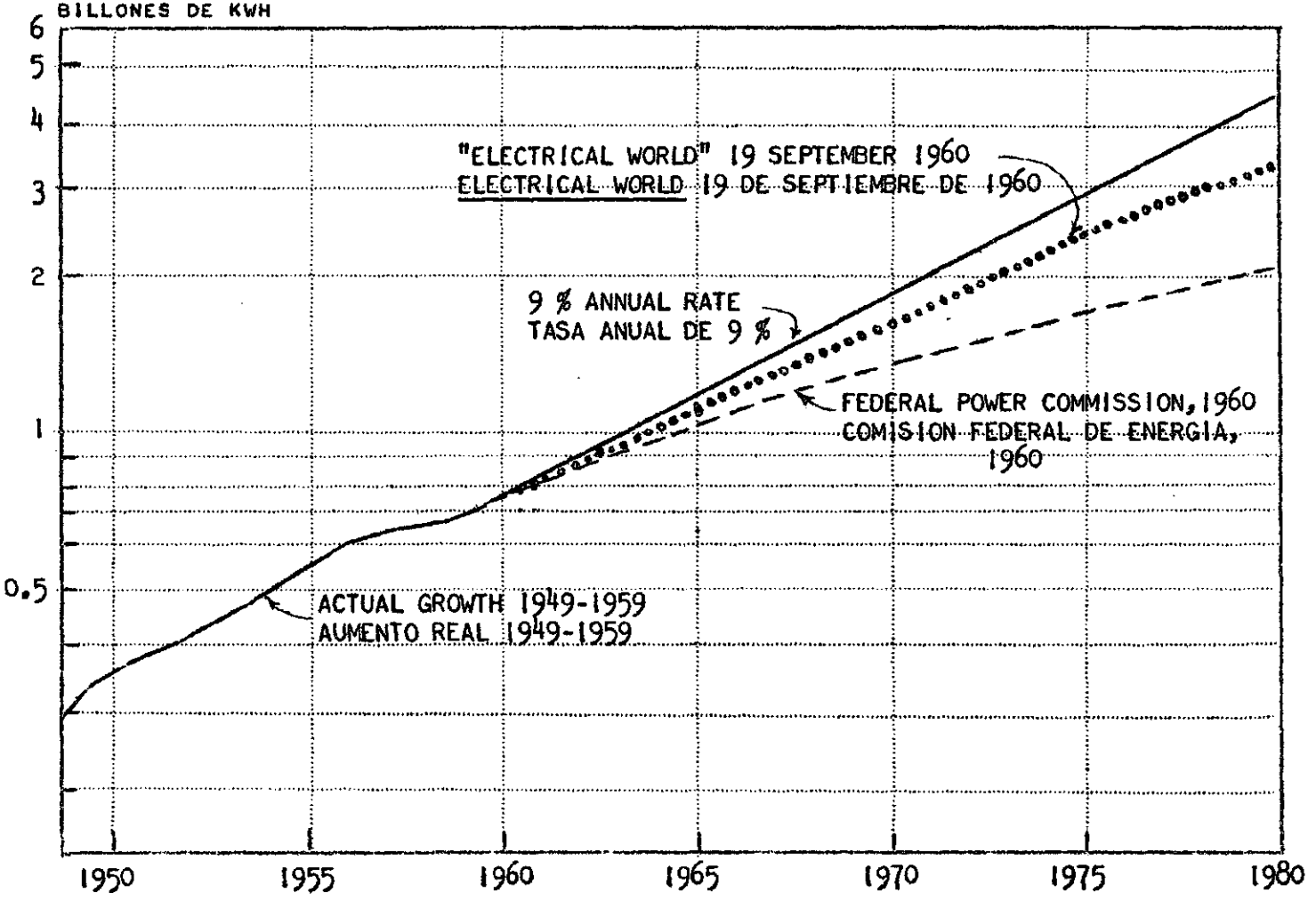
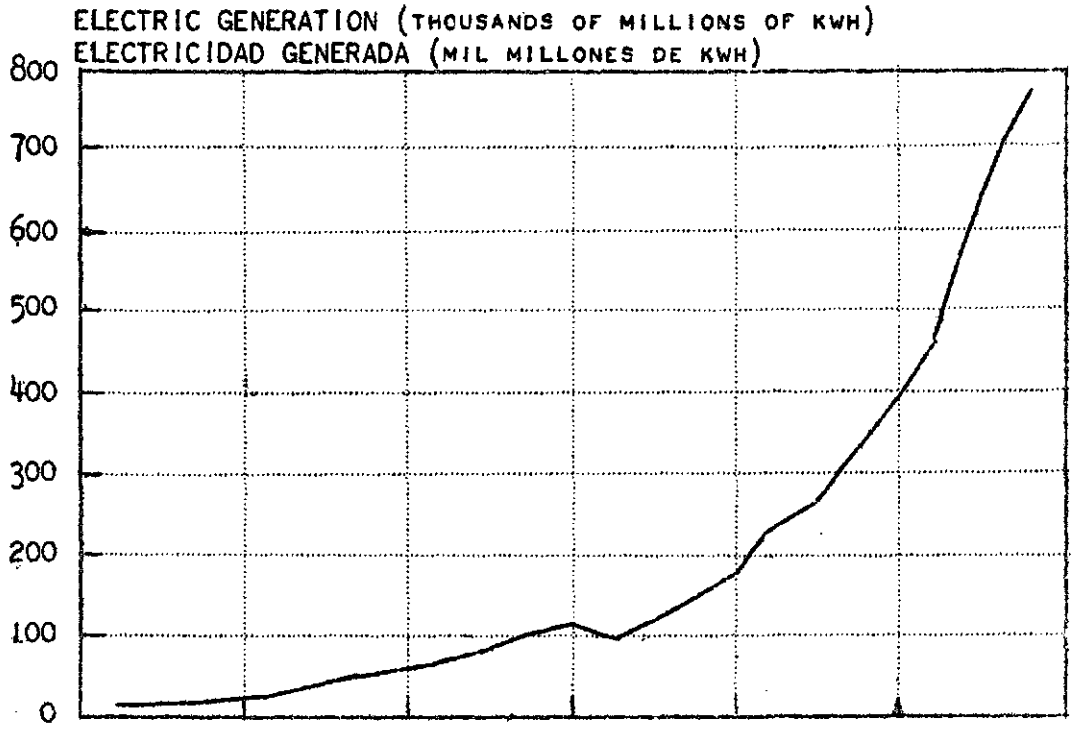


FIGURE III
GRAFICO III

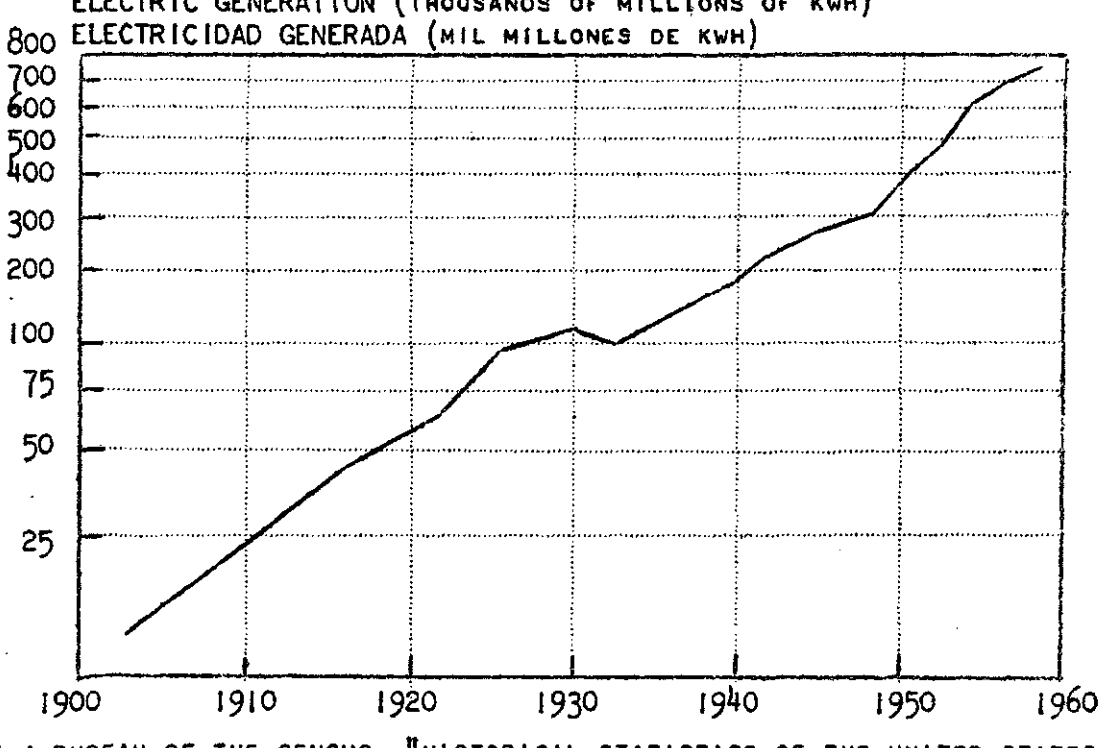
GENERATION OF ELECTRICITY IN THE UNITED STATES - 1902-1958

GENERACION DE ELECTRICIDAD EN LOS ESTADOS UNIDOS - 1902-1958



RATE OF INCREASE.-GENERATION OF ELECTRICITY IN THE UNITED STATES-1902-1958

TASA DE AUMENTO.-GENERACION DE ENERGIA EN LOS ESTADOS UNIDOS - 1902-1958



SOURCE : BUREAU OF THE CENSUS, "HISTORICAL STATISTICS OF THE UNITED STATES, 1789 - 1945", P.156, G-171-182. FEDERAL POWER COMMISSION ANNUAL REPORTS.

FUENTE : BUREAU OF THE CENSUS, HISTORICAL STATISTICS OF THE UNITED STATES, 1789 - 1945. P.156, G-171-182. INFORMES ANUALES DE LA COMISION FEDERAL DE ENERGIA.

Table 2

UNITED STATES: GROWTH OF THREE SECTORS OF THE ELECTRIC UTILITY INDUSTRY, 1945-58
(Millions of kilowatt-hours)

Year	T.V.A.a/ distributors (Sales)	B.P.A.b/ (Sales)	Private power companies c/ (Generation)
1945	3 024	8 513	180 926
1946	3 382	5 830	181 020
1947	4 110	8 261	208 106
1948	4 967	10 291	228 231
1949	5 766	11 970	233 112
1950	6 584	13 039	266 860
1951	8 028	15 076	301 845
1952	8 902	17 012	322 126
1953	10 010	16 395	354 272
1954	11 063	18 773	370 970
1955	12 483	21 830	420 869
1956	14 280	25 977	459 015
1957	15 555	28 212	480 943
1958	17 504	28 364	490 305*

Source: FPC statistics of privately owned electric utilities in the United States, 1958, (table 23).

a/ Tennessee Valley Authority, Annual Reports (fiscal years), Sales of Distributors only. Excludes large TVA sales to AEC, other federal agencies and certain large industrial customers.

b/ Bonneville Power Administration: Generation and Sales Statistics - Fiscal year 1959.

c/ Edison Electric Institute, Statistical Bulletin, 1958, pg. 14.

/The top

The top, rectilinear graph shows actual quantities consumed while the bottom, logarithmic graph shows the historical rate of growth of electric generation from 1902 to 1958. For this total period, the average annual growth rate was about 9 per cent. Since 1935, the United States has recorded more than a six-fold increase in electricity production, more than doubling every ten years.

Electric power production by the utilities, exclusive of industrial production, has achieved an even more rapid rate of growth. Power production by utilities rose from 95.3 million kilowatt-hours in 1935 to 716 million in 1959, more than a seven-fold increase. Since 1940, the average annual rate of growth has been about 9 per cent per year compounded.

Figure IV compares the curve of utility generation of electricity with the curve of Gross National Product. Developed by Mr. Philip Sporn, president of American Electric Power Company, for the 1959 hearings of the Subcommittee on Automation and Energy Resources of the United States Congress, these curves illustrate an apparent close relationship between GNP and power generation up to 1945.5/ But the years that follow indicate that the relationship is more apparent than real. The continuing, brisk ascent of the power curve contrasts markedly with the falling growth rate of the gross national product index.

This phenomenon of steady growth in electric power production, dependent on a considerably weaker curve of national economic growth, suggests one reason for FPC underestimates of future electric production. The Commission assumed in its 1954 projections that "obviously, however, no segment of the economy can continue indefinitely to grow at a faster rate than the total economy."6/

As a matter of fact, that a direct relationship between energy consumption and GNP is not "obvious" has been pointed out in testimony before the

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5/ Statement before the Subcommittee on Automation and Energy Resources, Joint Economic Committee, October 13, 1959. And, Philip Sporn, "The Role of Energy and the Role of Nuclear Energy in the U.S.", Peaceful Uses of Atomic Energy; Proceedings of the International Conference in Geneva, 1955, Vol.1, p. 423.

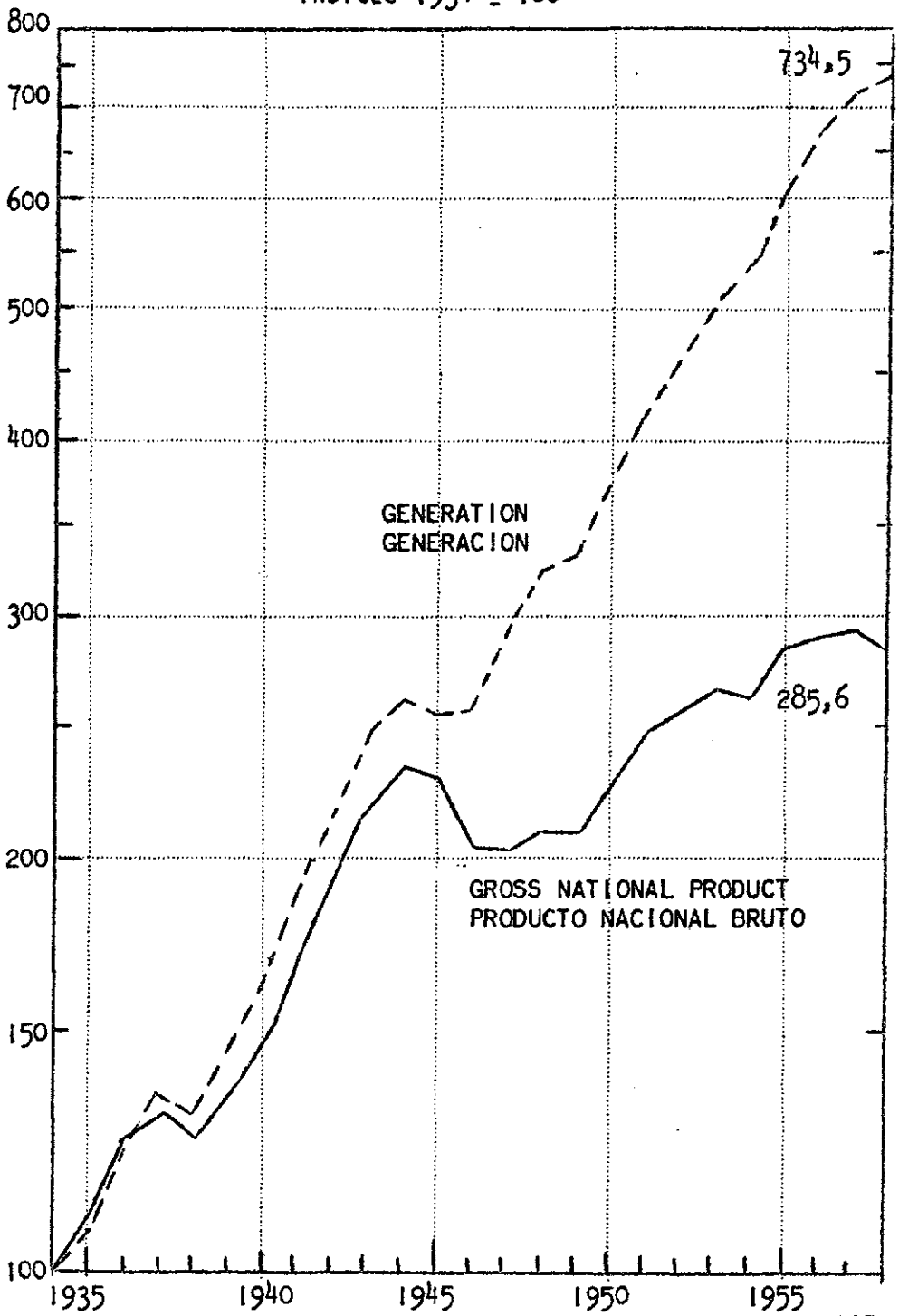
6/ Federal Power Commission, "Estimated Future Power Requirements: 1953-1975", 1954, p. 5.

/Joint Economic

FIGURE IV
GRAFICO IV

INDEXES OF TOTAL ELECTRIC UTILITY GENERATION AND GROSS NATIONAL PRODUCT, 1934-58
(DOLLARS AT 1958 PRICES)
INDEXES 1934 = 100

INDICES DE LA ELECTRICIDAD TOTAL GENERADA POR LAS EMPRESAS DE SERVICIO PUBLICO Y EL PRODUCTO NACIONAL BRUTO
(DOLARES A PRECIOS DE 1958)
INDICES 1934 = 100



SOURCE : PHILIP SPORN, AMERICAN ELECTRIC POWER COMPANY, OCTOBER, 1959
FUENTE ; PHILIP SPORN, AMERICAN ELECTRIC POWER COMPANY, OCTUBRE, 1959

Joint Economic Committee of the United States Congress in October 1959. Mr. Sam H. Schurr, of Resources for the Future, Inc., concluded that "Total energy consumption cannot be related in a straightforward way to other broad economic factors such as GNP and population".

He stated that a major study by his organization pointed to a national consumption of electricity of almost two million million kWh by 1975, representing about a 210 per cent increase over 1955. This figure contrasted sharply with FPC testimony at the same hearings that annual utility output will pass two million million kilowatt hours by 1980.

(d) Innovation and electricity consumption

The rapid and constant climb of national electricity production and consumption results from many factors. Edward S. Mason, Dean of The Graduate School of Public Administration, Harvard University, has concluded that (underlining supplied):

> "Increased consumption of electric power seems in a variety of ways to be more intimately bound up with economic development than increase in mineral fuel intake. It seems to a greater degree to relate to new products, new producing equipment, and new sources of materials, for example, the electro-process industries; it seems more closely tied to the whole process of innovation. The divisibility and easy control of electricity in very small amounts, furthermore, make it peculiarly well suited for appliances and other improved technology within the home, as handmaiden and handyman; and thereby it is heavily responsible for the liberation for other economic activity of housewives and for the almost complete disappearance (in the United States) of household servants". 7/

Whatever the reason, electricity's share of total energy consumption has become increasingly large in the United States.

Consumption of all energy (coal, oil and natural gas liquids, natural gas, water power), is "about 13 per cent less" now than it was in 1900 for the United States, Dr. Schurr has testified, in terms of energy input per unit of Gross National Product. This index has experienced "persistent decline" since 1920.

7/ Edward S. Mason, Productive uses of Nuclear Energy, "Energy Requirements and Economic Growth", National Planning Association, 1955, p.31.

/By contrast,

By contrast, consumption of electricity, as noted earlier, has increased at a rate exceeding the growth rate of Gross National Product. The rate of growth in the use of electricity will continue to outpace growth rates for primary energy sources between 1955 and 1975, Dr. Schurr predicted. Elaborating, he estimated that electricity consumption will experience a 210 per cent increase in that period, compared to about 100 per cent for natural gas, 95 per cent for oil and gas liquids, 75 per cent for bituminous coal, and a decline of about 30 per cent for anthracite coal.8/

(e) High future growth rate likely

Considering past experience, it would seem reasonable to project an average United States growth rate for electricity generation of 9.0 to 9.5 per cent per year, the rate computed for utilities from 1946 (223,00 million kWh) to 1958 (645,000 million kWh).9/ At this rate of future growth, a total utility generation of about 3 million million kWh is projected for 1975, and about 4,600,000 million kWh for 1980.

By comparison, the 1960 forecast of the Federal Power Commission predicts less than one-half this 1980 figure - 2,100,000 million kWh as against 4,600,000 million.

(f) Some effects of low estimates

Forecasts of future electric power requirements influence the planning of both private and public organizations.

For example, the Department of Commerce in 1959 published a study of capital investments needed for water resources by 1975.10/ Its bibliography indicated reliance upon FPC predictions, and upon other studies which utilized FPC figures. Its conclusions are therefore subject to serious question, and its usefulness may be severely limited.

8/ Sam H. Schurr, Director of Energy and Mineral Resources Program, Resources for the Future, Inc., before the Subcommittee on Automation and Energy Resources, Joint Economic Committee, October 12, 1959. Resources for the Future Reprint No. 14, December, 1959, p. 20.

9/ 1946 and 1958 figures from Edison Electric Institute, "Electric Utility Industry Statistics for the Year 1958", table 9, p. 4.

10/ "Water Resources Development - Capital Investment Values - 1900-1975", by Walter L. Picton, Director, Water and Sewerage Industry and Utilities Division, Business and Defense Services Administration, U.S. Department of Commerce.

/Another example

Another example is furnished by the testimony of the nuclear technology expert, Dr. Walter Zinn, in the October, 1959 hearings of the Automation and Energy Resources Subcommittee of the Joint Economic Committee (United States Congress). Dr. Zinn referred to the possibility that nuclear power production by 1980 would amount to twenty per cent of total electrical generation, but described this as an optimistic assumption. He applied his percentage prediction to an FPC forecast made in 1955 to derive a prediction of 360,000 million kWh of nuclear power production in 1980.

Yet, the FPC forecast upon which Dr. Zinn relied is so conservative that it is doubtful that the 360,000 million kWh is particularly "optimistic". Using other, and probably more accurate forecasts as a base, such as the recent estimates of Electrical World, one need only to assume a ten per cent share for nuclear power - half of the Zinn assumption - to derive an estimate of 350,000 million kWh, approximately Dr. Zinn's figure.

The influence of predictions by government agencies was reflected also in the study of "Nuclear Energy and the United States Fuel Economy, 1955-1980," published in 1958. In it, the author, Perry D. Teitelbaum, used the FPC's 1955 predictions of residential consumption of electricity, which were far below those of Electrical World of the same year.

The author also used modifications of the predictions made by the President's Materials Policy Commission for commercial consumption, which assumed a lower figure for 1975 than the Electrical World predicted for 1970. His resultant overall estimate reflected an annual growth rate of 4.3 per cent for the period of 1955 to 1980, lower than any of the other contemporary predictions noted in his study. His conservatism doubtless was encouraged by the pessimistic predictions of FPC and PMPC.

In short, there is a real need in the United States for the development of standards and procedures which will produce more nearly accurate power use forecasts. To be realistic, such standards must be freed of criteria and attitudes which have produced such low estimates in the past.

2. Experience of two regions

The experience of distributors of power in the Tennessee Valley and in the service area of the Bonneville Power Administration supports the suggestion that the future annual rate of growth of electricity generation in the United States may well approximate that recorded from 1946 to 1958 - i.e., 9-9.5 per cent per year - and that present forecasts of the Federal Power Commission and private power company spokesmen are too conservative.

Figure V outlines the rates of growth of electricity consumption by customers of the distributors of the wholesale power supplied by TVA and BPA. TVA figures include only that power distributed by municipalities and rural electric cooperatives. The huge power requirements of the Atomic Energy Commission and other Federal agencies and some direct industrial customers have been excluded. Had these been included, the TVA curve would slope upward even more sharply.

BPA sales to Federal agencies account for less than 10 per cent of the total sales, and so an adjustment similar to that made for the TVA curve was not made. Its growth curve approximates that of TVA quite closely. That of the private power companies shows a consistently weaker growth rate despite the fact that it includes all sales, including those of Federal agencies.

The achievements of the municipal utilities and rural electric cooperatives in these two regions are instructive: by 1958, the total sales of the distribution utilities served by TVA power had increased to 5.8 times the level of sales in 1945; in the case of BPA, 1958 sales were 3.3 times the agency's 1945 figure. In contrast, the private power companies' generation was 2.66 times their 1945 figure.

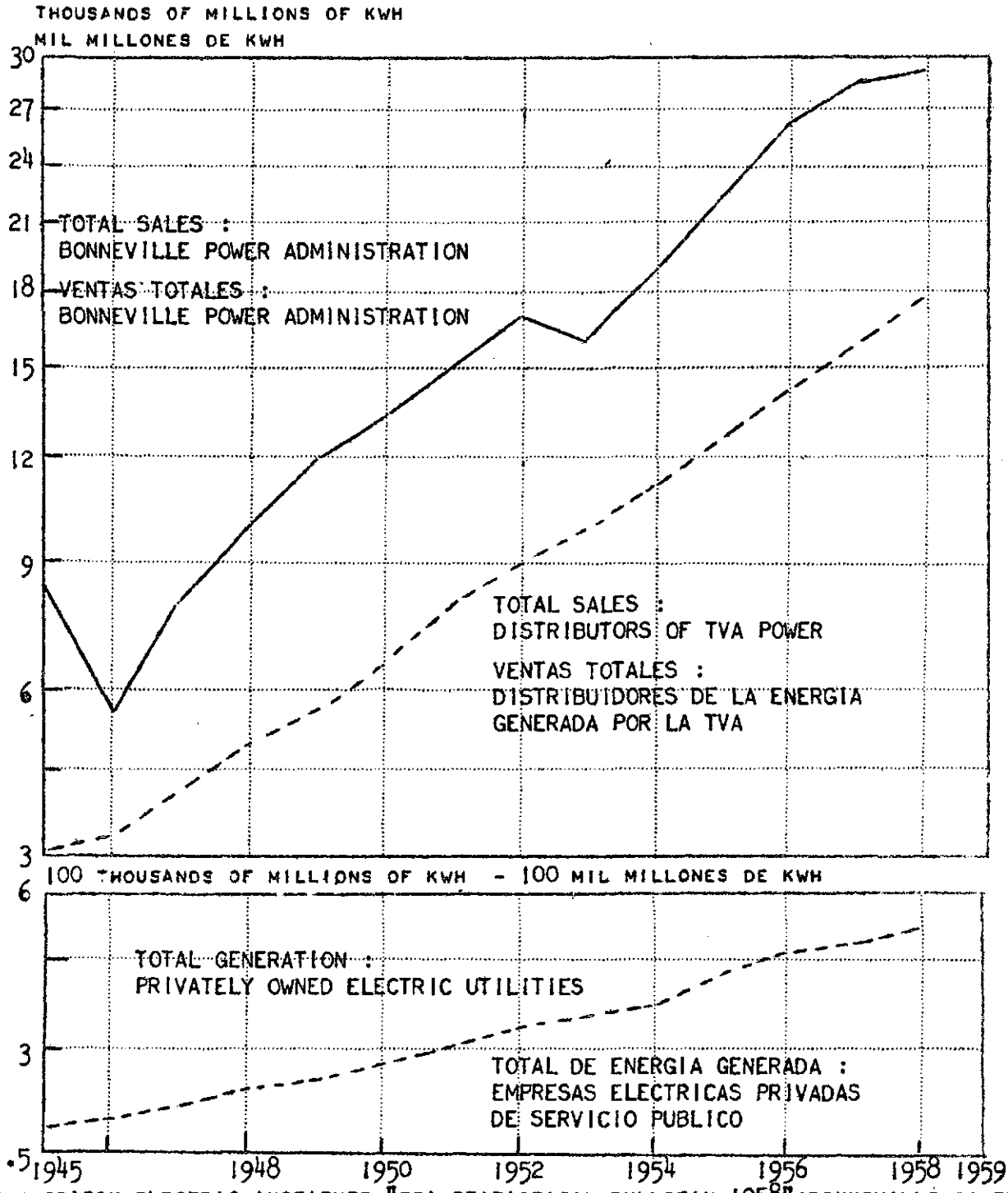
Since the war, TVA area loads - exclusive of enormous Federal demands - have grown at an annual average rate of 12.7 per cent, about one-third greater than the national average. In its Power Annual Report, 1960 the Tennessee Valley Authority states that its sales of power to distributing utilities have "been growing at an average rate of approximately 12 per cent annually. The residential, commercial and industrial customers

/of these

FIGURE V
GRAFICO V

RATES OF GROWTH IN THREE SECTORS OF THE UNITED STATES ELECTRIC UTILITY INDUSTRY, 1945-1958

TASAS DE INCREMENTO DE TRES SECTORES DE LA INDUSTRIA ELECTRICA DE SERVICIO PUBLICO EN LOS ESTADOS UNIDOS 1945-1958



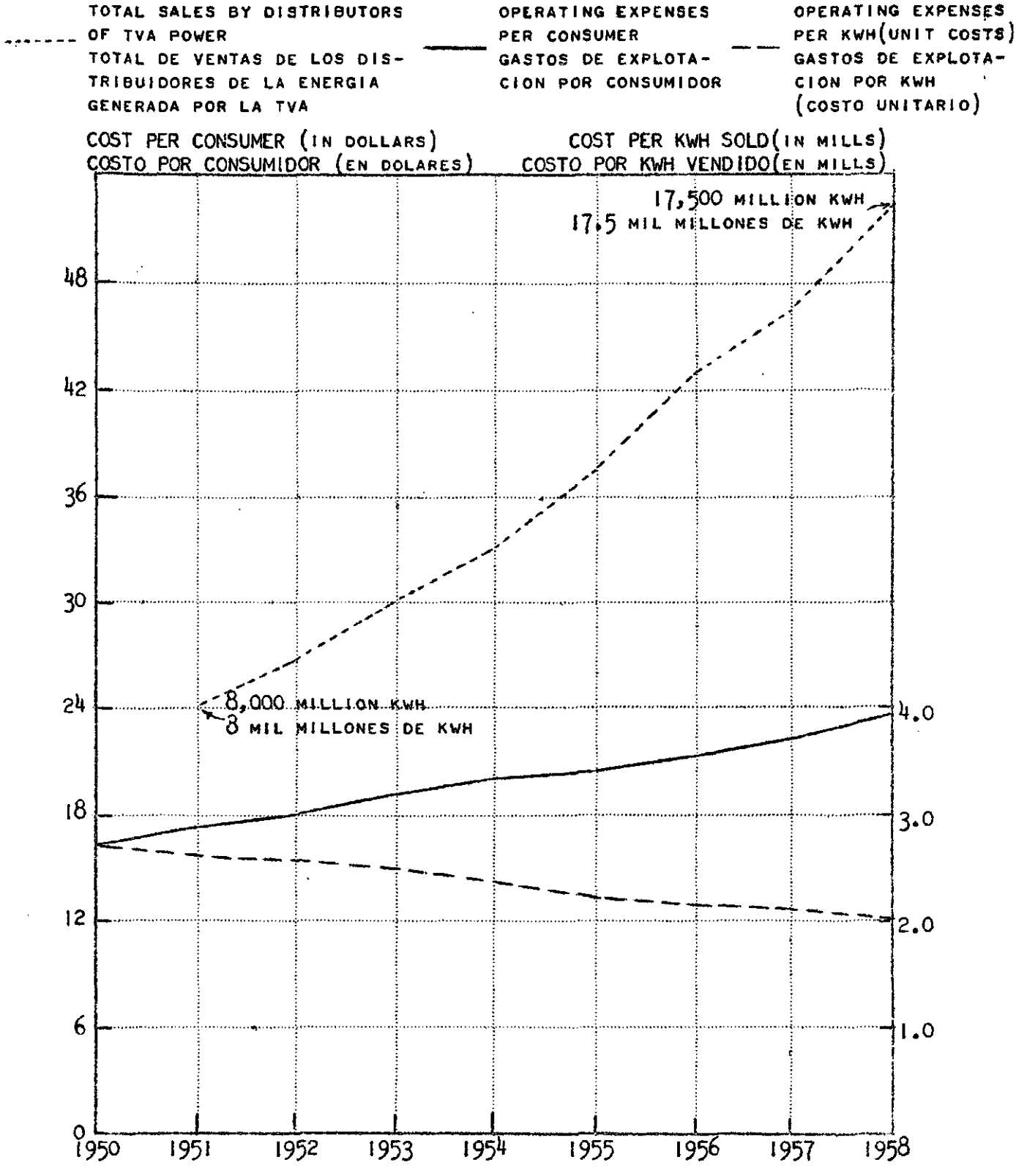
SOURCE ; EDISON ELECTRIC INSTITUTE, "EEI STATISTICAL BULLETIN-1958"; BONNEVILLE POWER ADMINISTRATION, "GENERATION AND SALES STATISTICS". FISCAL YEAR 1959; TENNESSEE VALLEY AUTHORITY, "ANNUAL REPORTS".

FUENTE ; EDISON ELECTRIC INSTITUTE, EEI STATISTICAL BULLETIN-1958; BONNEVILLE POWER ADMINISTRATION. GENERATION AND SALES STATISTICS. AÑO FISCAL 1959; TENNESSEE VALLEY AUTHORITY, INFORMES ANUALES.

FIGURE VI
GRAFICO VI

ST/ECLA/CONF.7/L.1.12

DISTRIBUTORS OF TVA POWER : SALES, PER CUSTOMER COSTS AND UNIT COSTS 1950-1958
DISTRIBUIDORES DE LA ENERGIA GENERADA POR LA TVA, VENTAS, COSTOS POR CONSUMIDOR Y COSTO UNITARIO, 1950-58



SOURCE ; PAPER PRESENTED BY G.O.WESSENAUER, MANAGER OF POWER, TENNESSEE VALLEY AUTHORITY, AT THE SIXTEENTH ANNUAL CONVENTION OF THE AMERICAN PUBLIC POWER ASSOCIATION, SEATTLE, WASHINGTON, 26-28 MAY 1959

FUENTE : DOCUMENTO PRESENTADO POR G.O.WESSENAUER, MANAGER OF POWER, TENNESSEE VALLEY AUTHORITY A LA DECIMOSEXTA CONVENCION ANUAL DE LA AMERICAN PUBLIC POWER ASSOCIATION, SEATTLE, WASHINGTON, MAYO 26-28, 1959

of these distributors have been doubling their use of electricity every six or seven years". The annual growth in sales to residential customers, TVA said, "were 15 per cent higher in (fiscal year) 1960 than in 1959. Annual growth has been averaging about 12 per cent and the same rate of growth is anticipated in the foreseeable future".

The Pacific Northwest has experienced similarly rapid growth and high use. Sales by the Bonneville Power Administration rose meteorically from 191.9 million kWh in 1940 to 8,500 million kWh in 1945 to 13,000 million kWh in 1950, and to 28,200 million kWh in 1957, responding to ever-increasing demands which declined but momentarily after the war effort halted. Up to 1957, the annual average growth rate since The Second World War averaged 13.3 per cent, including one year of decline.

The unusually high sustained growth rates in electricity use in the TVA and BPA areas demonstrate that low rates coupled with vigorous sales promotion programmes have a dramatic effect on the "demand" for power. Thus, TVA reports that "the average residential use in the TVA service area during (fiscal year) 1960 was 8,806 kilowatt-hours...The average rate was .99 cent a kilowatt-hour, the first time it dropped below one cent. The corresponding national averages were 3,700 kilowatt-hours and 2.5 cents."

In the Pacific Northwest, many local public power agencies and rural cooperatives retailing power under the same low-rate, high-use philosophy have approximated or surpassed the achievements of the distributors in the TVA service area.

The high consumption per customer in these areas has, in turn, reduced unit costs and made it possible to maintain low rates or to reduce them to still lower levels - during a period when rate increases by power companies have become increasingly common. Increased revenues and an accelerated rate of expansion in electricity generation also have resulted.

By 1958, as seen in figure VI, operating expenses per consumer were 150 per cent those of 1950 for distributors of TVA power. These costs did not include wholesale power charges and represented unit costs to some degree under the control of management. On the other hand, operating expenses per kilowatt-hour had declined sharply, from about 2.7 mills to 2 mills. Total 1958 kilowatt-hour sales by all distributors were 275 per

/cent those

cent those of 1950.

Results similar to those in the TVA area are reported by public and cooperative power systems in the Pacific Northwest who also have adhered to principles of low rates and vigorous load promotion.

As a further illustration of the relationship of volume of use per customer to unit costs, figure VII notes the national residential service revenue and use curves, as formulated by FPC. The 1958 average national residential use approaches 230 per cent of the 1950 figure, while the average retail unit price decreased from about 2.9 mills to 2.5 mills.

Professor Roy E. Huffman, writing in the journal, Law and Contemporary Problems for a 1957 symposium on "Water Resources" said that the elasticity of demand for electrical energy was an example of a theoretical concept of resources development and use which had "not been accepted by private enterprise." He endorsed the conclusion reached by Anshen and Wormuth in their 1954 study that:

> "By showing that lower rates led to increased consumption which more than compensated for rate reduction, it (TVA) stimulated expansion into new markets by privately owned utilities. This is a task which in all probability could have been performed only by public ownership. Public utilities are conservative, partly because of their monopoly position and partly because they know that in the long run, despite all their exertions, their earnings will be pretty largely limited by the regulatory authority to a fixed return on their valuation. The prospective rewards of innovation are much outweighed by the risks. Nor could a regulatory commission constitutionally compel a public utility to embark upon speculative rate reductions in the hope that the resulting increase in consumption would compensate for the lower selling price per power unit. Yardstick competition comes down in the end to the use of public "risk capital" to pilot the way for expansion of private enterprise." 11/

3. Experience in Puerto Rico

The Commonwealth of Puerto Rico is another area of the United States in which there has been remarkably rapid growth in electricity production

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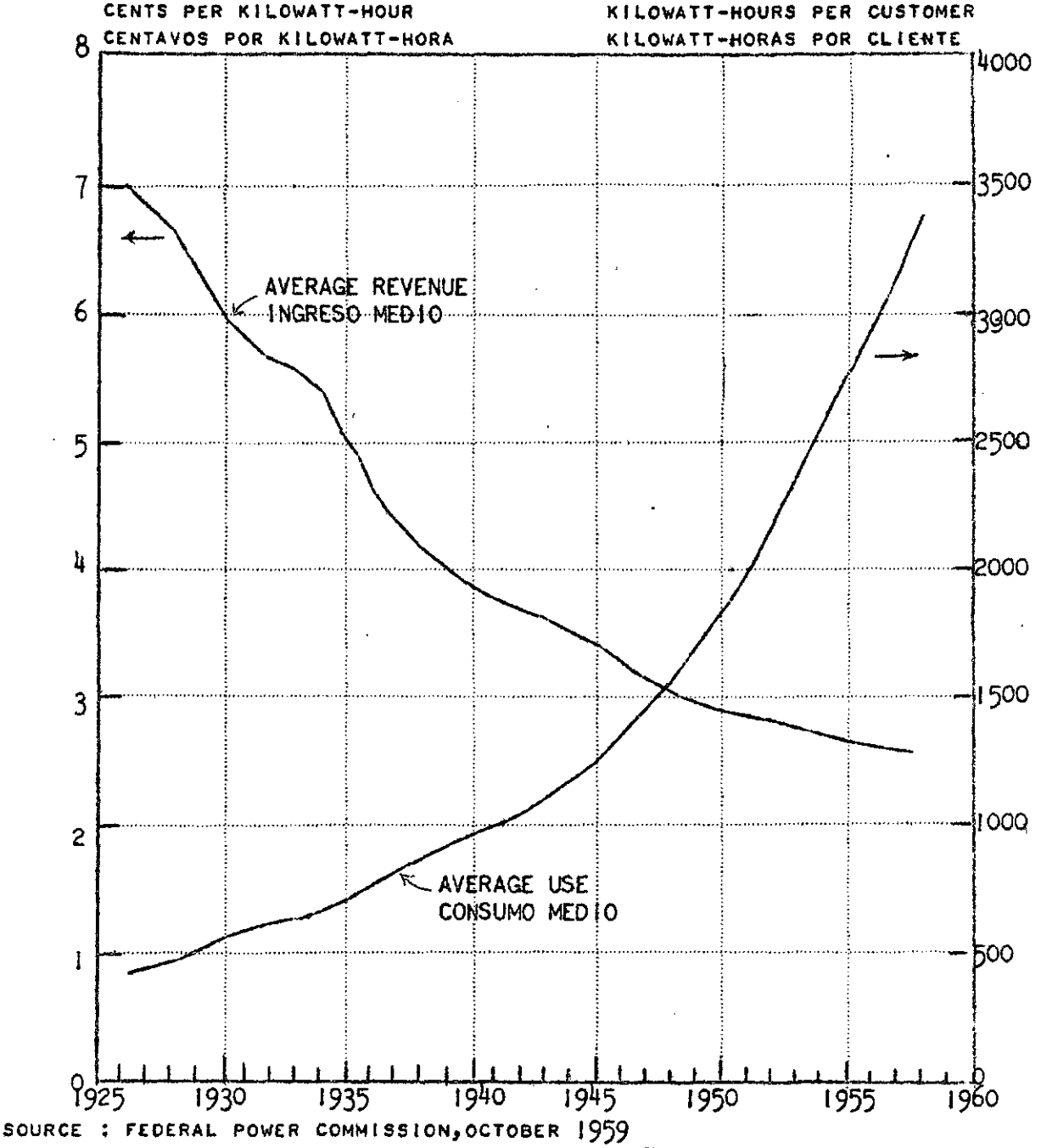
11/ Melvin Anshen and Francis D. Wormuth, Private Enterprise and Public Policy, 1954, pag. 288. Cited in "Role of Private Enterprise", Law and Contemporary Problems, Vol. XXII, 1957, Duke University School of Law, pg. 443.

/and consumption

FIGURE VII
GRAFICO VII

RESIDENTIAL SERVICE AVERAGE USE PER CUSTOMER AND AVERAGE REVENUE PER KILOWATT- HOUR : TOTAL ELECTRIC UTILITY INDUSTRY, 1926-1958

CONSUMO RESIDENCIAL MEDIO POR CLIENTE E INGRESO MEDIO POR KILOWATT-HORA DEL TOTAL DE LA INDUSTRIA ELECTRICA DE SERVICIO PUBLICO 1926 - 1958



SOURCE : FEDERAL POWER COMMISSION, OCTOBER 1959
FUENTE : COMISION FEDERAL DE ENERGIA, OCTUBRE 1959

and consumption during the past fifteen years. The Puerto Rico Water Resources Authority was created in 1941 and by 1944 assumed responsibility for providing power for the island.

Although retail power rates are markedly higher than in such areas as the Tennessee Valley because all fuel must be imported, the growth in requirements for electricity in Puerto Rico has been unusually great since the Authority went into operation. The Authority has established an island-wide integrated power supply system and pursued effective programs of electrification in both rural and urban areas. These have been important elements in the Commonwealth programmes for economic improvement and industrialization, which in turn have contributed importantly to the rapidly rising demands for electric energy.

The table below illustrates the rate of growth in gross generation by the Authority since 1946.

Fiscal year	PRWRA Gross generation (millions of kilowatt-hours)	Annual compound rate of growth
1946	342.9	
1950	529.4	12% during 1946-50
1955	933.6	12% during 1950-55
1959	1,733.8	16% during 1955-59

4. Forecasts of future hydro development

Hydroelectric development is a particularly important element in a nation's power development program. Thus hydro ordinarily offers the advantages of a source of power in which the fuel cost is zero combined with the concurrent development of the water resource for such other purposes as navigation, municipal and industrial water supply, flood control and recreation.

Furthermore, as a power system grows beyond the capacity of available hydro and turns increasingly to thermal stations, experience indicates that the value of hydropower facilities to the system actually increases as they are used more and more for peaking purposes.

/In the

In the United States, the forecasts of potential economic hydroelectric capacity unfortunately have suffered from the same conservatism as have the forecasts of total future power requirements. It seems likely that these consistently low forecasts have been one of several factors accounting for the fact that the rate of hydro development in the United States has not been as rapid as is desirable.

Total United States hydroelectric potential was estimated by the Federal Power Commission in 1959 at slightly more than 141 million kilowatts, including about 19 million kW in Alaska. About 29 million kW of this total have been developed. In addition, the FPC reported "with some confidence" that 36 million kW in additional capacity will be installed by 1980.12/

In Hydroelectric Power Resources of the United States, Developed and Undeveloped: 1957, the FPC described certain standards used in its classifications. "The estimates of undeveloped water power", the Commission states, "include projects on which economic feasibility has been demonstrated as well as projects at sites where physical conditions indicate engineering feasibility and promise at some time of economic feasibility". The Commission also recognizes that the picture of potential feasible hydro development is "constantly changing".13/

(a) Hydro estimates revised upward

The total United States potential of feasible hydro is "constantly changing" upward. A recent resources for the future analysis noted the conservatism of FPC estimates and pointed out that "hydropower resources are at least as much as the estimate, and certainly something more. Just how much more is, again, impossible to say."14/

12/ Statement of Francis L. Adams, Chief, Bureau of Power, Federal Power Commission, before the Subcommittee on Automation and Energy Resources of the Joint Economic Committee, October 13, 1959.

13/ Federal Power Commission, "Hydroelectric Power Resources of the United States, Developed and Undeveloped: 1957", 1957, pg. 19.

14/ Bruce Netschert, Senior Research Associate, Resources for the Future, Inc., before the Subcommittee on Automation and Energy resources, Joint Economic Committee, October 12, 1959.

/In its

In its 1935 National Power Survey - Interim Report, the Commission concluded that the hydro potential for the 48 States was probably about 53 million kW. This is less than half the 1959 estimate of about 122 million kW for the same 48 states, exclusive of Alaska and Hawaii. In less than 25 years, FPC predictions of the country's hydro potential went up by more than 100 per cent.

Furthermore, the 1959 figures exceed the Commission's 1957 forward estimate by about 4 million kW. The 1957 estimate, in turn, exceeds that of 1953 by 2.6 million kW. These past six years have thus witnessed "additions" of some 6.6 million kW of potential capacity - more than one-fifth of the total hydro capacity that had been developed up to 1958.

(b) Future upward revisions expected

A major reason for the consistent underestimating of future potential appears to have been the propensity to consider sites infeasible or marginally feasible if they, at any time, had been considered of marginal economic value. Thus a Resources for the Future consultant, Bruce C. Netschert, ably pointed out in testimony given before the Subcommittee on Automation and Energy Resources of the Joint Economic Committee in October 1959, that:

> "the specter of much higher marginal costs has clearly been in the minds of those who have attempted to project future levels of installed capacity. A survey of all published estimates of installed hydro capacity in 1975 reveals an implied growth rate of 3.5 per cent annum from the base year of each estimate to 1975."

However, the witness said, actual rates of annual hydro capacity growth have been considerably higher - 4.5 per cent from 1926 to 1958, 4.3 per cent from 1935 to 1945, and 5.5 per cent from 1946 to 1958. He estimated that these growth rates would increase to 8.0 per cent from 1958 to 1961.

FPC's record of hydro forecasts which consistently have had to be corrected upward parallels its record of conservatism in predicting total national use of electricity. Even so, the Commission's views regarding the nation's hydro potential are more optimistic than those held by a large segment of the United States private power industry.

/(c) Progress

(c) Progress in technology

Technical progress in fields related to water resources development has meant an ever-widening horizon for hydropower development. A major study sponsored by Resources for the Future and published in 1959 - Technology in American Water Development - analysed technology's impact on energy consumption. The authors, Ackerman and Lof, concluded that:

> "The steadily increasing efficiency with which electricity is generated has resulted in a gradual reduction in cost so that its use has gained at a greater rate than other sources of energy." 15/

As to continuing technological advances in hydropower, the authors pointed to developments which include:

(i) The "rapid increase" in the capabilities of earth-moving machines - 50-ton dumptrucks, conveyor belts, scrapers, bull-dozers and the like - which have contributed striking increases in efficiencies in dam construction.

(ii) Advances in design, utilization of materials and site preparation for concrete dams, affording cheaper ways to store and use river flows. New construction in the United States, the study notes, has been more conservative toward design innovations, up to now, than in Europe.

(iii) Development of integrated regional water systems, based specifically on the extensive experience of TVA in exploiting the economies possible in such a system, with hydro operating more often at capacity, new hydro units at sites previously considered economically impractical, and new methods of managing water flows being cited as important contributors to hydro's more favorable position.

Technical progress likewise has resulted in the introduction of pumped storage projects.

High-voltage transmission over long distances will also enhance hydropower development. The United States has some transmission at 345,000 volts and tests are underway on the feasibility of transmission voltages exceeding 460,000 volts. Voltages exceeding 345,000 volts are already in use in other countries.

Technical progress doubtless will continue to contribute to the development of economically feasible hydroelectric potentials where they did not exist previously.

15/ Edward A. Ackerman and George O. G. Lof, Technology in American Water Development, The Johns Hopkins Press, 1959, pg. 318.

/(d) Hydro

(d) Hydro power for peaking purposes

However, hydro necessarily will continue to represent a relatively small share of total United States electricity generation and the bulk of the massive future demands will be met by thermal generation, although regional exceptions will remain for some time.

Nevertheless, the "newer steam technology", in the words of Ackerman and Lof, "in almost every instance may be interpreted as having a favorable effect upon the development and management of multiple-purpose water facilities and multiple use of water in the United States." They conclude that:

> "In spite of the vast expansion of steam power generating facilities now anticipated, steam plants are not expected to displace hydroelectric plants, because of the much enhanced value of water power for peaking purposes on systems within reach of both types of generation." 16/

This coincides with the view of the Chief of the Division of River Basins of FPC who pointed to the two immutable virtues of hydro:

> "...hydro power, unlike fuel-produced power including atomic, is a renewable resource and once developed continues to produce without depletion of available resource reserves. Furthermore, as already noted, hydroelectric power can serve an important and useful place in regional power economics by carrying the variable demands of peak loads." 17/

In developing forecasts of hydroelectric development, it would seem desirable to give full consideration to hydro's unique role in natural resource development and power production as suggested by the foregoing comments.

5. Power industry organization

Among the factors influencing the rate of growth in power generation and consumption, an important one is the manner in which the power industry is organized.

16/ Ibid., p. 319.

17/ Frank L. Weaver, Chief, Division of River Basins, Bureau of Power, Federal Power Commission, "Outlook for Hydroelectric Development", 5th Annual Conference, Atomic Energy in Industry, National Industrial Conference Board, 1957, p. 10.

A means to cheaper and more plentiful electric service using large-scale generation and transmission was proposed 35 years ago by Governor Gifford Pinchot of Pennsylvania. Governor Pinchot's 1925 report of his Giant Power Survey Board to the General Assembly of the State of Pennsylvania contained principles which are generally relevant to the contemporary situation. Referring to the State of Pennsylvania, for example, the report recommended:

> "Mass production of thermal power by giant power generating stations of great capacity in or near the coalfields, supplying large capacity transmission lines connecting with all other major transmission lines in the State;
>
> "Creation of a common pool of power into which current from all sources will be poured, and out of which current for all uses may be taken. This is to be secured by making these giant power companies common purchasers of surplus power from all generating stations in the State and common sellers to all distributing systems in the State;
>
> "Free access by every waterpower and steam-generating station to every potential purchaser, which means every distributing system in the State which supplies the consumer, through making all major transmission lines common carriers;
>
> "Systematic extension of service lines throughout rural areas by farmers' mutual companies and rural electric districts served on an equality with all other distribution systems by current from the giant power companies or any other generating stations delivered over the common-carrier transmission lines." 18/

Testimony by power company officials in 1956 at hearings held by a committee of the United States Senate indicated that private industry had come to consider regional, large-scale generation and transmission not only as technically feasible but highly desirable. They described in detail the engineering and economic logic which supports the development of "giant power" wholesale supply systems in the course of an unsuccessful endeavor to amend major provisions of the Public Utility Holding Company Act of 1935.19/

The nature and number of generating plants throughout a country will depend to a great extent upon the manner in which the need for

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18/ From the Governor's Message of Transmittal of "The Report of the Giant Power Survey Board to the General Assembly", Commonwealth of Pennsylvania, February, 1925, pp. v-vii.

19/ Hearings before a Subcommittee of the Committee on Interstate and Foreign Commerce, United States Senate, on Amendments to Public Utility Holding Company Act, 1935, Government Printing Office, 1956, p.317 ff.

/...

large-scale generation and transmission is met. The economics of nuclear power, for instance, probably will favour very large plants operated on base load in large, integrated generation and transmission systems. Similarly, the value of hydro capacity for peaking energy is greatly enhanced when it is integrated into a regional supply system. As is well established, substantial economies are possible through the use of very large coal-fired plants and these, too, are feasible only for large, integrated power supply grids.

The achievement of a more rational organization of wholesale power supply is now generally recognized as being of great importance. It can make possible improvements in fuel utilization, transmission direct from power plants at coal fields to distributors, increases in thermal efficiency, reductions in unit capital costs, and other economies attainable only through large-scale production and the regional integration of wholesale power supply.

6. Conclusion

It is, obviously, difficult to forecast future needs and sources of electricity with a great sense of certainty. This memorandum has pointed to the historical expansion in the use of electricity in the United States, and has suggested that the 9-9.5 per cent annual rate of increase experienced in the United States since the Second World War may well continue for many years to come.

It is evident that hydro power will continue to be an important and integral part of the national power supply picture. Less than one-fourth of the currently estimated potential capacity of the country has been developed, and the total potential capacity itself doubtless will continue to increase as further technological developments occur. The inevitable trend to very large thermal stations will increase the value of hydro and further encourage the development of additional hydro capacity. Nuclear power ultimately will assume an important role, the timing depending upon a number of factors. A trend toward large generating units integrated by high voltage transmission is apparent, but policies and programmes are needed in the United States to guide as well

/as accelerate

as accelerate this development and to control it in the interests of the people of the United States.

Experience demonstrates that an abundant supply of low-cost power, coupled with vigorous promotion of power use, result in a rapid growth in power use per customer. These higher per customer sales result in reduced unit costs and make low rates economically feasible. The end result and, of course, the basic objective of a program for low-cost power supply and distribution is a dramatic improvement in living standards for the people of the region.

Forecasting future power requirements thus is more than the simple extension of past trends or the adding together of individual utility estimates. However done, a power forecast unavoidably becomes something of a goal or objective. More important, perhaps, it may have great influence on the scope and timing of expansion plans. An unduly conservative forecast to a degree is self- enforcing, to the extent that it encourages the utility system to build capacity only for definitely foreseeable demands, and to slow down growth of consumption by a policy of high rates.

In any case, forecasting should be recognized as the quantitative expresssion of the broad policies and plans of the power industry for providing electricity in future years to the people whom it serves.

SUMMARY

The forecasting of future power requirements requires making assumptions about the basic policies which are to govern the future power industry. Policies of widespread electrification, low rates and organization of the industry for production at lowest cost will mean a more rapid future growth in power consumption than if restrictive policies are followed.

Forecasts of future national power requirements in the United States characteristically have underestimated the rate of growth in power consumption. This tendency is still evident, although the U.S. rate of growth has approximated 9 per cent per year compunded since 1902. In the Tennessee Valley Authority service area, requirements have increased at an average annual rate of 12.7 per cent since World War II, exclusive of huge Federal agency loads. A similar rapid growth rate has been maintained in the Pacific Northwest. The experience of these regions demonstrates graphically the degree to which low rates and intensive promotion result in very high use of electricity per consumer. This high use per customer results in low unit costs which make the low rates feasible.

In Puerto Rico, annual growth rates of 12-16 per cent have been experienced since 1946, due in this case largely to a vigorous program for electrification of the island and establishment of an efficient generation and transmission system by the Puerto Rico Water Resources Authority.
The forecasting of future hydro power development is an especially important element in projecting the development of the power industry, because of hydro's unique advantages for and functions in a power supply system. In the United States, national forecasts of potential economic hydroelectric capacity have suffered from the same conservatism as have forecasts of total future power requirements. In less than 25 years (1935-59), the Federal Power Commission estimate of United States hydropower potential more than doubled. One reason for the growth in potential has been steady progress in water resources development technology.

The factors accounting for constant growth in the past of hydropower potential should be kept in mind in further forecasting, as should the prospects for the rational organization of additional regional power supply systems. The rate of development of low-cost hydro and the degree to which power production will be organized for achieving lowest costs both should affect the forecasts made of future total power requirements and production.

/Forecasting future

Forecasting future power requirements should be more than the simple extension of past trends of the adding together of individual utility estimates. A forecast inevitably becomes something of a goal or, if too conservative, possibly a limiting influence. Forecasting should be recognized as the quantitative expression of the plan for providing electricity in future years to the people to be served.