

Federal Power Commission.

National Power survey

Interim Report, Power series no. 1

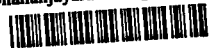
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FEDERAL POWER COMMISSION

NATIONAL POWER SURVEY
INTERIM REPORT

POWER SERIES No. 1

1935



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**NATIONAL POWER SURVEY
INTERIM REPORT**

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LETTER OF TRANSMITTAL

MARCH 22, 1935.

The PRESIDENT,
White House, Washington, D. C.

SIR: We submit herewith the first report of the National Power Survey which has been conducted by the Federal Power Commission under the provisions of Executive Order No. 6251 of August 19, 1933.

The facts developed in this interim report have an important bearing not only upon conditions in the electric light and power industry but also upon the problems of unemployment, industrial recovery, and national defense. This report presents for the first time an analysis of the relation between the Nation's power requirements and the generating capacity of existing power plants. It shows by districts the shortages and surpluses of power that will exist upon a resumption of normal industrial activity.

This information is essential to sound planning for the future development of the Nation's power resources.

Respectfully submitted.

FRANK R. MCNINCH,
Chairman.

BASIL MANLY,
Vice Chairman.

HERBERT J. DRANE,
Commissioner.

CLAUDE L. DRAPER,
Commissioner.

CLYDE L. SEAVEY,
Commissioner.

LETTER OF SUBMITTAL

MARCH 15, 1935.

To the FEDERAL POWER COMMISSION:

Pursuant to the instructions of the Commission and the provisions of the President's Executive Order authorizing the National Power Survey, there is submitted herewith the first of a series of reports on the Nation's power resources and power requirements. This is in the nature of an interim report.

The results and summaries contained in this report, as well as the tentative conclusions, are based largely on an analysis of the returns of 215 electric utility systems, comprising 391 privately owned major electric operating properties and 21 major municipally owned electric operating systems. The installed generating capacity of these 215 systems is 91 percent of the total installed generating capacity of electric utilities in the United States. Their output represents 93 percent of the electrical output of the publicly and privately owned utilities of the entire country.

The staff of the National Power Survey takes this opportunity to express its appreciation of the cooperation of the municipal plants and private companies in supplying detailed information concerning their generating plants and transmission systems, characteristics of their load, and other pertinent information; also of the information furnished in published and unpublished form by the Corps of Engineers, United States Army; the United States Geological Survey; the Bureau of Reclamation; the Department of Agriculture; the Bureau of Mines; the Bureau of the Census; and the Federal Emergency Administration of Public Works.

In the conduct of the survey valuable assistance has also been received from the regular staff of the Federal Power Commission, particularly its Chief Engineer and Chief Accountant, and from the staff of the Electric Rate Survey whose field forces assisted in collecting returns from municipalities and companies in the field. Without the cooperation of all of the above, it would not have been possible to present this report.

Respectfully submitted.

THOMAS R. TATE,
Director, National Power Survey.

FOREWORD

By BASIL MANLY, Commissioner in Charge, National Power Survey

This is a preliminary report on the results of the first engineering study of the electric light and power industry that has ever been made on a national scale in the United States.

Other nations have made elaborate surveys of their power resources and requirements extending over a period of years and involving large expenditures. Regional surveys have been made in this country and have proved their value both to the Government and to industry. Individual utility systems have made detailed studies of their available resources and probable demands for power at an expense exceeding the appropriation made for this nation-wide survey. But hitherto no attempt has been made in this country, either by the Government or by any private agency, to determine from a national standpoint the relation between present and future requirements for electrical energy and the capacity necessary to meet such demand. Nor has there been an appraisal of the efficiency of the generating plants of the major public and private utility systems. The water power resources of the country have been studied by various public and private agencies and a vast amount of more or less valuable data has been accumulated. But no attempt has been made on a national scale to evaluate these data and coordinate them with information regarding present and future markets for power.

A Pioneer Undertaking

The National Power Survey is, therefore, a pioneer undertaking. Congress had clearly indicated in the Federal Water Power Act of 1920 its intention that such an inquiry should be made, but until the President issued his Executive Order of August 19, 1933, the Commission had neither the authority nor the funds to carry it out. When the work was begun not even a complete and accurate list of private utilities and municipal plants was available. Months had to be spent in making preliminary inquiries and analyzing such fragmentary information as was available before sound and effective plans could be devised for the conduct of the survey.

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Whatever valuable results the Power Survey has been able to accomplish may be attributed primarily to three principal factors:

1. The solid foundation established in the early stages of the undertaking through conferences with the best informed public and private authorities connected with the electric light and power industry.

2. Careful selection of the staff, in the course of which 3,000 applications for engineering positions and 2,000 applications for other employment were reviewed, the majority being personally interviewed by two or more persons experienced in the choice of personnel. As a result of this careful selection from the large number of exceptionally qualified men rendered idle by the depression, the National Power Survey has assembled a staff that ranks high in technical training, practical experience and other qualifications.

3. Whole-hearted cooperation of the officials of municipal plants and the executive officers of the private companies. Recognizing the great practical value of such a survey they have, almost without exception, not only compiled and furnished the required data but in many cases have also made available the results of special investigations which had been conducted for their private information.

Its Practical Value

The National Power Survey is not an academic inquiry but a practical undertaking of great immediate and future value not only to the Government but to every branch of the electrical industry. "It should have been made 10 years ago," one of the leading engineering authorities of the country recently declared. "If it had been, the industry would have been saved many of its most serious blunders and the Government would have been able to plan its public-works program on a solid foundation of established facts." Such a survey of the Nation's power resources and power requirements is an essential factor of national defense. The War Department, acutely realizing this fact as a result of the critical shortage which occurred during the World

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War, has sought to compile certain essential information annually through the district offices of the Corps of Engineers. But there has never been available hitherto even a fraction of the comprehensive and accurate information that has been assembled and is now being analyzed by the National Power Survey.

This Interim Report presents a birdseye view of certain major aspects of the electric light and power industry. It is not a microscopically accurate picture such as might be obtained if it were possible to make a thorough study of the conditions in each separate district. The possible margins of error are, however, small and the results are not likely to be materially affected by the refinements which will be employed in the preparation of subsequent reports. It is significant that the results reached by the National Power Survey in estimating the demand that will exist upon the resumption of normal industrial activity coincide almost exactly with the forecasts for the same districts prepared by private companies and municipal plants for their own purposes.

This information is of great public value not only in its bearing upon conditions in the electric light and power industry but also in relation to the problems of unemployment and industrial recovery. Much has been said during the past 5 years about the supposed surplus of electric generating capacity in the United States. Until quite recently this has been true enough if the situation was viewed from the short-range standpoint of the relation between existing capacity and the immediate demand during a period of depression. In recent months, however, the use of power has been rapidly increasing until in many districts the demand is nearing the limit of available efficient generating capacity.

It takes 2 years to plan and construct a large modern steam plant and from 2 to 7 years to plan and build a large water-power project. It is the part of wisdom, therefore, to determine at this time what new generating plants and transmission lines will be required to meet the demands that will be created by a resumption of normal industrial activity and where they should be located to supply the demand most efficiently and economically. It is time also to take stock of the existing private and public plants and ascertain which of them are inefficient or have become obsolete. Finally, the

national interest requires the most accurate possible inventory of the Nation's undeveloped water-power resources in their relation to present and future markets for power.

Outstanding Results

These are the principal lines of inquiry that have been pursued by the National Power Survey during its initial stages. The first tentative but significant results are presented in this Interim Report. They may be summarized as follows:

1. The use of electricity for domestic purposes as well as in certain branches of industry has grown at such a rate during the depression that, upon a resumption of normal industrial activity, the demand for power will be at least 4,000,000 kilowatts in excess of that which existed in 1929. This is equivalent to the capacity of some 50 large generating stations.

2. Very little new generating capacity has been constructed by the privately owned utilities since 1930. As a result, the capacity of existing plants is 2,325,000 kilowatts less than the demand that will exist for power upon a resumption of pre-depression industrial activity, assuming maintenance of normal reserve capacity.

3. This shortage is being rapidly accentuated by the obsolescence of plants which would have been replaced under normal conditions. As of January 1, 1935, 56 percent of the total installed steam-electric capacity of the United States was at least 10 years old, 11 percent was 20 years old or older, and about 1 percent at least 30 years old. Inefficient and obsolete plants with a capacity of at least 2,000,000 kilowatts should be scrapped and replaced within the near future.

4. Analysis by districts of the relation between the capacity of existing plants and the demand that will be created with the resumption of normal industrial activity shows that critical shortages will exist in almost every section of the United States. The only regions in which substantial surpluses of capacity now exist to meet normal demand are Florida, part of Michigan, an area along the lower Mississippi, North Dakota, Idaho, Utah, and New Mexico and parts of Texas, Minnesota, Montana, Washington, and Oregon.

5. Government plants provided for or under construction will meet these shortages in cer-

tain limited areas. Only one major private power development and one major municipal plant are now under construction. Many of the regions where the greatest power markets now exist and where the shortage will be most acute when industrial activity is renewed do not have projects under construction at the present time sufficient to carry the loads that will develop upon resumption of normal industrial activity.

6. In view of the time required to plan and construct large generating plants, whether hydro or steam, early construction of new plants with an aggregate capacity of between 3,000,000 and 4,000,000 kilowatts is imperative. This would involve capital expenditures of at least \$300,000,000.

7. The critical shortage of existing generating capacity most seriously affects the great industrial districts of the East and Middle West. It would, therefore, be disastrous in case the United States should become involved in war. The situation might be even more acute than that which existed during the World War when, in many districts, electric service had to be denied to domestic and commercial customers and nonessential industries to meet war needs for power.

8. Careful planning under Federal supervision of new power plants and facilities for transmission is required to promote the safety and welfare of the Nation. Selection of sites for hydro or steam plants, to be developed either by public or private agencies, should take into consideration not only the pertinent engineering and economic factors but also essential considerations of broad national policy.

A Chart for the Future

Control of power is a social as well as an engineering and economic problem. If the flow of electricity should suddenly cease, it would be a national catastrophe of unimagin-

able magnitude. Our homes, streets, and highways would be in darkness. Street cars, subways, elevators, and conveyors would suddenly stop and even railroad transportation would be impossible at night without electric signals. Radios would cease to function and the ships on the high seas would be immediately endangered. Factories would be forced to shut down, modern bakeries would cease to produce bread, the water supply of cities would be interrupted by the failure of the electric pumps and perishable food would rapidly deteriorate for lack of refrigeration. There would be no fire alarm, no burglar alarm, no telegraph, no telephone, and few newspapers. Electric light and power has come to be almost as essential an element in our daily lives as the bread we eat and the water we drink. Modern civilization would collapse with the failure of the sources of electric light and power.

The national safety and welfare, the productivity of our industries and the comfort and convenience of our homes are thus dependent upon the maintenance at all times of an abundance of electricity available at rates which will permit its use wherever it is needed. We must, therefore, not only provide for our immediate requirements but we must also plan for continued improvement and expansion of the Nation's electrical systems to meet the demand that may be reasonably anticipated for the future.

Complete engineering knowledge of the existing electric industry, our probable future requirements for power and our available resources are necessary to sound planning either by the Government or private industry. The National Power Survey has been conducted with a view to supplying this essential information. It is in this spirit of fact-finding, rather than of prophesy, that this, its first report, is presented. It is, in effect, a chart for the future development of the electrical resources of the United States.

INTRODUCTION

Authority

The President of the United States by Executive Order No. 6251, dated August 19, 1933, authorized and directed the Federal Power Commission to make—

A survey of the water resources of the United States as they relate to the conservation, development, control, and utilization of water power; of the relation of water power to other industries and to interstate and foreign commerce; and of the transmission of electrical energy in the United States and its distribution to consumers; and on the basis of this survey * * * formulate a program of public works.

It is under this authority that the National Power Survey is being carried on by the Federal Power Commission.

Scope of Survey

One of the primary objectives of the Survey as specifically stated in the Executive Order of President Roosevelt is to formulate a program of public works. This calls not only for a survey of water resources as they relate to the conservation, development, control, and utilization of water power, but to be of practical value must of necessity include a determination of the power requirements of the country and a study of the economic relation between water power and power from fuel plants. This is necessary in order that a correct answer can be made to the following questions:

1. What are the present and future power requirements of the continental United States?
2. From what sources can these power requirements be supplied most economically and efficiently in the public interest?

The Survey is collecting facts and figures from all available sources, including published and unpublished data, and is making original investigations and studies of the following major subjects:

1. The water-power resources, both developed and potential.
2. The relation of the power resources to interstate and foreign commerce, particularly as it is related to the interstate and international transfer of electrical energy and the electrification of certain main-trunk-line railroads.

3. The existing development and utilization of electric power in the United States, the extent of the existing market, and the potential growth of market to be expected.

4. The adequacy of existing facilities and those under construction to meet the present and future power requirements.

5. The possibility of increased utilization of existing facilities through more extensive and coordinated interchange of power.

6. The transmission and distribution of electrical energy.

7. The approximate amount of additional facilities necessary to meet power demands and a determination of the type of projects, whether fuel or water power, best suited to meet the requirements.

The determination of market requirements necessitated special studies of increased domestic use of electrical energy, rural electrification, potential railroad electrification, and use of electric power in industries, including the electrochemical and electrometallurgical fields.

The cost of distribution of electrical energy to domestic and commercial light and power customers is being studied under authority of Senate Resolution No. 80, Seventy-third Congress, first session, and a separate report will be submitted at a later date.

Organization and Procedure

Upon receipt of the Executive Order, Commissioner Basil Manly, vice chairman of the Federal Power Commission, was designated commissioner in charge of the National Power Survey. Thereafter the staff to carry out the Survey was employed and organized. The heads of the staff included Mr. Thomas R. Tate, director, an engineer with extensive practical experience, formerly chief engineer of one of the leading consulting engineering firms and generally familiar with the power problems in every section of the country east of the Rocky Mountains. Prior to his employment on the Survey he had been chief valuation engineer of the Public Utilities Commission of the District of Columbia and was also associated with the Federal Emergency Administration

of Public Works. Mr. Lester S. Ready was employed as chief consulting engineer. He was formerly chief engineer of the California Railroad Commission, and for a number of years has been engaged in consulting practice for State and municipal agencies on the Pacific coast. Heads of divisions included Mr. Percy H. Thomas, chief of the Power Requirements Division, a consulting engineer of proved experience in electrical matters; Mr. Erich A. Mees, chief of the Power Resources Division, a consulting engineer who has had much experience in design and construction of water and fuel power developments; Dr. Fayette S. Warner, chief of the Research Division, a former member of the industrial research department and professor of political science at the University of Pennsylvania, and an engineer with practical consulting experience; Mr. George H. Morse, chief of the Distribution Cost Division, who has specialized for some years on the problem of the cost of distribution of electricity, and Mr. Robert H. Barclay, chief of the Reviewing and Tabulating Section, an electrical engineer with extensive experience with consulting and construction organizations on power and industrial projects. A staff of engineers and assistants, chosen for their special qualifications, have been employed to assist in the collection and study of data. In work of this highly technical character, the education and practical experience of the staff is of vital importance. There is included in appendix A, therefore, a roster of all the staff members with data indicating their general and special qualifications.

Because of the magnitude and extent of the survey, it was apparent that much of the information required regarding present utility development and the power market must be obtained from the various electric utilities through detailed questionnaires and personal investigations and visits to the larger systems; also, that much of the data regarding power resources would of necessity be obtained from the various Federal and State agencies. With this in mind preliminary conferences were held with other Federal agencies, including the Corps of Engineers, United States Army; the United States Geological Survey; the Forest Service of the United States Department of Agriculture; the United States Bureau of Reclamation; the Bureau of Mines; and others; to determine the

extent and source of data and to arrange for obtaining all information available and the cooperation of all Federal agencies.

The Commission also invited a number of the leading representatives of both public and privately owned utilities to participate in the preliminary conferences on ways and means of making this survey. The first of these conferences was held on April 18 and 19, 1934, with Commissioner Basil Manly as chairman. To it were invited those who had been identified with or interested in public ownership of electric utilities. Those present included managers of the larger municipal utilities, consulting engineers for many of the smaller municipal utilities, and representatives of the National Municipal Utilities Association, together with representatives of the Tennessee Valley Authority and the Mississippi Valley Committee. The second preliminary conference took place on April 25 and 26, 1934, those present representing almost exclusively officials occupying prominent positions in the privately managed utility companies. Commissioner Frank R. McNinch, chairman of the Federal Power Commission, and his associates were present at this conference, together with the director of the National Power Survey and chief consulting engineer and division heads.

The scope of both the power survey and the concurrent related survey of electric rates was outlined and discussed and the tentative outline of questionnaires submitted and considered. Valuable suggestions were obtained from the various municipal and private utility representatives and those present gave assurance of the wholehearted cooperation of the various interests in supplying data, thus making possible as adequate a survey as could be made within the limitation of funds and time available.

Following the conferences, an exhaustive report form dealing with the power phases of the electric utilities was prepared. This called for data from all operating electric utilities dealing with the installed capacity, output, and operating characteristics of each power plant, the total power production, the annual quantity of electricity purchased and sold by each company for the last 7 years, details and characteristics of the system load, the load on generating plants and interchange with other systems, operating costs of power plants, and

other statistics required for making a complete and adequate analysis of the company's power operation and in determining the distribution and growth of the power market. These report forms were mailed to all private and municipal electric utilities in August and September 1934. Prior to the mailing of the report blanks, the engineers of the National Power Survey staff called on all of the major private and municipal

gently on the power problems of the country would necessitate the division of the continental United States into a limited number of zones. Although many statistics are given by States and can be so compiled, the present development of the electric-power industry, with the extended transmission systems crossing State lines in many instances, made it advisable to include several States in each zone.

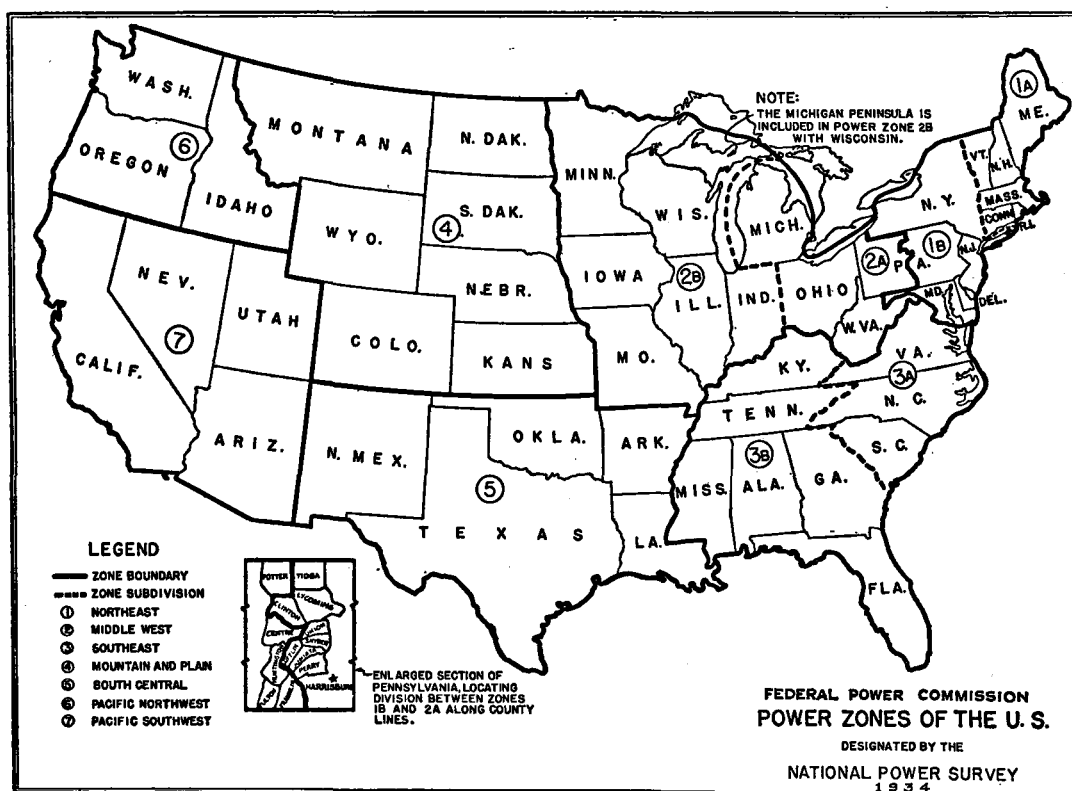


FIGURE 1.—Power zones of the United States.

electric utilities to explain the forms to be used both by the National Power Survey and the Electric Rate Survey. Upon the mailing of the report forms the field staff agents and regional supervisors of the Electric Rate Survey, which had then opened up local offices in several regions throughout the country, followed up inquiries made of private and municipal electric utilities by both surveys and visited practically every electric utility in the United States, advising and assisting them in preparing the returns.

In the planning of the survey it developed early that to study, analyze, and report intelli-

Seven major zones were determined upon as shown in figure 1 (Power zones of the United States). With two exceptions the zone boundaries follow State lines. Three of the zones were further divided into subzones. An examination of the transmission map, figure 3, will indicate generally the considerations which influenced the determination of the zone boundaries.

Information and data on potential power resources were secured through field trips by members of the staff and through the cooperation which made available from the various Federal agencies in Washington reports and

data covering hitherto completed surveys of undeveloped water-power sites in the United States. Engineers of the National Power Survey staff were sent to confer with the State engineers and public-utility commissions of the various States, also with the local offices of the United States Army Engineers, of the Reclamation Service, and of the United States Geological Survey. Many private reports on prospective power developments by utilities and by consulting firms were also secured in these field investigations. As a result the National Power Survey possesses today the most complete and comprehensive information on undeveloped and existing water-power developments in the United States that has ever been collected. The cataloging and evaluation of these sites is in process, and the preliminary discussion of them in this report will be supplemented by further studies which will be made available in a subsequent report.

Special questionnaires were sent to the major electrochemical and electrometallurgical indus-

tries and to the other major industries and in connection with these surveys contacts were made and extensive data obtained by the staff representatives in the field.

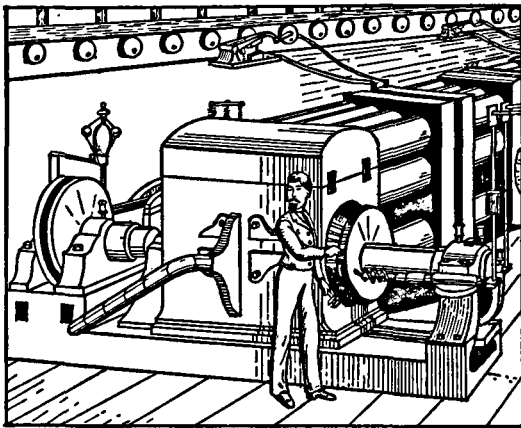
Report forms were sent to private electric utilities and municipal electric utilities. All the larger utilities, both private and municipal, have reported, and it is reasonable to conclude that over 99 percent of the total production of electrical energy by utilities in the United States is covered by the reports received.

The thoroughness with which this work was done together with the high percentage of returns and the carefulness with which the forms were prepared gives the Federal Power Commission the most complete and accurate information concerning the power producing and transmission facilities, loads and load characteristics of the electric utility business that could possibly be secured without making individual field investigations of every electric utility plant and system in the continental United States.

I. DEVELOPMENT OF ELECTRIC POWER IN THE UNITED STATES

Early History

Less than 53 years ago the electric industry in this country was born. From its very small beginnings in New York City it has grown in this period into a great industry which penetrates into every corner of the social and economic life of the country. Few industries,



First steam-electric central station, Pearl Street, New York, N. Y., 1882.

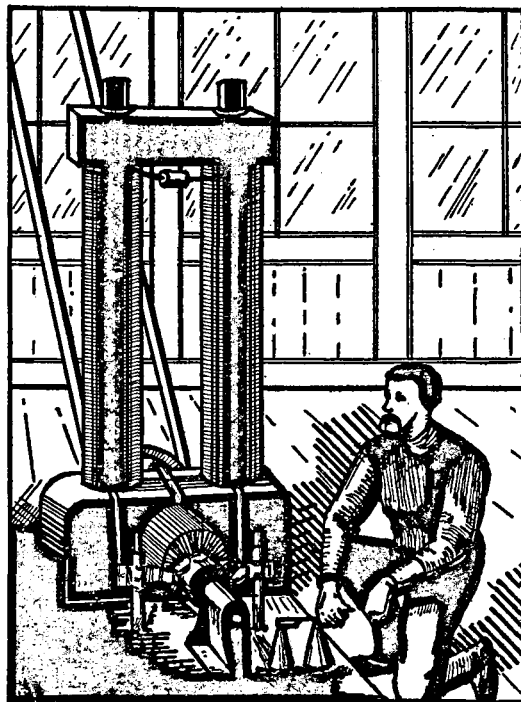
affecting the welfare of the people to the extent that this one does, have had such a rapid growth. Present conditions reflect this. The kaleidoscopic pattern of public and private ownership of power systems and of Federal power development has been determined not only by the method, but also by the very speed with which the industry had to grow to satisfy the ever-pressing need for more power. It is the product of many forces and numerous individuals working without plan or coordination to supply electrical energy over a vast area.

Operation of the first Edison central station distribution system was begun in New York City on September 4, 1882, the prime movers being steam engines. A few days later the second Edison station began operating at Appleton, Wis., the electric generator in this case being driven by water power. These two plants were the nucleus of the electric power industry which now has a total generating capacity of 45,000,000 horsepower. The two methods of power production, by falling water and by steam, represented in these primitive plants, have continued to be the principal

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methods used in the production of electrical energy, the development in different regions being determined by the relative availability of the natural resources of water power or fuel.

In its first decade the industry was relatively small; generating plants averaging not more than 200 to 300 kilowatts in capacity with a maximum not exceeding 600 kilowatts. The distribution area served by one plant was restricted by the then limited knowledge and ability to transmit power, and seldom exceeded one square mile. The large cities were served by several groups of isolated power systems from small steam stations, and each small town or village enterprising enough to desire electric



Edison generator, 1882.

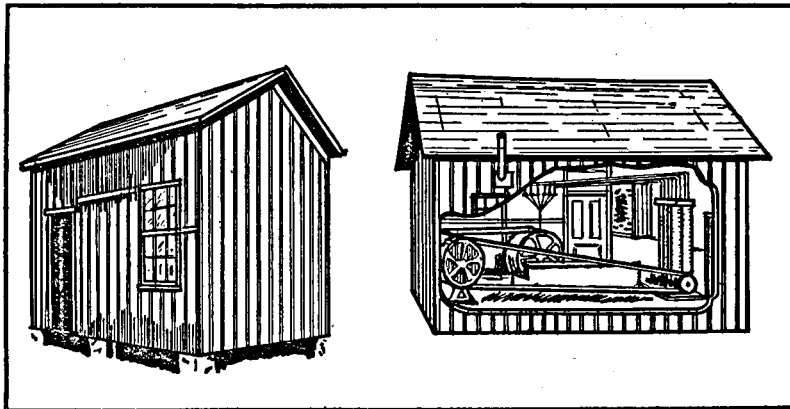
service had its own plant. As the ability to transmit power over greater distances increased, the separate distributing systems in the large cities gradually grew together, were interconnected, and the areas formerly supplied by separate generating stations then received their supply from substations to which the energy was transmitted from larger

stations. Continuance of this growth in metropolitan areas and the development of transmission networks serving many small communities from one or more principal central generating stations has produced the great regional power systems of today. In those areas where water-power developments were predominant, the extension of transmission lines proceeded much faster than it did in the fuel-producing areas, because the water power had to be brought to the load from long distances whereas it was more economical to locate steam plants at or near the load center. This has brought about such a centralization of power production that approximately 73 percent of the energy generated for public use in the United States is now being produced in

3,600 privately and publicly owned electric generating systems supplying the public. By 1917 they had grown in number to 6,500. The period of mergers and consolidations which followed the World War reversed this trend so that today there are approximately 1,600 privately owned and 1,900 municipally owned electric utilities operating in this country.

Technical Advances

To keep pace with the rapid expansion of the industry, new technical developments in the art of producing and transmitting power appeared with almost bewildering rapidity. The steam turbine was introduced as a new type of prime



Exterior and interior views of the first hydroelectric development, Appleton, Wis., 1882.

only 222 generating plants. The location of these plants is shown on figure 2. (Location of electric generating plants in the United States with annual outputs of over 100 million kilowatt-hours).

In the early part of the twentieth century the then infant industry became conscious of the fact that its usefulness extended not only into the home for lighting but into commercial and industrial activities as well. Alternating current motors were coming into general use. The industries of the country were expanding rapidly and there was a continually greater demand for more power to run the mills and factories. Attracted by the opportunity to supply this demand, the power industry also expanded its activity; companies and generating plants increased in number and power outputs grew. In 1902 there were approximately

5,000-kilowatt capacity in the first all-turbine steam-generating plant, installed in 1905, the size of generating units has increased rapidly, so that today units of 50,000- and 75,000-kilowatt capacity are not uncommon. The city of New York alone is partly served from 5 units of 160,000 kilowatts of capacity each. The State-Line plant in the Chicago district has a unit of 200,000 kilowatts effective capacity. Over-all efficiencies of steam plants were greatly improved. The average fuel consumption per unit of electricity produced has been reduced from 3 pounds per kilowatt-hour in 1920 to 1.45 pounds per kilowatt-hour in 1934, an increase in over-all efficiency of over 100 percent. Improvements in the efficiency of water-power generating units, while not so spectacular as those in the steam-power field, were also made. Larger and

more efficient water-power plants have been built.

The Diesel oil engine was introduced in this country in 1898. Its progress in the field of power production has been slow, but it has certain recognized advantages which are rapidly overcoming early prejudices against it. As of January 1, 1934, the installed capacity in Diesel or other internal-combustion engine plants generating electricity for public use was approximately 500,000 kilowatts. Of this total about 280,000 kilowatts were installed in municipally owned plants. It is estimated that about 5,000 kilowatts of additional internal-combustion engine capacity were installed in municipal plants during 1934. Additions of this type of equipment to privately owned systems during the same year were negligible. The data in this report, however, reflect little of the installed oil-engine capacity. In the 215 major power systems to which this report has been limited, the economic merit of the oil engine is not so apparent as it is in smaller systems.

Transmission Developments

At the same time developments in the art of transmitting power have permitted the extension of transmission lines for the serving of large areas from central electric-generating stations. The map, figure 3 (Principal generating plants and electric transmission lines of the United States, 1934), shows the extent and location of the major power developments and transmission systems as they exist at the present time in the United States. This, the first official map of the industry published in the United States, has been prepared by the National Power Survey on the basis of up-to-date maps and data furnished by the reporting power systems. This map shows every power plant of 15,000-kilowatt capacity and over, and in addition indicates smaller plants where they form an important part of the major transmission network. Water and fuel power plants are distinguished by separate symbols, with special designations to indicate municipally owned plants, Federal projects, water-power plants licensed by the Federal Power Commission, and Federal and municipal projects now under construction.

The transmission lines shown are limited to those of 60,000 volts and over with the exception of certain areas, mainly in the upper reaches of the Mississippi Valley, where lower voltage lines have been shown as part of certain interconnected systems.

This map shows that the high state of development of the country's electric power networks is confined largely to the great industrial districts east of the Mississippi River and to the Pacific coast. It is particularly apparent in the areas depending mainly upon water power sources for power, such as the South Atlantic States, the New England States, and in the interconnected system of combined steam plants and water power plants in eastern Pennsylvania. In zone 2 in the Middle West, which depends largely upon fuel sources of power, interconnected lines extend from the Great Lakes in the Buffalo and Niagara Falls region through Indiana and Ohio and through West Virginia to the southeast. This area although interconnected is not closely integrated. It consists of several operating systems which rely upon each other to a certain extent for emergency supply, for interchange of capacity and maintenance of frequency, but are not operated closely as a coordinated system.

Little major transmission has been developed in the central part of zone 4, the mountain and plain States, particularly western North and South Dakota, western Nebraska, Wyoming, and the western half of zone 5, New Mexico. Throughout these parts of zones 4 and 5 the population density is relatively low, communities are small and scattered, so that up to the present time long interconnecting transmission lines have not been justified and many isolated plants of smaller size than those shown on the map are found. However, there are many minor transmission lines of voltages below 60,000 in this territory, which will be shown on transmission maps of each zone accompanying a subsequent report.

Outstanding Transmission Lines

A few of the outstanding transmission-line developments are:

1. The 285,000-volt double tower lines of the city of Los Angeles, from Boulder Canyon to Los Angeles, now under construction.

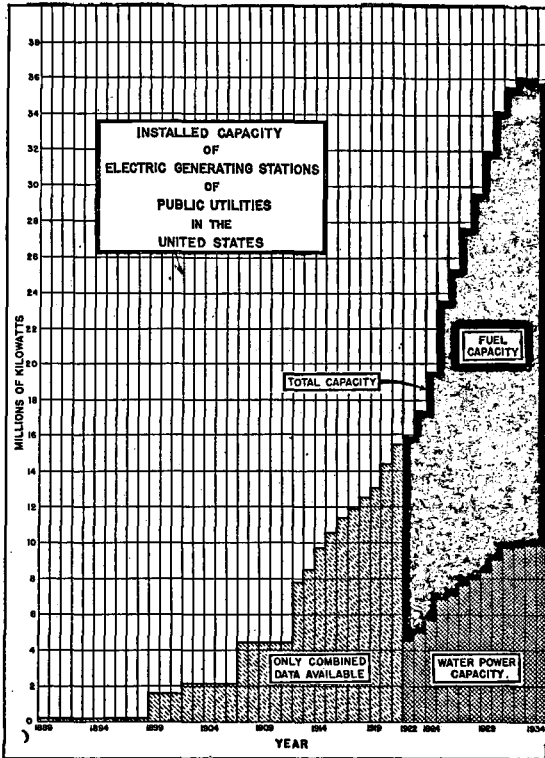


FIGURE 4.—Installed capacity of electric generating stations of public utilities in the United States by years, 1889-1934.

2. The Big Creek lines, also feeding Los Angeles, about 240 miles long and operating at 220,000 volts.

TABLE 1.—Installed capacity in major private, municipal, and public district electric utility power plants in the United States, 1934

[Data taken from reports of 215 systems]

| Zone | Region | Hydroelectric plants | | | Fuel electric plants | | Total electric plants | |
|------|---------------------------|----------------------|--------------------------------|-----------------------|----------------------|--------------------------------|-----------------------|--------------------------------|
| | | Kilowatts | Percent of United States total | Percent of zone total | Kilowatts | Percent of United States total | Kilowatts | Percent of United States total |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | Northeast..... | 2,412,000 | 28.9 | 23.1 | 8,036,000 | 35.5 | 10,447,000 | 33.0 |
| 2 | Middle West..... | 1,037,000 | 11.5 | 10.2 | 9,153,000 | 40.5 | 10,190,000 | 32.2 |
| 3 | Southeast..... | 2,355,000 | 28.2 | 56.2 | 1,821,000 | 8.1 | 4,176,000 | 13.2 |
| 4 | Mountain and Plain..... | 345,000 | 3.8 | 34.9 | 644,000 | 2.9 | 989,000 | 3.2 |
| 5 | Southwest..... | 93,000 | 1.0 | 6.1 | 1,428,000 | 6.3 | 1,520,000 | 4.8 |
| 6 | Pacific Northwest..... | 1,068,000 | 11.9 | 74.4 | 368,000 | 1.6 | 1,437,000 | 4.6 |
| 7 | Pacific Southwest..... | 1,675,000 | 18.7 | 69.8 | 1,153,000 | 5.1 | 2,829,000 | 9.0 |
| | Total, United States..... | 8,985,000 | 100.0 | 28.4 | 22,603,000 | 100.0 | 31,588,000 | 100.0 |

3. The 220,000-volt lines of the Pacific Gas & Electric Co. extending from the Pit River development in northern California to San Francisco Bay and southward to Fresno.

4. The 220,000-volt network interconnecting the great industrial districts of Philadelphia, northern New Jersey, and the anthracite mining fields and connecting with the Conowingo

water-power development on the Susquehanna River and the Wallenpaupack development in the Delaware River Basin.

5. The 220,000-volt lines of the New England Power Co. from its Comerford (Fifteen Mile Falls) water-power plant on the Connecticut River in northern New England to the outskirts of Boston.

Present Installation

The United States Geological Survey reports as of December 1, 1934, a total of approximately 33,800,000 kilowatts of generating capacity installed in private and municipal electric utility plants in the United States. Of this total approximately 2,000,000 kilowatts are installed in municipal plants. An additional 2,000,000 kilowatts are installed in plants of electric railways, Federal and other public works, and industries engaged in supplying public service. See figure 4 (Installed capacity of electric generating stations in the United States, 1889-1934).

Size of Power Systems

The size of individual electric power systems varies from plants owned by an individual, serving ten to a dozen customers and supplying a few thousand kilowatt-hours per year, to systems serving over 2,000,000 customers. Twenty-two

systems each produced over 1 billion kilowatt-hours in 1933. The largest system, consisting of several operating companies, is the Niagara Hudson Power Corporation of New York with a production for 1933 of slightly over 5 billion kilowatt-hours. The system serving the largest number of customers is the Consolidated Gas

Co. of New York. Individual plants vary from a few kilowatts to 770,000 kilowatts in capacity.

Power Systems Included in Report

For the purpose of this interim report analysis has been limited to the large privately and municipally owned utilities. This group includes 194 privately owned systems, comprising 391 operating companies, and 21 municipal systems, a total of 215 systems, each with an output of 25 million kilowatt-hours a year or greater. These systems in the aggregate produce and handle over 93 percent of the total electrical energy reported by the United States Geological Survey as generated and distributed for public use in 1933 in the United States (excluding generation by electric railways and railroads). The remaining systems, approxi-

mately 3,100 in number, both private and municipal, mainly small municipalities, distributing purchased power or operating isolated plants serving small communities, supply the balance of approximately 7 percent of the total.

Analysis of the reports (tables 1 and 2) of the 215 private and municipal systems above referred to shows a total installed capacity as of June 30, 1934, of 31,600,000 kilowatts and a production for 1933 of 76.9 billion kilowatt-hours. This is 91 percent of the capacity and 93 percent of the production of all plants reported by the United States Geological Survey as being engaged in the generation of electrical energy for public use (excluding generation by electric railways and railroads). The addition of the data for the smaller private companies and municipal plants would not, therefore, materially affect the findings of this interim report.

TABLE 2.—Annual production of electricity by major private, municipal, and public district electric utility plants in the United States, 1929-33

[Data taken from reports of 215 systems]

| Zone | Region | Type of prime mover | 1929 | | 1930 | | 1931 | | 1932 | | 1933 | |
|----------------------|---------------------|---------------------|-------------------------|--------------------------------|-------------------------|--------------------------------|-------------------------|--------------------------------|-------------------------|--------------------------------|-------------------------|--------------------------------|
| | | | Thousand kilowatt-hours | Percent of United States total | Thousand kilowatt-hours | Percent of United States total | Thousand kilowatt-hours | Percent of United States total | Thousand kilowatt-hours | Percent of United States total | Thousand kilowatt-hours | Percent of United States total |
| 1 | Northeast | Hydro | 8,795,080 | | 8,390,311 | | 8,443,586 | | 9,813,507 | | 10,120,853 | |
| | | Steam | 17,667,549 | | 18,100,565 | | 17,541,394 | | 14,486,498 | | 14,682,012 | |
| | | Internal combustion | 9,255 | | 1,361 | | 2,379 | | 2,335 | | 2,387 | |
| | | Total | 26,463,253 | 30.3 | 26,492,237 | 30.8 | 25,987,359 | 31.5 | 24,302,340 | 32.4 | 24,806,252 | 32.2 |
| 2 | Middle West | Hydro | 3,511,415 | | 2,935,548 | | 2,903,032 | | 3,334,498 | | 3,218,066 | |
| | | Steam | 27,148,590 | | 26,918,510 | | 25,171,763 | | 21,474,784 | | 22,462,412 | |
| | | Internal combustion | 9,255 | | 15,507 | | 24,257 | | 27,504 | | 23,462 | |
| | | Total | 30,667,260 | 35.1 | 29,869,565 | 34.8 | 28,099,052 | 34.1 | 24,836,846 | 33.2 | 25,703,940 | 33.4 |
| 3 | Southeast | Hydro | 6,830,733 | | 5,780,329 | | 5,749,126 | | 6,130,019 | | 6,243,838 | |
| | | Steam | 1,900,150 | | 2,345,203 | | 2,273,977 | | 1,459,821 | | 1,695,541 | |
| | | Internal combustion | 27,175 | | 30,896 | | 30,595 | | 14,921 | | 11,467 | |
| | | Total | 8,758,058 | 10.0 | 8,156,428 | 9.5 | 8,053,698 | 9.8 | 7,604,761 | 10.2 | 7,950,846 | 10.4 |
| 4 | Mountain and Plain | Hydro | 1,788,010 | | 1,492,514 | | 1,108,854 | | 780,134 | | 1,065,794 | |
| | | Steam | 1,585,429 | | 1,667,702 | | 1,612,606 | | 1,475,377 | | 1,470,893 | |
| | | Internal combustion | 18,784 | | 25,923 | | 21,992 | | 19,476 | | 18,450 | |
| | | Total | 3,392,223 | 3.9 | 3,186,139 | 3.7 | 2,743,452 | 3.3 | 2,274,987 | 3.0 | 2,555,137 | 3.3 |
| 5 | Southwest | Hydro | 66,805 | | 57,757 | | 62,578 | | 144,713 | | 156,040 | |
| | | Steam | 4,343,009 | | 4,464,395 | | 4,127,795 | | 3,597,642 | | 3,694,974 | |
| | | Internal combustion | 99,729 | | 66,807 | | 32,177 | | 19,685 | | 15,399 | |
| | | Total | 4,514,543 | 5.2 | 4,588,872 | 5.3 | 4,222,550 | 5.1 | 3,762,040 | 5.0 | 3,836,413 | 5.0 |
| 6 | Pacific Northwest | Hydro | 3,472,967 | | 3,645,668 | | 3,689,855 | | 3,551,100 | | 3,523,456 | |
| | | Steam | 765,393 | | 710,051 | | 513,503 | | 155,552 | | 165,010 | |
| | | Internal combustion | 36 | | 52 | | | | | | | |
| | | Total | 4,238,401 | 4.9 | 4,355,771 | 5.1 | 4,203,358 | 5.1 | 3,706,652 | 4.9 | 3,688,466 | 4.8 |
| 7 | Pacific Southwest | Hydro | 6,713,394 | | 7,157,799 | | 5,404,608 | | 7,385,925 | | 7,287,492 | |
| | | Steam | 2,547,599 | | 2,168,583 | | 3,727,867 | | 1,023,577 | | 1,054,516 | |
| | | Internal combustion | 376 | | 269 | | 222 | | 207 | | 203 | |
| | | Total | 9,261,279 | 10.6 | 9,326,741 | 10.8 | 9,132,695 | 11.1 | 8,409,709 | 11.3 | 8,342,211 | 10.9 |
| Total, United States | Hydro | 31,178,404 | | 29,459,926 | | 27,861,637 | | 31,139,896 | | 31,618,539 | | |
| | Steam | 55,990,634 | | 56,374,922 | | 54,999,208 | | 45,673,251 | | 45,195,358 | | |
| | Internal combustion | 155,979 | | 140,905 | | 111,622 | | 84,188 | | 71,368 | | |
| | Grand total | 87,265,017 | 100.0 | 85,975,753 | 100.0 | 82,972,467 | 100.0 | 77,897,335 | 100.0 | 76,885,265 | 100.0 | |

II. POWER REQUIREMENTS UPON RESUMPTION OF PRE-DEPRESSION INDUSTRIAL ACTIVITY

Need for Estimates of the Present and Expected Power Loads

The last 2 years (1933 and 1934) have witnessed a rapid recovery in the use of electricity supplied by electric power systems. Although

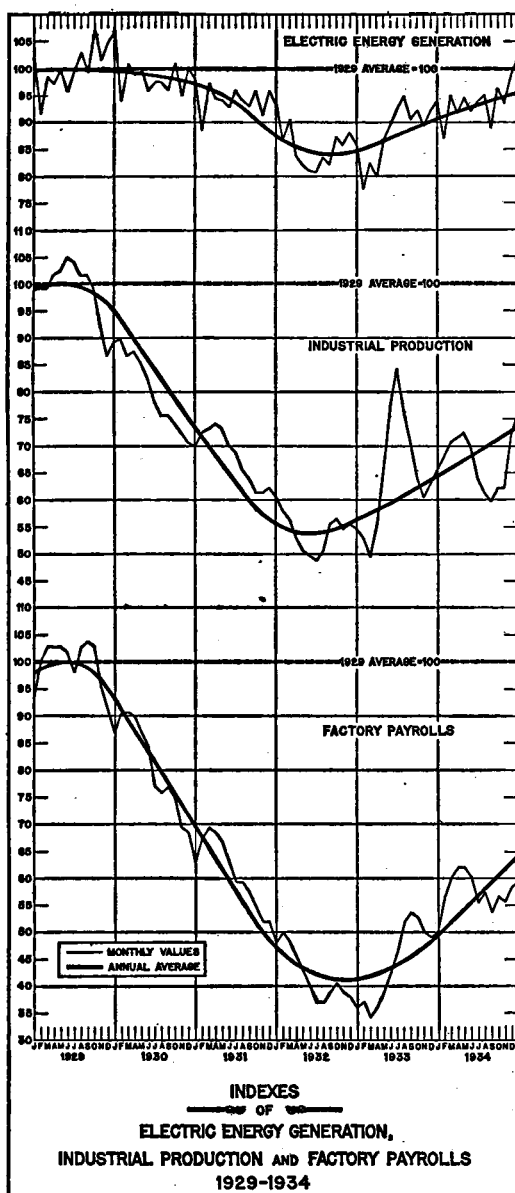


FIGURE 5.—Indexes of electrical energy generation, industrial production and factory pay rolls 1929-34.

pre-depression industrial activity and purchasing power have not yet been reached, indications are that these may occur fairly soon, carrying with them increased demands for electricity. In the last 4 years very little new generating capacity has been added to the existing capacity. Advances in steam power-plant efficiency have been made rendering the older and less efficient plants obsolete. Shifts in location and extent of demand are apparent.

It is important, therefore, that a reasonably accurate determination be made of the adequacy of present facilities and those under construction to meet the needs that will exist upon the resumption of pre-depression activity. Such determination is also important in order that the groundwork may be laid for the formulation of a sound national power policy before a rapid expansion of facilities is begun to meet pressing needs. This is the aim of the interim report.

In this report no attempt has been made to estimate power requirements for a specific date in the future. Effort has been directed solely to the preparation of an estimate of the demand for power in the various sections of the country upon the resumption of a rate of industrial activity comparable to that experienced previous to the depression. Since this estimate indicates an increase of approximately 20 percent over the previous maximum, the construction of additional facilities to meet this demand constitutes an immediate problem.

It is not possible in a short time to select the location for a new power project; solve the many complex problems of type and size of plant necessary to supply most economically the growing power requirements of an area; to design such a plant and to build it. Such a task from inception to completion is a matter of years; for a large steam development it may require at least 2 years, and for a water-power development 3 years or more.

Expected Growth in Power Requirements

During 1934 power requirements showed a rapid increase in almost every section of the country. Power generated during January 1935 was 10 percent in excess of that for the

previous January and was approximately equal to the amount generated during January 1929. If the persistent growth in demand for power experienced during the past 2 years continues during this current year, power generation for 1935 will exceed 1929 and establish a new all-time record.

The curves set forth in figure 5 (Indexes of electric-energy generation, industrial production, and factory pay rolls, 1929-34) show monthly indexes of electric generation, industrial production, and factory pay rolls. The indexes have been reduced to the average of 1929 as 100 percent. Data for curves of industrial production and factory pay rolls were obtained from the publications of the Federal Reserve Bank of New York. Data for the curve on electrical generation were obtained from the reports of the United States Geological Survey. Through the scattered points representing monthly figures a smooth line has been drawn showing the trend based on yearly averages. The average index of electric generation has not fallen appreciably below 85 percent of the 1929 averages. This low point was reached in 1932, and since that year there has been a gradual increase in output so that the index at the end of 1934 had approached very close to the 1929 figure.

On the other hand, the average index of industrial production fell in 1932 to a low point of 55 percent of the 1929 average. Since then it has evidenced a very remarkable recovery, but it still remains 25 percent below the level

of electric energy, suffered a reduction in 1932 to 40 percent of 1929, and, although it has increased materially, it still remains 35 percent below the previous high.

These curves are of great significance in the consideration of the power requirements for which provision must be made in the immediate future. It is apparent that as the indexes of industrial production and pay rolls approach the previous high level, the index of electric generation pursuing a parallel tendency upward must pierce the previous level, which it is now approaching, and extend itself considerably above it. Therefore, upon resumption of pre-depression industrial activity and national spending, demand for power will be not only that of the maximum pre-depression year but much greater.

Basis of Estimates

To establish quantitatively the amount by which power requirements will exceed the previous maximum, special investigations have been made of residential power consumption, rural electrification, commercial and industrial uses of power, additional and new uses for power in electrochemical and electrometallurgical processes, and the requirements of railroad electrification.

The power sales by major classes of service were determined from reports submitted by each of the 215 major companies. The total power sold and the separate maximum demands

TABLE 3.—Annual consumption of electricity in the United States, 1929-33, by classes of customers

[Data taken from reports of 215 systems. Thousand kilowatt-hours]

| | 1929 | 1930 | 1931 | 1932 | 1933 | Estimated consumption upon return of pre-depression industrial activity |
|--|------------|------------|------------|------------|------------|---|
| Farm..... | 1,503,000 | 1,666,000 | 1,787,000 | 1,448,000 | 1,502,000 | 2,069,000 |
| Residential and domestic..... | 7,957,000 | 9,157,000 | 9,904,000 | 10,120,000 | 9,971,000 | 13,033,000 |
| Small light and power..... | 10,636,000 | 11,312,000 | 10,852,000 | 9,987,000 | 9,727,000 | 13,014,000 |
| Large light and power..... | 40,255,000 | 38,021,000 | 34,850,000 | 29,606,000 | 32,153,000 | 43,800,000 |
| Municipal street lighting..... | 1,556,000 | 1,696,000 | 1,824,000 | 1,748,000 | 1,592,000 | 2,335,000 |
| Municipal light and power..... | 1,443,000 | 1,612,000 | 1,709,000 | 1,738,000 | 1,748,000 | 1,966,000 |
| Street railway and interurban railway..... | 4,833,000 | 4,629,000 | 4,386,000 | 4,020,000 | 3,815,000 | 4,265,000 |
| Electrified steam railroad..... | 520,000 | 551,000 | 572,000 | 544,000 | 698,000 | 1,390,000 |
| Miscellaneous..... | 2,730,000 | 2,725,000 | 2,550,000 | 1,680,000 | 1,793,000 | 3,415,000 |
| Total..... | 71,433,000 | 71,369,000 | 68,434,000 | 60,891,000 | 62,999,000 | 85,347,000 |

of 1929. The index of factory pay rolls, used as one evidence of national spending power and a measure of the ability of domestic and commercial customers to increase their consump-

were obtained from the same source. These data were grouped by districts, 45 in number, consisting of logical subdivisions of the zones. The districts were chosen after careful study of

the existing systems so that as nearly as possible, completely interconnected groups were included in a single district. Owing to the extension of several major systems across the State lines which form the boundaries of the geographical zones adopted for the survey, it was necessary, for this study, to modify the zone lines somewhat. Estimates of the expected sales by classes of service, the annual production to meet these requirements and the system demands, were also made by districts. These estimates are summarized for the entire United States in tables 3 and 4.

This tabulation for the 215 large systems, represents approximately 92 percent of the

65 percent over that in 1929. Up to 1933 the gain was 25 percent. Preliminary data for 1934 indicate that the use of this class of service had grown substantially since 1933 and that the advance may be expected to continue.

Table 5 shows that the average annual consumption of the domestic customer increased throughout the depression from 484 kilowatt-hours in 1929 to 593 kilowatt-hours in 1933, or 22.5 percent. Due to the depression, however, there has been little growth in the number of customers. In fact, the number fell off from the high point reached in 1931. With restoration of income, however, the number will doubtless reach the previous maximum and

TABLE 4.—Production of electric energy and maximum demands in 1929, and annual requirements upon resumption of pre-depression industrial activity

[Data taken from reports of 215 systems]

| Zone | Power region | 1929 | | Resumption of pre-depression industrial activity | | | |
|------|-------------------------|--------------------------------|------------------------|--|------------------------|-------------------------------|-----------------------------------|
| | | Generation ¹ | Sum of maximum demands | Generation | Sum of maximum demands | Increase over 1929 generation | Increase over 1929 maximum demand |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| | | <i>Thousand kilowatt-hours</i> | <i>Kilowatts</i> | <i>Thousand kilowatt-hours</i> | <i>Kilowatts</i> | <i>Percent</i> | <i>Percent</i> |
| 1 | Northeast..... | 26,030,000 | 4,305,000 | 33,816,000 | 7,869,000 | 29.5 | 24.8 |
| 2 | Middle West..... | 30,747,000 | 4,732,000 | 36,163,000 | 7,969,000 | 17.6 | 18.4 |
| 3 | Southeast..... | 8,292,000 | 1,839,000 | 10,002,000 | 2,273,000 | 20.6 | 23.8 |
| 4 | Mountain and Plain..... | 2,996,000 | 534,000 | 2,964,000 | 569,000 | -1.1 | 6.6 |
| 5 | Southwest..... | 5,221,000 | 1,068,000 | 5,984,000 | 1,222,000 | 14.6 | 15.5 |
| 6 | Pacific Northwest..... | 4,680,000 | 923,000 | 5,226,000 | 1,066,000 | 11.7 | 15.4 |
| 7 | Pacific Southwest..... | 8,829,000 | 1,730,000 | 10,550,000 | 2,071,000 | 19.5 | 19.8 |
| | Total..... | 87,295,000 | 19,121,000 | 104,705,000 | 23,039,000 | 19.9 | 20.7 |
| | Increase over 1929..... | | | 17,410,000 | 3,918,000 | | |

¹ Individual items in this column differ slightly from those given in table 2 as the boundaries of the selected power districts do not in all cases conform exactly to the zone boundaries.

total farm service of the country, 86 percent of the residential and domestic service, and approximately 96 percent of total energy consumed by other classes of customers. The percentage of residential energy included is apparently low for the reason that there are many small companies and municipal plants not covered by the present compilation. These small systems distribute energy, a large portion of which is purchased from the major systems, principally to domestic consumers. This purchased energy is included under Miscellaneous in table 3.

The Domestic Load

The summary indicates that with resumption of pre-depression industrial activity domestic consumption will increase approximately

continue with a rate of growth approaching that experienced prior to 1929.

Another consideration supporting the estimate of greater residential consumption is the large number of appliances sold during the depression, the effect of which has not been fully apparent owing to the general curtailment of consumption resulting from reduced purchasing power.

Table 6 shows that during the 5 years (1930-34) sales of appliances added a total of more than 4 million kilowatts of electric-range load; more than 1 million kilowatts of refrigerator load; and nearly one-half million kilowatts of water-heater load. These major energy-consuming appliances, together with a vast number of miscellaneous items, such as radios, toasters,

heaters, and fans, are estimated to consume more than 8 billion kilowatt-hours annually. Some of the above appliances were, of course,

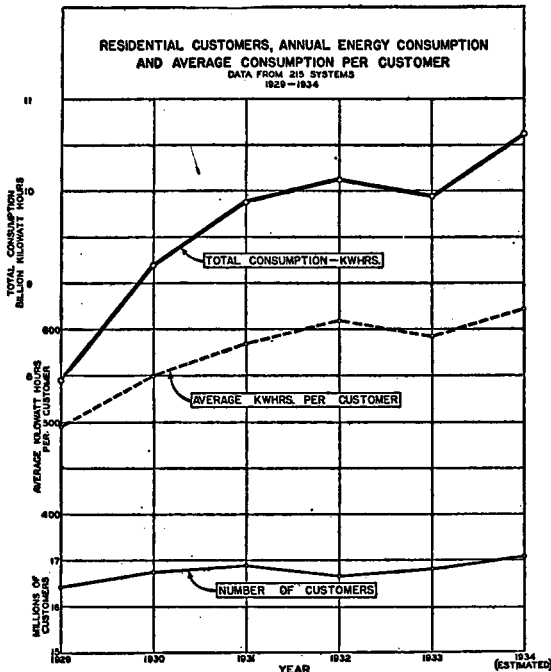


FIGURE 6.—Residential customers, annual energy consumption, and average consumption per customer, 1929-34.

replacements, and the total energy consumption will not be increased by this amount. However, even if the estimate is discounted 25 percent it would still account for all of the expected increase in domestic consumption. This load was added in spite of the depression, and the sale of such appliances may be expected to increase rapidly with restored purchasing power. The stimulus of reduced rates

pared to 1929. (See table 3.) Although at present the total amount of energy consumed by farm customers is small, consumption may be expected to increase rapidly in the near future.

There are today approximately 725,000 farms receiving central-station electric service out of a total of 6,300,000 farms. The estimated increase is based on the addition of approximately 250,000 farm customers. When it is considered that during the year 1928, without the great stimulus which various agencies of the Government have given to rural electrification, 110,000 farm customers were connected, this estimate appears particularly conservative. The rate at which farm customers were being added slowed up during the depression, though there was a definite net increase in 1934. At present, special attention is being directed by the Federal Government to the expansion of rural service. Several States are also working out definite programs. Leading utilities are carrying on special campaigns and are considering liberalized line-extension policies. Federal expenditures for rural electrification to the extent of 100 million dollars are provided for in the pending Public Works Relief bill. All of these factors will give impetus to a rapid expansion of this service.

The Small and Large Light and Power Load

Total annual consumption of central station energy by small light and power consumers is estimated to increase about 2.4 billion kilowatt-hours and by large light and power consumers about 3.6 billion kilowatt-hours, a total

TABLE 5.—Sales of electricity to residential and domestic customers in the United States, 1929-33

[Data taken from reports of 215 systems]

| | 1929 | 1930 | 1931 | 1932 | 1933 |
|--|------------|------------|------------|------------|------------|
| Sales in thousand kilowatt-hours..... | 7,957,000 | 9,157,000 | 9,904,000 | 10,120,000 | 9,971,000 |
| Number of customers..... | 16,418,000 | 16,738,000 | 16,897,000 | 16,652,000 | 16,807,000 |
| Average kilowatt-hours per customer..... | 484 | 647 | 588 | 608 | 593 |

will also constitute a powerful incentive to increased domestic use of power.

The Farm Load

Farm service for the 215 systems covered in this report is estimated to increase approximately 566 million kilowatt-hours when com-

increase for the two groups of 6 billion kilowatt-hours, or about 12 percent over 1929.

The 153,000 industrial establishments of the country, including mines and quarries, during the years prior to 1930 consumed about 62 billion kilowatt-hours annually. Of this amount, 22 billion kilowatt-hours (estimated)

were generated by industrial power plants. Upon the return of a similar period of activity, it is estimated that the increase in electrical consumption by industry will be in excess of 5 billion kilowatt-hours, and that of this increase about 3.6 billion will be generated in central stations.

The same degree of industrial activity will be accompanied by a greater utilization of electric energy than in the past, due to the greater employment of electro processes. A major increase in the use of power will be found in

transportation loads to other methods. Expansion of railroad electrification is taking place in certain instances, and the use of electrical energy by this class of service should increase substantially with resumption of pre-depression industrial activity.

Summary

The estimates based on the resumption of pre-depression industrial activity show that the

TABLE 6.—Capacity of electric appliances added since 1929

[Data supplied by manufacturers]

| | 1930 | 1931 | 1932 | 1933 | 1934 | Total |
|---|-----------|-----------|-----------|-----------|-----------|------------|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Ranges..... kilowatts..... | 1,472,000 | 829,500 | 481,000 | 388,200 | 1,029,100 | 4,199,800 |
| Refrigerators..... do..... | 174,500 | 213,500 | 173,300 | 240,000 | 316,000 | 1,117,300 |
| Water heats..... do..... | 107,500 | 67,000 | 30,000 | 50,000 | 103,800 | 358,300 |
| Miscellaneous appliances..... do..... | 5,016,000 | 4,865,000 | 3,500,700 | 4,731,800 | 5,151,100 | 23,264,600 |
| Total kilowatts..... | 6,870,000 | 5,975,000 | 4,185,000 | 5,410,000 | 6,600,000 | 28,940,000 |
| Approximate consumption thousand kilowatt-hours annually..... | 1,825,000 | 1,735,000 | 1,245,000 | 1,580,000 | 2,200,000 | 8,565,000 |

the synthetic processes, such as the production of ammonia, alcohols, resins, and the like. Another will result from the increasing electrolytic production of such metals as aluminum and magnesium and the electric melting and heat treating of steels, brass, and nonmetallic products. A large proportion of these metals, particularly aluminum and stainless and other alloy steels, will be used in the fabrication of lightweight equipment for land, air, and water transportation.

The use of air-conditioning equipment in industrial establishments, mines, and quarries, for the prevention of occupational disease and the general improvement of working conditions and products, is growing rapidly. Large amounts of power are required for the operation of this equipment and for the production of the necessary materials and the fabrication of the apparatus.

Street Railway Load and Railroad Electrification

The amount of power required by street and interurban railroads should recover somewhat above the low of 1932, but may not reach the total of 1929 because of further shifting of

annual power production of the 215 major companies will exceed 104 billion kilowatt-hours with a corresponding peak demand of 23 million kilowatts. The production of energy and the sum of the individual system demands in kilowatts for 1929 and the estimated amounts are summarized by zones in table 4.

Comparisons also show that the estimates, based upon return of pre-depression activities, closely check with the composite forecast of power requirements for the year 1937 submitted by the reporting companies. This check has been made both with reference to demand and to production, and the check is equally close in each case. The estimated sum of the demands of the power systems of the country is approximately 4 million kilowatts greater than the demands in 1929. This is an average increase for the entire nation of slightly over 20 percent. As a comparison, the amount of this increase is considerably in excess of the total present central station power requirements in the entire southern part of the country, including the States of Virginia, West Virginia, North and South Carolina, Kentucky, Tennessee, Mississippi, Alabama, Georgia, Florida, Arkansas, Louisiana, Texas, Oklahoma, and New Mexico.

The results for each zone are based on studies and estimates of the load requirements by districts as previously described. The probable growth of load for each district was considered separately, although it must be borne in mind that it was not possible at this time to go into much detail concerning the economic foundation and growth of each section. The increase in maximum demands has been estimated somewhat greater than the increase in production. This means that the average load factor is estimated to be slightly lower upon the resumption of industrial activities than it was in 1929. The load forecasts of the utilities confirm this assumption. Load factors at the present time are in general lower than in 1929, and it would seem reasonable to assume that this condition will continue for some time in the future. It cannot be assumed, however, that lower load factors will prevail for an indefinite period. On the contrary, the load factors anticipated upon resumption of industrial activity, while lower than those for 1929, are higher than those prevailing at present, and it is reasonable to assume that in future years load factors will progressively improve with increase in load as they have in the past.

Special attention is directed to zone 4, Mountain and Plain States, where the estimated generation shows a slight reduction below 1929, while the estimated demand shows an increase. This zone comprises the mountain States of Montana, Wyoming, and Colorado and the plain States of North and South Dakota, Nebraska, and Kansas. In 1929, approximately half of the total power production of the major companies in this zone was in the State of Montana in connection with copper-mining activities. Severe dropping off of the power requirements of this industry has been experienced, the return of which to the 1929 level has not been considered in the estimates. The power requirements of the eastern portion of this zone, dependent largely on agriculture, are estimated to increase in an amount approximately equal to the reduction in estimated output in Montana and the other mountain States. Owing, however, to the difference in the characteristics of load in the other districts, the demand in these eastern districts will be greater, thus causing a general increase in the power demand for the entire zone in excess of the relative change in energy requirements.

III. ADEQUACY OF PRESENT POWER-PRODUCING FACILITIES

The sum of the estimated system peak demands upon resumption of pre-depression industrial activity for the 215 major companies covered in this report is 23,039,000 kilowatts (table 4). The present installed capacity of the plants operated by these companies is 31,588,000 kilowatts. It might appear from a casual consideration of these two amounts that there are more than sufficient facilities to supply the need. This, however, would not be a correct conclusion.

A number of factors must be considered before any conclusion can be reached as to the adequacy of the present generating facilities to meet future requirements. They are:

1. The dependable capacity of present plants as hereinafter defined.
2. The spare or reserve plant capacity necessary to prevent interruptions of supply and to assure adequate service.
3. The leeway or additional reserve capacity required to meet load growth.
4. The extent to which existing facilities are obsolete or inadequate.

Dependable Capacity of Present Plants

The dependable capacity of the plants of the 215 systems surveyed is 27,300,000 kilowatts, or 14 percent less than the installed capacity.

It is often sound economics to build a steam power plant with insufficient boiler capacity to operate all the generating units at full load. Many steam power plants have been so reported. In such cases that part of the installed generating capacity for which boilers have been provided has been called throughout this report the "dependable" capacity of the plant. In some other situations the ability to carry a load equal to the installed capacity of the generating units has been reported as limited by the availability and temperature of condensing water or the temperature rise in the generators. In such cases these factors were considered in determining the dependable capacity.

The dependable capacity of existing water power plants is defined as the output capacity of the plant available at the time of system peak as limited by stream flow, storage and load-factor characteristics of the load. In some few cases the determining period is other than

that of the system peak and occasionally the determination is based on the condition of maximum flood flow and resulting reduced effective head and on inadequate transmission facilities.

The values for dependable capacity, both of steam-power and water-power plants, used in this report are the values reported by the companies, except that small plants which had not been operated since 1927 were not considered as dependable capacity.

The dependable capacity of water-power plants under low-water conditions is often substantially below both the installed capacity and the capacity which can be supplied under normal or average water conditions. All streams, with a few exceptions, have fairly wide variations in stream flow. Droughts occur, such as was experienced during the past year (1934), which greatly reduce the water supply for the production of power even in the case of plants with extensive storage facilities. For plants installed in connection with reservoirs, the head of the plant reduces with depletion of storage, thus fixing the dependable capacity in periods of drought. A certain 30,000-kilowatt plant installed in connection with an irrigation project has no dependable capacity under dry-year conditions.

Because of complete draw-down of water during the irrigation season, water-power plants with constant or non-variable head are sometimes limited in dependable capacity by inadequate pondage or forebay capacities. In some cases regulation of stream flow, as it is affected by irrigation, navigation, or other controlling factors on the stream, limits the plant's capacity available under low-water conditions, thus fixing a dependable capacity substantially below installed capacity. In one extreme instance, a plant with 35,000 kilowatts installed capacity has a dependable capacity of only 5,000 kilowatts under extreme dry-year conditions because of these limitations. Another group of water-power plants installed with constant head and fairly extensive storage facilities is limited as to dependable capacity because in dry periods sufficient water is not available in the streams or reservoirs to make possible full use of the capacity of these plants except for very short periods.

Table 7 shows the installed capacity and dependable capacity for both the water-power and steam-power plants of the 215 reporting systems. The dependable capacity of the water-power plants of the country, considered as a whole, is approximately two-thirds of the installed capacity. The dependable capacities of water-power plants in zones 2, 3, and 7 average 55 percent of the installed capacities. In zones 1, 4, 5, and 6 the average approximates 80 percent. The average dependable capacity of steam-power plants is approximately 95 percent of the installed capacity. The total dependable capacity of the plants of the 215

the instant it occurs, whether it be a few kilowatts or many thousands. It is not possible for the utility to advise that delivery will be made in a few hours or that the order will be filled during the coming week. Service requires that sufficient capacity be always in operation to supply demands the instant they are made.

Power plant units have to be overhauled from time to time. Transmission lines have to be repaired. This requires definitely that spare capacity be maintained. For isolated power systems the amount of this spare capacity is measured by the size of the largest unit. For extended transmission systems capacity

TABLE 7.—Installed and dependable capacity of major private, municipal, and public district electric utility power plants in the United States, 1934

[Data taken from reports of 215 systems]

| Zone | Power region | Hydroelectric capacity | | Fuel-plant capacity | | Total capacity | |
|------|--|------------------------|----------------------|---------------------|----------------------|---------------------|----------------------|
| | | Installed kilowatts | Dependable kilowatts | Installed kilowatts | Dependable kilowatts | Installed kilowatts | Dependable kilowatts |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1 | Northeast..... | 2,426,000 | 1,803,000 | 8,004,000 | 7,537,000 | 10,430,000 | 9,390,000 |
| 2 | Middle West..... | 1,095,000 | 592,000 | 9,321,000 | 8,759,000 | 10,416,000 | 9,351,000 |
| 3 | Southeast..... | 2,099,000 | 1,213,000 | 1,521,000 | 1,463,000 | 3,620,000 | 2,676,000 |
| 4 | Mountain and Plain..... | 344,000 | 275,000 | 499,000 | 496,000 | 843,000 | 771,000 |
| 5 | Southwest..... | 93,000 | 79,000 | 1,672,000 | 1,622,000 | 1,765,000 | 1,701,000 |
| 6 | Pacific Northwest..... | 1,183,000 | 951,000 | 393,000 | 371,000 | 1,576,000 | 1,322,000 |
| 7 | Pacific Southwest..... | 1,745,000 | 974,000 | 1,193,000 | 1,115,000 | 2,938,000 | 2,089,000 |
| | Total..... | 8,985,000 | 5,887,000 | 22,603,000 | 21,413,000 | 31,588,000 | 27,300,000 |
| | Ratio of dependable to installed capacity..... | | Percent 65.5 | | Percent 94.7 | | Percent 86.4 |

NOTE.—Installed capacities shown for each power region differ slightly from those shown in table 1, as the boundaries of the selected power districts do not in all cases conform exactly to zone boundaries.

systems is 27,300,000 kilowatts compared with an installed capacity of 31,588,000 kilowatts.

A factor which tends to off-set the higher ratio of dependable capacity to installed capacity for steam-power plants compared with that of water-power plants is the fact that steam turbines and boilers normally require overhauling at more frequent intervals than water-power equipment. For this reason greater reserve capacity is usually required for systems supplied by steam-electric plants than for those systems where the larger part of the dependable capacity is in water-power plants.

The Minimum Spare Capacity Necessary to Assure Adequate Service

A minimum spare capacity of 3,917,000 kilowatts is needed to assure adequate service for the loads estimated.

Electric power must be available when the switch is turned on or service demanded. There must always be enough generating plants in operation to deliver the increase in demand

equivalent to several of the largest steam units may be required as spare.

All companies were requested to file reports showing the location, and installed and dependable capacities of each plant, together with maps showing existing transmission lines and their nominal capacities. Without attempting detailed analyses of all these data, a general study of the production and transmission facilities and the extent of interconnection between systems was made in order to determine the necessary spare capacity. In general, the largest steam unit in each isolated system and the largest unit in each major division of interconnected systems were considered as necessary for spare capacity. From these studies estimates were prepared of the amount of spare capacity as a minimum that would be required in each of the 45 zone subdivisions or districts in order to assure service to the public.

The ratio of the spare capacity to the dependable capacity varies widely among the districts, depending upon the size of the units and the extent of interconnection. On the large inter-

connected water-power systems the ratio is low. This is due to the fact that these systems, under minimum water conditions, in practically all cases, have fairly large capacities that can be operated for a few hours or possibly a few days to take care of temporary break-downs, but do not have sufficient water to carry the load over prolonged periods. A relatively high percentage of spare capacity is required in zones containing several isolated systems. For example, the ratio of spare capacity to dependable capacity in zone 7, Pacific Southwest, is 10 percent, compared with 23.7 percent in zone 5, Southwest, where there is more steam power and less interconnection of systems.

The minimum reserve capacity for the 215 systems is estimated at 3,917,000 kilowatts, or 14.3 percent of the total dependable capacity. This reserve, as stated before, represents the minimum that should be maintained. It does not take into account leeway to meet growth of load or nonuniformity of growth of load within districts. Normally, greater spare capacity must be maintained as a matter of practical operation.

Leeway in Capacity to Cover Growth Requirements

An additional leeway of 10 percent of the estimated peak demands in addition to the minimum spare capacity is reasonably required.

It is essential and it is the general practice for each utility system to have spare capacity to care for anticipated growth in demand. Where growth of load is being experienced, as may be expected with the recovery of industrial activities, power companies must anticipate this growth and install capacity ahead of demand. This may be estimated on the basis of past practice to amount on the average to at least 1 year's load growth. In the case of isolated systems greater leeway may be expected. With fairly large interconnected systems, units may be added in different plants so as to reduce the amount of this extra leeway. However, to obtain the highest efficiency the tendency has been to install larger units than immediately required, so that even with the general interconnection of systems now in effect the leeway to cover average growth remains fairly large. Another factor which must be considered in

determining this leeway is the variation in the distribution of load growth on extended systems. Facilities added in one portion of the system may exceed the local growth while in other sections which are not fully interconnected a more rapid growth may occur requiring added installation.

An analysis made of several of the larger and more important systems indicates that their practice prior to the depression, when system loads were growing, was to install capacity in excess of peak demands equal to from 25 percent to 45 percent of the dependable system capacity.

Based on this analysis of the past practices of the electric utilities and on consideration of the probable conditions of load growth on resumption of predepression activities a leeway of 10 percent of the estimated maximum system demands, which is the basis adopted for the purposes of this study would appear to be the smallest allowance for load growth that can reasonably be made. This is on the basis of present system interconnections.

Extent to Which Existing Facilities Are in Part Obsolete or Inadequate

With resumption of pre-depression activities as much as 2,000,000 kilowatts of capacity may need to be replaced.

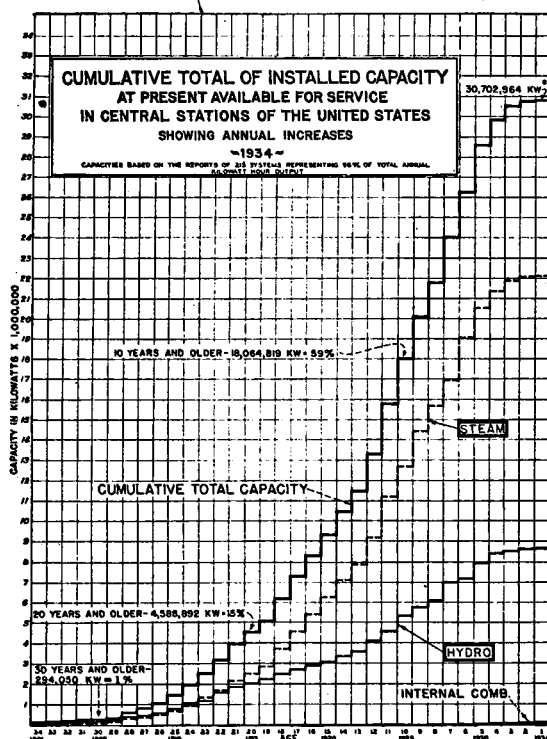
In determining the adequacy of present facilities to serve prospective loads, obsolescence must be considered; obsolescence in this case being defined as the inability of the present equipment adequately to perform the same functions at equal or lower cost than they can be performed by the new. It follows, therefore, that an old plant should be replaced just as soon as a new plant can be built for which the sum of the fixed charges on investment, interest, taxes, etc., and the operating cost is less than the operating cost of the old plant.

The determination of such obsolescence, requiring the study of loads, plant performance, extent of use of present plants, and many other contributing factors, is beyond the scope of this interim report. From the data in hand, however, some conclusions may be drawn.

Age alone is not a definite factor in determining the obsolescence of either a steam- or water-power plant. It does serve, however, as an index of the probable operating efficiency

and operating cost of a plant and, therefore, the degree of obsolescence.

The history of steam-electric power development has been one of constantly increasing efficiency. In the early days of power development the principal prime mover was the steam engine. Steam pressures were low, boilers were mostly hand-fired and great in number; generating units were small in capacity, the larger



* DOES NOT INCLUDE 885,222 KW CAPACITY IN UNITS SMALLER THAN 2,500 KW FOR STEAM AND HYDRO AND 500 KW FOR INTERNAL COMBUSTION, AND ANY SIZE UNIT ON WHICH DATE OF INSTALLATION WAS NOT GIVEN

FIGURE 8.—Cumulative total of installed capacity at present available for service in central stations of the United States showing annual increases, 1934.

plants contained a great many units and many men were needed for operation. Plant economy, as is now understood, was given scant attention; the real problem being one of keeping the operating units "on the line." With the advent of the steam turbine in the early part of the twentieth century and because of the increasing size of the plants and outputs, more attention was directed to this subject. Efficiencies were greatly improved and production costs reduced. Figure 9 (Trend in fuel consumption of steam-electric generating stations in the United States) shows that in the period 1902 to 1914 the average fuel consumption was reduced from

more than 6.5 pounds of coal per kilowatt-hour to less than 4 pounds. In 1914 the plant that represented the best in design required approximately 1.7 pounds of coal (22,200 B. t. u.) per kilowatt-hour. By 1922 this had further been reduced to 1.45 pounds per kilowatt-hour.

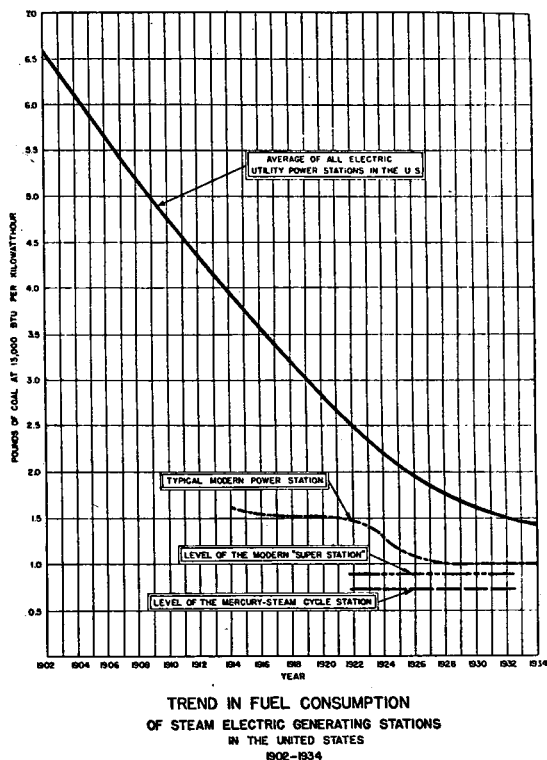


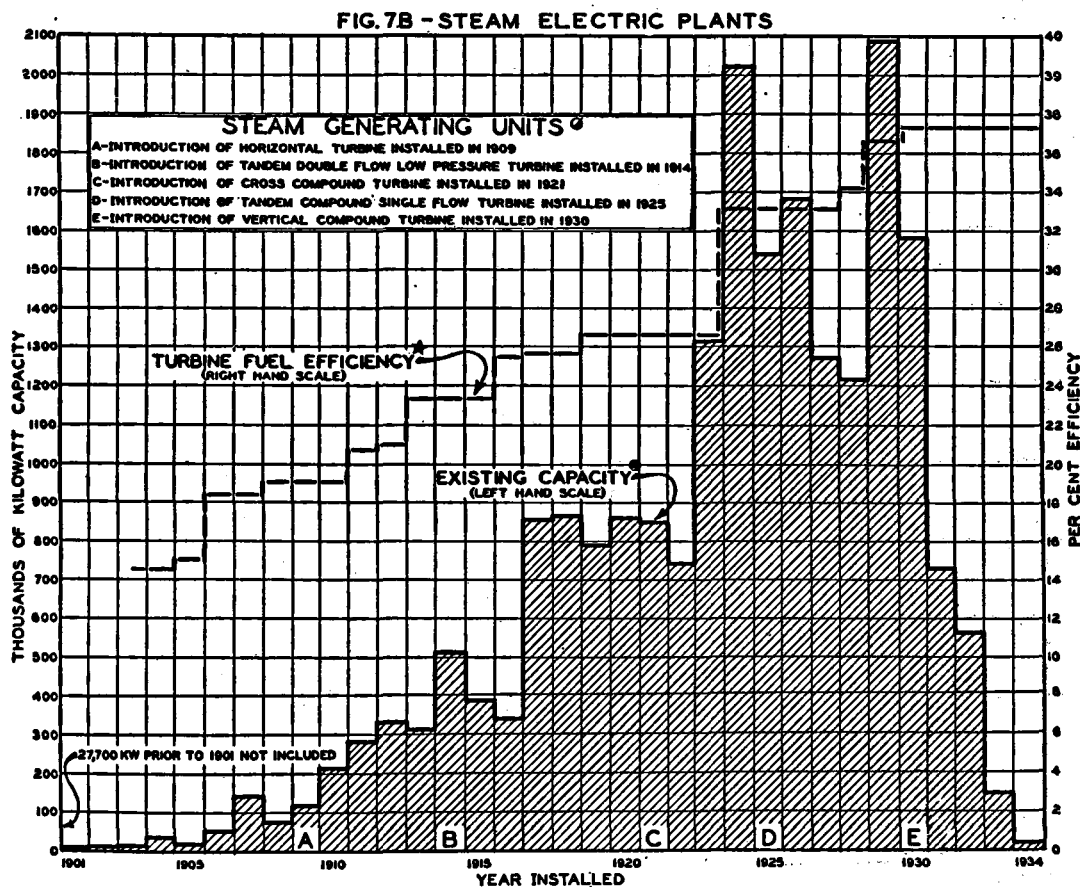
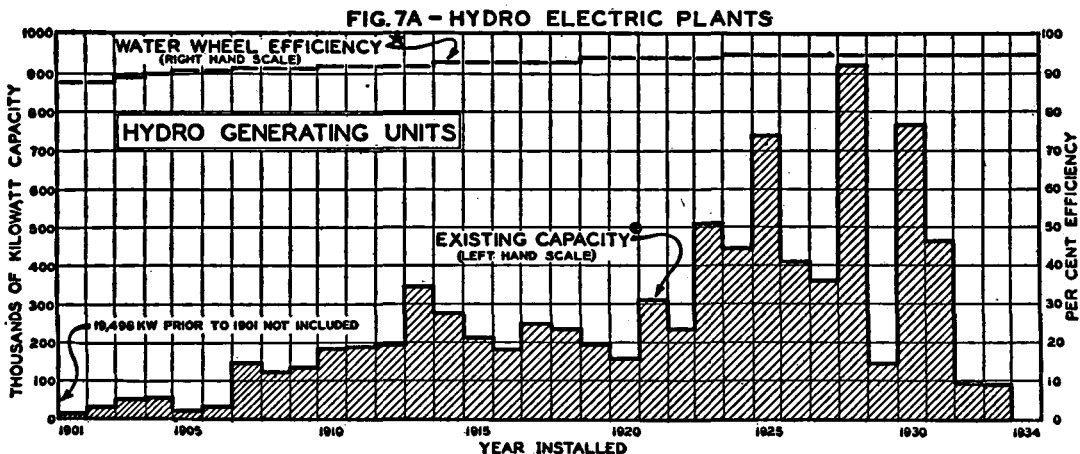
FIGURE 9.—Trend of fuel consumption in steam-electric generating stations in the United States.

For data on power production and fuel consumption see Horton, A. H., *Developed and Potential Water Power in the United States and Production of Electricity by Public Utility Power Plants, 1919-26*; U. S. Geol. Survey Water Supply Paper 579, 1928, 210 pp.; also monthly power reports, mimeographed.

For the years before 1919 the data are taken from a special study by F. G. Tryon, to be published elsewhere. Certain incomplete data are given by the 5-year census of the electrical industries made by the Federal Bureau of the Census covering 1902, 1907, 1912, and 1917. The census does not separate the kilowatt-hours generated by fuels and by water but gives sufficient data on installed capacity of prime movers to permit an approximate separation. The quantity of coal used was reported in 1902 (incomplete) and 1917 (complete), and the cost of fuel was reported in 1902, 1907, 1912, and 1917, from which the total consumption and the pounds per kilowatt-hour have been derived. The result, though not precise, is reasonably accurate and indicates the trends. Reference: U. S. Bureau of Mines, "Coal in 1927", p. 419.

The period immediately following the World War witnessed tremendous increases in the price of coal. The stimulus of such prices brought about a marked change in steam-plant design and efficiency. Generating units and plants were increased rapidly in capacity, and efficiencies were improved greatly by new de-

YEAR OF INSTALLATION OF CAPACITY IN SERVICE IN 1934
AND
MAXIMUM TURBINE EFFICIENCY IN EACH YEAR



NOTE: ★ EFFICIENCY BASED UPON THE BEST PRACTICE ATTAINED WITH ANY UNIT IN THAT YEAR.
 Ⓛ THE FIRST ALL STEAM TURBINE PLANT (VERTICAL TURBINES) WAS PUT IN OPERATION IN CHICAGO IN 1903. RECORDS INDICATE THAT CENTRAL STATIONS HAD INSTALLED EXPERIMENTAL STEAM TURBINES AS EARLY AS 1898.
 ● CAPACITIES BASED ON THE REPORTS OF 216 SYSTEMS.

velopments in boilers, firing equipment, and other auxiliaries. The trend toward higher steam pressures, begun during the war, continued. Fuel consumption in these more modern stations for base load operation was reduced to 1 pound of coal per kilowatt-hour and even less in some exceptional cases.

These great advances in efficiencies in steam power plants have rendered obsolete as major sources of energy production that portion of capacity now remaining which was installed prior to the war period. As loads increase, economy will dictate the abandonment of a large portion of this capacity. Some may be retained because of the necessity for spare capacity to insure service while more efficient units are being overhauled and also for peak load service in the areas primarily served from hydroelectric developments. Some also will be retained because it will lend itself to rehabilita-

tion by the superimposing of modern high-pressure boilers and generating units.

To find out the extent to which the retirement of this old steam equipment may be carried, tables 8 and 9, relating to age, and tables 10 and 11, relating to efficiencies, have been prepared.

Many observers estimate the economic life of steam power plant equipment at 20 years. Referring to table 8, it will be seen that approximately 2,500,000 kilowatts of capacity is at least 20 years old (installed prior to 1915). From table 9 it may be concluded that this capacity is made up principally of small units. Table 10 shows that approximately 2,600,000 kilowatts of capacity have a fuel consumption greater than 25,000 B. t. u. per kilowatt-hour, thus dating most of it prior to 1915. (See fig. 9.) This is 11.7 percent of the steam-electric capacity which the 215 reporting systems now have in service.

TABLE 8.—Present power-plant capacity of the major electric utilities in the United States classified according to year of installation and type of prime movers

[Data taken from reports of 215 systems]

| Zone | Region | Type of prime movers | Prior to | 1901-05 | 1906-10 | 1911-15 | 1916-20 | 1921-25 |
|--|-------------------------|--------------------------|--------------------|---------------------|----------------------|----------------------|----------------------|----------------------|
| | | | 1901 | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | Northeast..... | Hydro..... | Kilowatts 3,300 | Kilowatts 82,460 | Kilowatts 134,950 | Kilowatts 293,796 | Kilowatts 273,965 | Kilowatts 468,390 |
| | | Steam..... | 13,800 | 41,900 | 211,550 | 769,179 | 1,416,666 | 2,235,610 |
| | | Internal combustion..... | | | | | | |
| | | Total..... | 17,100 | 124,360 | 346,500 | 1,062,975 | 1,690,631 | 2,704,000 |
| 2 | Middle West..... | Hydro..... | 1,200 | 4,500 | 59,110 | 211,620 | 154,745 | 214,990 |
| | | Steam..... | 16,900 | 187,637 | 633,410 | 1,714,675 | 2,803,580 | 2,803,580 |
| | | Internal combustion..... | | 268 | 1,295 | 1,128 | 3,678 | 3,678 |
| | | Total..... | 1,200 | 21,400 | 247,015 | 846,325 | 1,870,548 | 3,022,248 |
| 3 | Southeast..... | Hydro..... | | 15,790 | 97,310 | 311,291 | 238,000 | 672,845 |
| | | Steam..... | 2,600 | 6,360 | 41,420 | 148,750 | 265,900 | 568,950 |
| | | Internal combustion..... | | | | | 128 | 3,200 |
| | | Total..... | 2,600 | 22,090 | 138,730 | 460,041 | 504,028 | 1,244,995 |
| 4 | Mountain and Plain..... | Hydro..... | | 3,000 | 68,400 | 70,650 | 107,500 | 14,000 |
| | | Steam..... | 1,698 | 6,738 | 53,475 | 26,700 | 119,900 | 200,250 |
| | | Internal combustion..... | | | | 108 | 1,068 | 1,500 |
| | | Total..... | 1,698 | 9,738 | 111,875 | 97,458 | 228,468 | 215,750 |
| 5 | Southwest..... | Hydro..... | | | | | | 15,370 |
| | | Steam..... | 1,500 | 4,150 | 28,905 | 63,500 | 138,796 | 291,950 |
| | | Internal combustion..... | | | 80 | 2,140 | 890 | 2,154 |
| | | Total..... | 1,500 | 4,150 | 28,985 | 65,640 | 139,686 | 309,474 |
| 6 | Pacific Northwest..... | Hydro..... | 6,000 | 24,980 | 109,225 | 179,983 | 86,200 | 253,330 |
| | | Steam..... | | 800 | 15,500 | 26,000 | 32,500 | 85,000 |
| | | Internal combustion..... | | | | | | |
| | | Total..... | 6,000 | 25,780 | 124,725 | 205,963 | 118,700 | 338,330 |
| 7 | Pacific Southwest..... | Hydro..... | 17,200 | 39,334 | 168,220 | 158,130 | 160,705 | 589,324 |
| | | Steam..... | | | 76,100 | 155,860 | 46,500 | 20,700 |
| | | Internal combustion..... | | | | 300 | 700 | 1,140 |
| | | Total..... | 17,200 | 39,334 | 244,320 | 314,290 | 207,905 | 881,164 |
| Total capacity of hydro units..... | | | 27,700 | 170,064 | 627,215 | 1,225,450 | 1,021,115 | 2,228,249 |
| Number of hydro units..... | | | 28 | 107 | 203 | 288 | 198 | 328 |
| Average size of hydro units..... | | | 991 | 1,586 | 3,090 | 4,255 | 5,160 | 6,795 |
| Total capacity of steam units..... | | | 19,498 | 76,788 | 614,587 | 1,823,399 | 3,734,937 | 6,476,040 |
| Number of steam units..... | | | 18 | 41 | 151 | 309 | 375 | 430 |
| Average size of steam units..... | | | 1,082 | 1,872 | 4,060 | 5,900 | 9,960 | 15,040 |
| Total capacity of internal-combustion units..... | | | | | 348 | 3,843 | 3,914 | 11,672 |
| Grand total, capacity of all types..... | | | 47,198 | 246,852 | 1,242,150 | 3,052,692 | 4,759,966 | 8,715,961 |

TABLE 8.—Present power-plant capacity of the major electric utilities in the United States classified according to year of installation and type of prime movers—Continued

[Data taken from reports of 215 systems]

| Zone | Region | Type of prime movers | 1926-30 | 1931-34 | Total | Year of installation not given ¹ | Grand total |
|--|-------------------------|--------------------------|-----------------------------|-----------------------------|-------------------------------|---|-------------------------------|
| | 1 | 2 | 9 | 10 | 11 | 12 | 13 |
| 1 | Northeast..... | Hydro..... | <i>Kilowatts</i> 822,329 | <i>Kilowatts</i> 172,440 | <i>Kilowatts</i> 2,251,630 | <i>Kilowatts</i> 160,134 | <i>Kilowatts</i> 2,411,764 |
| | | Steam..... | 2,633,750 | 658,000 | 7,980,455 | 50,585 | 8,031,040 |
| | | Internal combustion..... | 1,300 | | 1,300 | 4,362 | 5,662 |
| | | Total..... | 3,457,379 | 830,440 | 10,233,385 | 215,081 | 10,448,466 |
| 2 | Middle West..... | Hydro..... | 104,012 | 171,800 | 921,977 | 114,829 | 1,036,806 |
| | | Steam..... | 3,085,450 | 467,500 | 8,009,152 | 215,528 | 9,124,678 |
| | | Internal combustion..... | 8,236 | 5,422 | 20,027 | 8,216 | 28,243 |
| | | Total..... | 3,197,698 | 644,722 | 9,851,156 | 338,571 | 10,189,727 |
| 3 | Southeast..... | Hydro..... | 951,490 | 25,520 | 2,312,246 | 42,786 | 2,355,032 |
| | | Steam..... | 661,750 | 37,250 | 1,732,820 | 66,888 | 1,799,708 |
| | | Internal combustion..... | 10,677 | | 14,005 | 7,415 | 21,420 |
| | | Total..... | 1,623,917 | 62,770 | 4,059,071 | 117,089 | 4,176,160 |
| 4 | Mountain and Plain..... | Hydro..... | 70,250 | 3,000 | 326,800 | 17,738 | 344,538 |
| | | Steam..... | 162,250 | 35,500 | 606,511 | 15,865 | 622,376 |
| | | Internal combustion..... | 8,805 | 3,030 | 14,511 | 6,878 | 21,389 |
| | | Total..... | 241,305 | 41,530 | 947,822 | 40,481 | 988,303 |
| 5 | Southwest..... | Hydro..... | 2,800 | 71,820 | 89,990 | 3,101 | 93,091 |
| | | Steam..... | 721,000 | 89,500 | 1,339,301 | 51,497 | 1,390,798 |
| | | Internal combustion..... | 12,214 | 790 | 18,268 | 19,011 | 37,279 |
| | | Total..... | 736,014 | 162,110 | 1,447,559 | 73,609 | 1,521,168 |
| 6 | Pacific Northwest..... | Hydro..... | 239,130 | 137,700 | 1,036,528 | 31,878 | 1,068,206 |
| | | Steam..... | 169,000 | 35,000 | 363,800 | 3,700 | 367,500 |
| | | Internal combustion..... | | | | 64 | 64 |
| | | Total..... | 408,130 | 172,700 | 1,400,328 | 35,442 | 1,435,770 |
| 7 | Pacific Southwest..... | Hydro..... | 401,090 | 80,600 | 1,614,603 | 60,787 | 1,675,370 |
| | | Steam..... | 418,000 | 125,000 | 1,112,160 | 3,800 | 1,115,960 |
| | | Internal combustion..... | 6,740 | 28,000 | 36,880 | 382 | 37,262 |
| | | Total..... | 825,830 | 233,600 | 2,763,643 | 64,949 | 2,828,592 |
| Total capacity of hydro units..... | | 2,591,101 | 662,880 | 8,553,774 | 431,033 | 8,984,807 | |
| Number of hydro units..... | | 226 | 54 | 1,404 | | | |
| Average size of hydro units..... | | 11,460 | 12,270 | 6,095 | | | |
| Total capacity of steam units..... | | 7,851,200 | 1,447,750 | 22,044,199 | 407,861 | 22,452,060 | |
| Number of steam units..... | | 309 | 48 | 1,663 | | | |
| Average size of steam units..... | | 25,400 | 30,200 | 13,240 | | | |
| Total capacity of internal-combustion units..... | | 47,972 | 37,242 | 104,981 | 46,528 | 151,319 | |
| Grand total, capacity of all types..... | | 10,490,273 | 2,147,872 | 30,702,964 | 885,222 | 31,588,186 | |

¹ Represents capacity of water-power and steam-power plants of less than 2,500 kilowatts and oil-engine plants of less than 500 kilowatts on which these data were not obtained.

FEDERAL POWER COMMISSION

TABLE 9.—Capacity of steam electric generators in the major electric utility stations in the United States classified according to age and size of unit

[Data taken from reports of 215 systems]

| Zone | Power region | Year of installation | Under 10,000 kilowatts | 10,000 to 30,000 kilowatts | Over 30,000 kilowatts | Total kilowatts |
|---|-------------------------|----------------------|------------------------|----------------------------|-----------------------|---------------------|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | Northeast..... | Prior to 1901..... | Kilowatts 13,800 | Kilowatts | Kilowatts | Kilowatts 13,800 |
| | | 1901 to 1910..... | 102,450 | 151,000 | | 253,450 |
| | | 1911 to 1925..... | 630,205 | 2,494,250 | 1,297,000 | 4,421,455 |
| | | 1926 to 1934..... | 71,500 | 755,500 | 2,464,750 | 3,291,750 |
| | | Total..... | 817,955 | 3,400,750 | 3,761,750 | 7,980,455 |
| 2 | Middle West..... | Prior to 1901..... | | | | |
| | | 1901 to 1910..... | 71,537 | 133,000 | | 204,537 |
| | | 1911 to 1925..... | 834,265 | 2,939,900 | 1,377,500 | 5,151,665 |
| | | 1926 to 1934..... | 134,700 | 848,750 | 2,569,500 | 3,552,950 |
| | | Total..... | 1,040,502 | 3,921,650 | 3,947,000 | 8,909,152 |
| 3 | Southeast..... | Prior to 1901..... | 2,500 | | | 2,500 |
| | | 1901 to 1910..... | 47,720 | | | 47,720 |
| | | 1911 to 1925..... | 313,600 | 610,000 | 60,000 | 983,600 |
| | | 1926 to 1934..... | 55,000 | 344,000 | 300,000 | 699,000 |
| | | Total..... | 418,820 | 954,000 | 360,000 | 1,732,820 |
| 4 | Mountain and Plain..... | Prior to 1901..... | 1,698 | | | 1,698 |
| | | 1901 to 1910..... | 40,213 | 20,000 | | 60,213 |
| | | 1911 to 1925..... | 136,850 | 210,000 | | 346,850 |
| | | 1926 to 1934..... | 85,250 | 112,500 | | 197,750 |
| | | Total..... | 264,011 | 342,500 | | 606,511 |
| 5 | Southwest..... | Prior to 1901..... | 1,500 | | | 1,500 |
| | | 1901 to 1910..... | 33,055 | | | 33,055 |
| | | 1911 to 1925..... | 231,746 | 262,500 | | 494,246 |
| | | 1926 to 1934..... | 108,500 | 560,500 | 141,500 | 810,500 |
| | | Total..... | 374,801 | 823,000 | 141,500 | 1,339,301 |
| 6 | Pacific Northwest..... | Prior to 1901..... | | | | |
| | | 1901 to 1910..... | 16,300 | | | 16,300 |
| | | 1911 to 1925..... | 101,000 | 42,500 | | 143,500 |
| | | 1926 to 1934..... | 14,000 | 60,000 | 140,000 | 204,000 |
| | | Total..... | 131,300 | 92,500 | 140,000 | 363,800 |
| 7 | Pacific Southwest..... | Prior to 1901..... | | | | |
| | | 1901 to 1910..... | | 22,000 | 54,100 | 76,100 |
| | | 1911 to 1925..... | 104,560 | 328,500 | 75,000 | 493,060 |
| | | 1926 to 1934..... | 5,000 | 83,000 | 440,000 | 543,000 |
| | | Total..... | 109,560 | 433,500 | 569,100 | 1,112,160 |
| Total, all zones..... | | Prior to 1901..... | 19,498 | | | 19,498 |
| | | 1901 to 1910..... | 311,275 | 326,000 | 54,100 | 691,375 |
| | | 1911 to 1925..... | 2,352,226 | 6,887,650 | 2,809,500 | 12,034,376 |
| | | 1926 to 1934..... | 473,950 | 2,764,250 | 6,055,750 | 9,298,950 |
| | | Total..... | 3,156,949 | 9,987,900 | 8,919,350 | 22,044,199 |
| Date of installation not given ¹ | | | | | 407,861 | |
| | | Total..... | | | 22,452,060 | |

¹ Represents capacity of plants of less than 2,500 kilowatts capacity on which data were not obtained.

Table 11 shows, however, that this capacity produced in 1933 only 1.8 billion kilowatt-hours, equivalent to about 7 percent average load and 4 percent of the total steam energy produced. To supplant this capacity would require new investment of approximately \$220,000,000, incurring annual fixed costs of \$25,000,000, which together with plant oper-

ating costs, if distributed over the 1.8 billion kilowatt-hours would mean that the unit operating cost of the present plants would have to be in excess of 1.75 cents per kilowatt-hour to make it economically possible to abandon them. However, if loads increase, these plants will be called upon to produce more energy and the potential savings will become greater.

TABLE 10.—Steam electric plant capacity classified according to efficiency at 60 percent load, 1934¹

[Data taken from reports of 215 systems]

| Zone | Power region | Under 14,000 B.t.u. | 14,000 to 18,000 B.t.u. | 18,000 to 22,000 B.t.u. | 22,000 to 25,000 B.t.u. | 25,000 to 30,000 B.t.u. | Over 30,000 B.t.u. | Total |
|------|-------------------------|---------------------|-------------------------|-------------------------|-------------------------|-------------------------|--------------------|------------------|
| | | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| | | <i>Kilowatts</i> | <i>Kilowatts</i> | <i>Kilowatts</i> | <i>Kilowatts</i> | <i>Kilowatts</i> | <i>Kilowatts</i> | <i>Kilowatts</i> |
| 1 | Northeast..... | 2,155,000 | 2,297,000 | 1,851,000 | 955,000 | 410,000 | 275,000 | 7,943,000 |
| 2 | Middle West..... | 1,609,000 | 3,782,000 | 1,735,000 | 912,000 | 600,000 | 376,000 | 9,014,000 |
| 3 | Southeast..... | 60,000 | 794,000 | 294,000 | 195,000 | 195,000 | 160,000 | 1,698,000 |
| 4 | Mountain and Plain..... | | 281,000 | 86,000 | 134,000 | 88,000 | 29,000 | 618,000 |
| 5 | Southwest..... | | 947,000 | 181,000 | 50,000 | 94,000 | 70,000 | 1,342,000 |
| 6 | Pacific Northwest..... | | 70,000 | 100,000 | 85,000 | 50,000 | 52,000 | 357,000 |
| 7 | Pacific Southwest..... | 308,000 | 421,000 | 121,000 | 79,000 | 102,000 | 83,000 | 1,114,000 |
| | Total..... | 4,132,000 | 8,592,000 | 4,368,000 | 2,410,000 | 1,539,000 | 1,045,000 | 22,086,000 |
| | Percent of total..... | 18.7 | 38.9 | 19.7 | 10.9 | 7.0 | 4.7 | 100.0 |

¹ Efficiency is measured as plant fuel consumption in B. t. u. per kilowatt-hour of net station output at 60 percent load. Since 1 kilowatt-hour is equivalent to 3,412 B. t. u., a fuel consumption of 14,000 B. t. u. per kilowatt-hour corresponds to 24.4 percent over-all thermal efficiency and of 30,000 B. t. u. per kilowatt-hour to 11.4 percent over-all thermal efficiency.

NOTE.—Steam plants under 2,500 kilowatts capacity not included in this tabulation.

Likewise, as loads increase, new plants must be built to meet the demands. In building such plants, additional or increment capacity can usually be installed at an increment cost much less than the average. This low incremental capital cost increases the probability of economically supplanting the older capacity. In the previous example the average cost of capacity was estimated as approximately \$85 per kilowatt. If in building a new plant it is found that additional capacity above that required for load growth can be installed at less

has proven this to be the case. As loads grew, new plants with larger capacity than actual load growth demanded, were built for base-load operation and the older, less efficient plants reserved for short-hour, peak load operation, with a gradual abandonment of the still older plants.

Therefore, the extent and rate of the retirement of this old capacity will depend on the growth of the load and the fuel cost in the particular area. In the relatively high-fuel-cost areas in zone 1, Northeast region, it will probably be rapid and of large volume. In the

TABLE 11.—Output of steam-electric plants classified according to efficiency of plants at 60 percent load, 1933¹

[Data taken from reports of 215 systems. Thousand kilowatt-hours]

| Zone | Power region | Under 14,000 B. t. u. | 14,000 to 18,000 B. t. u. | 18,000 to 22,000 B. t. u. | 22,000 to 25,000 B. t. u. | 25,000 to 30,000 B. t. u. | Over 30,000 B. t. u. | Total |
|------|-------------------------|-----------------------|---------------------------|---------------------------|---------------------------|---------------------------|----------------------|------------|
| | | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | Northeast..... | 6,355,000 | 4,370,000 | 2,399,000 | 613,000 | 313,000 | 60,000 | 14,100,000 |
| 2 | Middle West..... | 5,696,000 | 10,556,000 | 3,083,000 | 1,060,000 | 410,000 | 170,000 | 20,975,000 |
| 3 | Southeast..... | | 1,398,000 | 420,000 | 15,000 | 128,000 | 12,000 | 1,973,000 |
| 4 | Mountain and Plain..... | | 867,000 | 251,000 | 191,000 | 430,000 | 25,000 | 1,764,000 |
| 5 | Southwest..... | | 3,090,000 | 356,000 | 16,000 | 17,000 | 153,000 | 3,632,000 |
| 6 | Pacific Northwest..... | | | 39,000 | 106,000 | 40,000 | 6,000 | 191,000 |
| 7 | Pacific Southwest..... | 346,000 | 620,000 | 1,000 | 85,000 | 3,000 | | 1,055,000 |
| | Total..... | 12,397,000 | 20,901,000 | 6,549,000 | 2,086,000 | 1,341,000 | 416,000 | 43,690,000 |
| | Percent of total..... | 28.3 | 47.8 | 15.0 | 4.8 | 3.1 | 1.0 | 100.0 |

¹ Efficiency is measured as plant fuel consumption in B. t. u. per kilowatt-hour of net station output at 60 percent load. Since 1 kilowatt-hour is equivalent to 3,412 B. t. u., a fuel consumption of 14,000 B. t. u. per kilowatt-hour corresponds to 24.4 percent over-all thermal efficiency and of 30,000 B. t. u. per kilowatt-hour to 11.4 percent over-all thermal efficiency.

NOTE.—Output of steam plants under 2,500-kilowatts capacity not included in this tabulation.

cost than the average, say \$60 per kilowatt, then the burden of fixed charges on the small number of kilowatt-hours generated by that increment capacity becomes less and the probability of it being able to supersede the old becomes greater. Past experience of the power industry

low-fuel-cost areas and in areas basically supplied by water power, much of it will be retained to carry peak loads and act as reserve capacity. To place a concrete value on the amount that must be replaced without further analysis would be mere conjecture. Undoubtedly, however,

replacements will eliminate the major part of that capacity over 20 years old and consuming more than 25,000 B. t. u. per kilowatt-hour.

Obsolescence of water-power plants is not caused by development in the art of design and improved equipment to the extent that such improvements affect the usefulness of steam-electric plants, since only a small portion of the construction cost of a water-power plant is involved in those items of mechanical and electrical equipment which are subject to improvement. The improvement in generator or turbine efficiencies has not, in general, been of sufficient magnitude to warrant replacement of such equipment in existing plants on the basis of efficiency alone, except in the case of plants adapted to the use of the adjustable-blade-pro-

peller runner, where greatly increased efficiency at part load and at reduced head is obtainable through the use of this recently developed turbine. The other turbine replacements which have been made have been partially caused by the wearing out of moving parts and high maintenance cost.

From the data in table 8 it will be seen that about 9 percent of the water-power generating units are more than 25 years old. While it is not suggested that age will decide whether or not a water-power plant is obsolete, it follows, however, that as units and plants become older, the maintenance costs increase and there comes a time when the increased operating and maintenance costs justify reconstruction of the plants.

In the two preceding sections there has been determined first, what the demand for power will be when normal industrial activity is resumed; and second, the amount of existing dependable generating capacity, after making conservative allowances for that portion of such capacity which is clearly obsolete and inefficient.

This provides a basis for the determination of the most vital questions raised by the National Power Survey:

1. What is the relation between the effective demand, by districts, for power that will be created by a resumption of normal industrial activity and the capacity of existing reasonably efficient generating plants?
2. Is there a true surplus of generating capacity, or does a critical shortage of power capacity impend?
3. To what extent can any shortages be met by plants now under construction?

Surplus and Deficit of Capacity by Zones

Shortages of capacity upon the resumption of pre-depression industrial activity are indicated in some part of every zone. The total of these shortages based upon an allowance for minimum spare capacity is approximately 845,000 kilowatts. If a leeway for growth of load is added, the total of the shortages becomes 2,325,000 kilowatts. Surpluses are also found in some parts of all but one of the zones, but as will be explained they cannot necessarily be used to offset the shortages.

In table 12 there have been combined the results of the study of loads and dependable capacities in the 45 districts into which the zones were subdivided. Dependable capacity, column 2, has been taken from table 7, and the sum of the estimated system-peak demands, column 4, from table 4. Reserve capacity, column 3, has been determined on the basis of—

1. Minimum spare capacity to assure freedom from interruptions and adequate service as discussed in section III beginning on page 18.
2. Normal reserve (minimum spare capacity plus 10 percent of peak demand for growth) as discussed in section III beginning on page 19.

The reserve capacity listed in column 3 is the sum of the necessary estimated reserve capacities, under present conditions of interconnection, of the individual districts comprising the zone. The surplus and shortage in dependable capacity by zones, columns 5 and 6, are also the sums of the excesses and shortages by districts. Their algebraic sum is practically meaningless and therefore not shown, as the surplus in one district cannot be said to be available to supply the deficit in another district, except where these districts are adequately interconnected and coordinated. The study has taken into consideration the capacity of existing transmission connections between districts and the contractual relations reported as available at time of system peak. The demands caused by these contractual arrangements would be included twice if not deducted from column 4, Sum of Estimated System-Peak Demands. These demands include only the peak demands of ultimate consumers on the individual system plus system losses, system uses and energy unaccounted for.

Reference to section A of table 12, indicates that a shortage of 845,000 kilowatts in capacity is estimated in deficient districts under minimum reserve conditions. Surplus of capacity in excess of minimum reserve capacities in districts with excess facilities totals over 1,100,000 kilowatts. Section B of the same table shows that in deficient districts the capacity fails to equal that required to meet the load and maintain normal reserve by 2,325,000 kilowatts. The results of a study of possible interconnection and coordination of facilities between districts may in some cases point out ways to reduce the shortage conditions.

This shortage of 2,325,000 kilowatts represents the increase in net dependable capacity which should be in operation by the time there is a resumption of pre-depression industrial activities. The total gross additions to capacity required may be expected to exceed this amount by the extent to which obsolescence will cause removal. Based on the conclusions

in the discussion on obsolescence this will increase the total gross requirements of new capacity to 4,000,000 kilowatts.

Projects now under construction, see section V, will meet the requirements in certain parts of

Deficits and Surpluses in Zone 1, Northeast Region

In zone 1, Northeast region, the State of Maine may require additional facilities while there is a surplus in the other New England

TABLE 12.—*Excess and shortage of capacity by power regions in the United States upon resumption of pre-depression rate of industrial activity*

[Based on reports of 215 systems]

A. BASED ON MINIMUM OF RESERVE CAPACITY

| Zone | Power region | Estimated dependable capacity | Reserve capacity | Estimated sum of system peaks | Summary of district surpluses and deficits | |
|------|-------------------------|-------------------------------|------------------|-------------------------------|--|------------------|
| | | | | | Surpluses | Deficits |
| | 1 | 2 | 3 | 4 | 5 | 6 |
| | | <i>Kilowatts</i> | <i>Kilowatts</i> | <i>Kilowatts</i> | <i>Kilowatts</i> | <i>Kilowatts</i> |
| 1 | Northeast..... | 9,390,000 | 1,534,000 | 7,869,000 | 332,000 | 195,000 |
| 2 | Middle West..... | 9,351,000 | 1,209,000 | 7,909,000 | 441,000 | 268,000 |
| 3 | Southeast..... | 2,676,000 | 384,000 | 2,273,000 | 79,000 | 60,000 |
| 4 | Mountain and Plain..... | 771,000 | 190,000 | 589,000 | 46,000 | 34,000 |
| 5 | Southwest..... | 1,701,000 | 403,000 | 1,222,000 | 101,000 | 25,000 |
| 6 | Pacific Northwest..... | 1,322,000 | 187,000 | 1,066,000 | 140,000 | 71,000 |
| 7 | Pacific Southwest..... | 2,089,000 | 210,000 | 2,071,000 | 0 | 192,000 |
| | Total..... | 27,300,000 | 3,917,000 | 23,039,000 | 1,189,000 | 845,000 |

B. BASED ON MINIMUM RESERVE PLUS 10 PERCENT OF PEAK DEMAND TO COVER MARGIN FOR GROWTH OF LOAD

| | | | | | | |
|---|-------------------------|------------|-----------|------------|---------|-----------|
| 1 | Northeast..... | 9,390,000 | 2,121,000 | 7,869,000 | 58,000 | 658,000 |
| 2 | Middle West..... | 9,351,000 | 2,006,000 | 7,969,000 | 134,000 | 758,000 |
| 3 | Southeast..... | 2,676,000 | 611,000 | 2,273,000 | 32,000 | 240,000 |
| 4 | Mountain and Plain..... | 771,000 | 247,000 | 589,000 | 16,000 | 61,000 |
| 5 | Southwest..... | 1,701,000 | 525,000 | 1,222,000 | 22,000 | 68,000 |
| 6 | Pacific Northwest..... | 1,322,000 | 294,000 | 1,066,000 | 102,000 | 140,000 |
| 7 | Pacific Southwest..... | 2,089,000 | 418,000 | 2,071,000 | 0 | 400,000 |
| | Total..... | 27,300,000 | 6,222,000 | 23,039,000 | 364,000 | 2,325,000 |

the country, particularly the Pacific northwest, southern California, southern Nevada, and western Arizona, eastern Pennsylvania, Tennessee, Alabama, and Georgia, and in other areas adjacent to Federal projects.

Figure 10 indicates by the shading of areas the various districts in which the return of normal industrial activity will create surpluses or deficits in comparison with existing generating capacity and the relative percentage of such surplus or shortage. This map has been constructed on the basis of the practical necessity of maintaining a normal reserve capacity. The preponderance of red on the map shows that few of the districts have at present sufficient facilities to maintain normal spare capacity on return of pre-depression activities. This is a critical situation which merits thoughtful consideration and careful planning by both the Government and the electric light and power industry.

States. A deficit is estimated even under minimum spare capacity condition in central New York with an approximate equivalent surplus under similar conditions in the Metropolitan area of New York City. Further interconnection between these areas might be made, if feasible. Capacity to maintain normal reserves will be insufficient by over 600,000 kilowatts in that part of the zone west of the New England States. A surplus of 58,000 kilowatts is estimated for the New England States other than Maine. In eastern Pennsylvania, New Jersey, and Delaware the deficit indicated will be largely taken care of with the completion of the steam-electric generating unit of 165,000-kilowatt capacity now being installed in the Richmond steam-electric generating plant of the Philadelphia Electric Co. Interconnection between this district and the Washington-Baltimore area should be studied.

Deficits and Surpluses in Zone 2, Middle West Region

In zone 2, Middle West region, a surplus is indicated for Michigan and Illinois and a deficit in the remainder of this zone on the basis of normal reserves. Studies of transmission systems in the zone and of the possibilities of greater coordination should be made. Plant-capacity additions of 758,000 kilowatts are estimated as necessary, of which 400,000 is estimated for the eastern section of the zone, including Indiana, Ohio, western Pennsylvania and West Virginia. Power plants in Chicago and Milwaukee on which construction work was halted during the depression can be completed to meet requirements in the immediate region but will not be sufficient to take care of other areas.

Deficits and Surpluses in Zone 3, Southeast Region

In zone 3, the Southeast region, the entire area of Alabama, Georgia, Tennessee, and the eastern portion of Mississippi has been considered as one district. Present power developments are fairly well interconnected through existing transmission networks. This large district has at present nearly sufficient facilities to supply the estimated load with a minimum of spare capacity under coordinated operation of all systems. Present capacity will be inadequate, with normal reserve, by approximately 100,000 kilowatts. The additional installation necessary to allow for growth leeway will be available with the completion of the Norris and Wheeler projects of the Tennessee Valley Authority. This may necessitate some shifting of loads and expansion of transmission networks.

If the system in northern Alabama and Tennessee is separated and not operated to supply power to the entire area, a surplus will be created in this northern section and a corresponding shortage in Georgia, southern Alabama, and eastern Mississippi. Adequate capacity apparently exists in Florida, while additional capacity of approximately 140,000 kilowatts may be necessary in Virginia and North and South Carolina.

Deficits and Surpluses in Zone 4, Mountain and Plain States

Deficits may be expected in the southern half of zone 4, Mountain and Plain States, with a surplus indicated for North Dakota and Montana, where excess capacity exists largely as a result of the reduced copper-mining activities in this area. In the northern area the surplus is 16,000 kilowatts, and the deficit is 61,000 kilowatts in the southern portion.

Deficits and Surpluses in Zone 5, South Central Region

In zone 5, Oklahoma and northern Texas will apparently require added facilities, while in southern Texas and Louisiana and eastern Arkansas there appears to be a surplus.

Deficits and Surpluses in Zones 6 and 7, Pacific Northwest and Southwest Regions

Southern Idaho and Utah in zones 6 and 7 are quite fully interconnected by transmission lines. The present facilities in this area are apparently sufficient to supply requirements under resumed industrial activities with normal spare capacity. Similarly, eastern Washington, covering the major part of the upper Columbia River Basin and northern Idaho have sufficient spare capacity to meet the loads to be expected. Completion of the Grand Coulee project will produce a surplus unless extensive new markets are developed.

A shortage of approximately 50,000 kilowatts is indicated for the northwestern section of Washington in the Puget Sound area largely owing to lack of interconnection between the two separate groups of systems supplying that district. The Diablo project now under construction by the city of Seattle will meet the requirements of this area if a complete interchange of power can be developed, or it can be supplied by additions to existing plants which could readily be installed. The power producing facilities of southern Washington and northern Oregon are estimated as insufficient. Pooling of power resources in this area would assist. The Bonneville project, however, now under construction will make available more

than sufficient capacity to meet the needs and can be enlarged as the load demands increase.

The southern half of Oregon, which shows a surplus as a separate district, is interconnected through main transmission lines and the major system is obligated by contract to supply practically the entire amount of this surplus of approximately 50,000 kilowatts to the system serving northern and central California. The area of southern Oregon and northern and central California are a single unit from the standpoint of power supply. With the return of industrial activities this total area would have approximately sufficient capacity to meet its load with the minimum of stand-by facilities. On the basis of normal leeway capacity, however, a shortage of approximately 100,000 kilowatts may be expected.

Temporary relief in the way of additional capacity for northern and central California may be possible by interconnection with the systems serving southern California and by the use of Boulder Canyon power. Studies are being carried on to determine this possibility. Unless this can be done, additional facilities will be required, presumably in the form of steam power, before any additional hydroelectric facilities can be developed. The State of California has perfected comprehensive plans covering what is known as the Central Valley Project, combining irrigation, navigation, flood control, and power. This project, which will take several years to complete, would meet for some time in the future additional requirements for power in this area.

Southern California is supplied by two more or less separate systems, one operating at 50 cycles and the other at 60 cycles. Were it not for the completion of the Boulder Canyon development by 1936 a definite shortage could be expected in this area. The estimated shortage with normal spare capacity is approximately 200,000 kilowatts. Boulder Canyon development is contemplated to be completed in 1936 with the initial capacity of 370,000 kilowatts. The completion of major transmission lines by the Bureau of Power and Light of the city of Los Angeles and the use of the present transmission line built for construction purposes will transmit this amount of capacity

to the load centers in southern California. A total of 36 percent of the estimated output of Boulder Canyon is allocated to the pumping of water by the Metropolitan Water District from the Colorado River. The balance of the output is available to cover normal load growth in southern California, southern Nevada, and western Arizona. This source should be sufficient to meet the requirements for several years in the future. There are additional possibilities with the development at Parker dam site and on the All-American Canal now being constructed.

Development of power in Arizona is largely in the central section, the major development being in connection with irrigation in the Salt River Valley and with mining activities. The present capacity apparently will be inadequate if mining activities return to conditions of pre-depression magnitude. The distance from the Colorado River makes doubtful the economical transmission of power to this area.

Summary

Present projects under construction will meet the immediate requirements of eastern Pennsylvania and New Jersey in zone 1, the requirements in zone 6, the Pacific Northwest, the southern part of zone 7, the Pacific Southwest, and the central part of zone 3 including Tennessee, Alabama, and Georgia. Many of the areas where the greatest power markets now exist and where the demand will be most acute when industrial activity is resumed do not have at the present time specific projects under construction to meet the loads that will develop upon the resumption of pre-depression industrial activity. The installation of a considerable part of the new capacity required could be avoided by the interconnection and coordination of existing facilities. By this is not meant the mere physical interconnection of two or more separate systems, but proper coordination and unified operation of the properties. The determination of the benefits derived from such interconnection and coordination requires studies of a highly technical nature. The Survey is making such studies, the results of which will be published in due course.

V. POWER PLANTS RECENTLY COMPLETED AND UNDER CONSTRUCTION

There are at present 7 Federal projects, 5 public district projects, and 3 major private utility projects involving electric-power production, construction of which is either actively under way or scheduled for the immediate future. Seventy-eight municipal projects are under construction, have been approved by the Public Works Administration, or have been completed since January 1, 1934.

The capacity and location of these projects and probable date of completion are given in table 13. The Federal projects include:

| | Initial capacity | Ultimate capacity |
|---|------------------|-------------------|
| | <i>Kilowatts</i> | <i>Kilowatts</i> |
| Boulder Canyon, zone 7..... | 1,370,000 | 1,317,500 |
| Grand Coulee, zone 6..... | 102,900 | 617,000 |
| Bonneville, zone 6..... | 86,000 | 430,000 |
| Norris Dam, zone 3..... | 100,000 | 100,000 |
| Joe Wheeler Dam, zone 3..... | 32,000 | 258,000 |
| Fort Peck, zone 4..... | 50,000 | 400,000 |
| Caspar Alcova, ¹ zone 4..... | 26,000 | 38,000 |
| Total..... | 765,900 | 3,158,500 |

¹ Rating at 100 percent power factor.

² Project approved, but not under construction Feb. 1, 1935.

In addition to the above, power developments are contemplated in connection with the All-American Canal, now under construction

in southern California, consisting of 6 plants with total capacity of 65,000 kilowatts.

The public district projects include:

| | <i>Kilowatt capacity</i> |
|---|--------------------------|
| Red Bluff, zone 5..... | 3,000 |
| Buchanan Dam, ¹ zone 5..... | 20,000 |
| Loup River, zone 4..... | 40,000 |
| Sutherland, zone 4..... | 24,000 |
| Buzzard Roost, ¹ zone 3..... | 15,000 |
| Total..... | 102,000 |

Parker Dam under construction by the Metropolitan Water District of Southern California will ultimately have installed 80,000 kilowatts. Time of installation is not definite.

The largest municipal project is the Diablo hydroelectric plant of the city of Seattle, capacity 120,000 kilowatts. The other municipal power projects (table 13) represent relatively small plants or additions to existing plants averaging less than 3,000 kilowatts each. These smaller plants are in most instances not connected with the major systems considered in this report and do not assist in relieving the shortages in power discussed in section IV.

¹ Project approved, but not under construction Feb. 1, 1935.

TABLE 13.—Electric utility power-plant capacity completed since January, 1934, or under construction

| Zone | Region | Type of ownership | Number of projects | Capacity completed in 1934 | Capacity now under construction and to be completed in— | | | | | Total |
|----------------------------------|-------------------------|----------------------|--------------------|----------------------------|---|----------------|---------|----------------|------------------|----------------------------|
| | | | | | 1935 | 1936 | 1937 | 1938 | 1939 | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1 | Northeast..... | Municipal..... | 8 | <i>Kilowatts</i> 15,000 | <i>Kilowatts</i> 24,000 | | | | | <i>Kilowatts</i> 24,000 |
| | | Private..... | 5 | 30,000 | 165,000 | | | | | 165,000 |
| | | Total..... | 13 | 45,000 | 189,000 | | | | | 189,000 |
| 2 | Middle West..... | Municipal..... | 43 | 33,000 | 68,500 | | | | | 68,500 |
| | | Private..... | 2 | 29,000 | | | | | 29,000 | |
| | | Total..... | 45 | 33,000 | 97,500 | | | | | 97,500 |
| 3 | Southeast..... | Federal..... | 2 | | | 132,000 | | | | 132,000 |
| | | Public district..... | 1 | | | 15,000 | | | | 15,000 |
| | | Municipal..... | 5 | 1,500 | 9,000 | | | | | 9,000 |
| Total..... | 8 | 1,500 | 9,000 | 147,000 | | | | | 156,000 | |
| 4 | Mountain and Plain..... | Federal..... | 2 | | | | | | | 75,000 |
| | | Public district..... | 2 | | | 64,000 | | | | 64,000 |
| | | Municipal..... | 15 | 4,500 | 12,000 | | | | | 12,000 |
| Total..... | 19 | 4,500 | 12,000 | 64,000 | 75,000 | | | | 151,000 | |
| 5 | Southwest..... | Public district..... | 2 | | | 23,000 | | | | 23,000 |
| | | Municipal..... | 5 | 7,500 | 3,000 | | | | | 9,000 |
| | | Total..... | 7 | 7,500 | 3,000 | 23,000 | | | | 26,000 |
| 6 | Pacific Northwest..... | Federal..... | 2 | | | | 86,000 | | | 188,900 |
| | | Municipal..... | 1 | | 120,000 | | | | | 120,000 |
| | | Total..... | 3 | | 120,000 | 86,000 | | | 102,900 | 308,900 |
| 7 | Pacific Southwest..... | Federal..... | 1 | | | 370,000 | | | | 370,000 |
| | | Municipal..... | 1 | | 200 | | | | | 200 |
| | | Total..... | 2 | | 200 | 370,000 | | | | 370,200 |
| Total, United States..... | | Federal..... | 7 | | | 502,000 | 161,000 | | 102,900 | 765,900 |
| | Public district..... | 5 | | | | 102,000 | | | 102,000 | |
| | Municipal..... | 78 | 62,500 | 236,700 | | | | | 236,700 | |
| | Private..... | 7 | 30,000 | 194,000 | | | | | 194,000 | |
| | Total..... | 97 | 92,500 | 430,700 | 604,000 | 161,000 | | 102,900 | 1,298,600 | |

NOTE.—Capacity completed in 1934 not included in total for the 215 systems.

Private power developments under construction include 1 steam unit of 165,000 kilowatts in the Richmond plant of the Philadelphia Electric Co. There are 6 hydro plants, totaling 59,000 kilowatts, of which 4 were completed in 1934. In addition, there are certain other relatively large private power projects for which

equipment was ordered prior to 1932 but on which construction work has been indefinitely postponed pending resumption of load growth. Many existing hydro plants have been designed so as to permit the installation of additional units and the capacities of these plants can be increased in relatively short periods when required.

VI. UNDEVELOPED WATER POWER

Sources of Information

In conducting its studies of the undeveloped water-power resources of the United States, the National Power Survey has made full use of information obtained from other Federal agencies which have investigated and reported on potential water-power projects. Among the sources of information utilized are the Water Supply Papers and manuscript reports of the United States Geological Survey and the House Document 308 Reports of the Corps of Engineers, United States Army. To supplement the information available from Federal agencies, reports and data were obtained from private and municipal utilities, State authorities and others.

Summary of Data

Although the work of analyzing and compiling the data secured from the sources mentioned above has not been completed, it is sufficiently advanced to permit a preliminary summary of the undeveloped water-power resources of the country. This summary is presented as table 14, showing by zones the number of undeveloped water-power sites, the estimated average annual output available from these sites, and an estimate of the capacity which would be installed in the event of their development. The method of presentation differs somewhat from that used in other reports dealing with the same subject and has been adopted in order that the data may be easily compared with statistics relating to present capacity installation and power production. In estimating the installed capacities, consideration has been given to the character of the load to be supplied, the variation in stream flow, the possibility of storing water, and other factors. The values adopted are considered very conservative, especially in the case of zone 6, Pacific Northwest, and more detailed studies would probably show that they can be increased, unless the future use of electric energy results in system load factors higher than past experience indicates are to be expected. The kilowatt-hour outputs shown in the table are the average annual outputs ob-

tainable with the estimated flows and adopted installations.

TABLE 14.—*Undeveloped water power in the United States*

| Zone | Region | Num-ber of sites | Estimated average annual output | Estimated installed capacity, |
|------|-------------------------|------------------|---------------------------------|-------------------------------|
| | | | 1,000 kilowatt-hours | kilowatts |
| | 1 | 2 | 3 | 4 |
| 1 | Northeast..... | 327 | 21,075,000 | 5,886,100 |
| 2 | Middle West..... | 234 | 13,208,000 | 3,604,600 |
| 3 | Southeast..... | 369 | 41,112,000 | 10,826,000 |
| 4 | Mountain and Plain..... | 93 | 15,992,000 | 3,431,300 |
| 5 | Southwest..... | 83 | 6,301,000 | 1,522,900 |
| 6 | Pacific Northwest..... | 528 | 114,200,000 | 15,664,000 |
| 7 | Pacific Southwest..... | 249 | 63,800,000 | 11,694,000 |
| | Total..... | 1,883 | 275,683,000 | 52,628,900 |

The tentative summary shown in table 14 should not be considered as precise or final. Adequate field surveys of many of the streams studied are not available. In some cases the records of stream flow do not cover a sufficient length of time to permit reliable conclusions. At some sites the factors which determine the proper size of installation are unknown and can only be derived by further and more exhaustive studies. Every effort, however, has been made to have the figures presented represent a sound but conservative estimate of undeveloped water power. Preliminary studies of other reports show that the development of many of the sites which they include probably cannot be economically justified. These sites have not been included in the figures presented in this report. It is possible that more complete study will show that additional sites should be eliminated from consideration. It is equally possible that more detailed information will show that the values of power output and capacity assigned to many of the sites which are included in the figures presented have been too conservative.

Location of Undeveloped Water Power

Of the total undeveloped water power of the United States as determined above, 64.6 percent is located in zones 6 and 7 and 22.5 percent in zones 1 and 3. The remainder, or slightly less than 13 percent, is scattered throughout

zones 2, 4, and 5 which include the Mississippi Basin area and the industrial region adjacent to the Great Lakes. Most of the undeveloped water power in zone 4, Mountain and Plain

States, is located on the western slope of the Rocky Mountains and under present conditions is not available to the commercial and industrial centers of the Great Plain area.

INDEX TO AREAS OF UNDEVELOPED WATER POWER SHOWN ON MAP, FIGURE 11

| Reference Number | Reference Number |
|--|---|
| 1. Penobscot River, Maine | 53. Chippewa and Flambeau Rivers, Wis. |
| 2. Kennebec River, Maine | 54. Black River, Wis. |
| 3. Androscoggin River, Maine, N. H. | 55. St. Croix River, Wis., Minn. |
| 4. Saco River, Maine | 56. Mississippi River above St. Paul, Minn. |
| 5. Merrimack River, N. H. | 57. Rock River, Ill., Wis. |
| 6. Connecticut River, N. H., Vt., Mass., Conn. | 58. Cedar River, Iowa. |
| 7. Missisquoi River, Vt. | 59. Iowa River, Iowa. |
| 8. Lamoille River, Vt. | 60. Des Moines River, Iowa. |
| 9. Winooski River, Vt. | 61. Illinois River, Ill. |
| 10. Otter Creek, Vt. | 62. Gasconade River, Mo. |
| 11. Housatonic River, Conn. | 63. Rappahannock River, Va. |
| 12. Saranac River, N. Y. | 64. James River, Va. |
| 13. Ausable River, N. Y. | 65. Roanoke River, Va. |
| 14. Hudson River, N. Y. | 66. Cape Fear River, N. C. |
| 15. St. Lawrence River, N. Y. | 67. Yadkin-Pee Dee River, N. C. |
| 16. St. Regis River, N. Y. | 68. Wateree River, S. C. |
| 17. Raquette River, N. Y. | 69. Broad River, N. C., S. C. |
| 18. Black River, N. Y. | 70. Saluda River, S. C. |
| 19. Genesee River, N. Y. | 71. Savannah River, S. C., Ga. |
| 20. Niagara River, N. Y. | 72. Altamaha River Basin, Ga. |
| 21. Delaware River, N. J., Pa. | 73. Chattahoochee River, Ga., Ala. |
| 22. Lehigh River, Pa. | 74. Alabama River Basin, Ga., Ala. |
| 23. Susquehanna River, Pa. | 75. Warrior River, Ala. |
| 24. West Branch Susquehanna River, Pa. | 76. Tombigbee River, Ala., Miss. |
| 25. Juniata River, Pa. | 77. Pearl River, Miss., La. |
| 26. Potomac River Basin, Md., Va., W. Va. | 78. Tennessee River Basin, Ky., Tenn., Miss., Ala., Ga., S. C., N. C., Va. |
| 27. Youghiogheny River, Md. | 79. Cumberland River, Ky., Tenn. |
| 28. Clarion River, Pa. | 80. Green River, Ky. |
| 29. Cheat River, W. Va. | 81. Kentucky River, Ky. |
| 30. Kanawha and New Rivers, Va., W. Va. | 82. Big Sandy River, Va. |
| 31. Au Sable River, Mich. | 83. Missouri River, S. Dak. |
| 32. Manistee River, Mich. | 84. Upper Missouri River Basin, Mont. |
| 33. Muskegon River, Mich. | 85. Gallatin River, Mont. |
| 34. St. Joseph River, Mich. | 86. Madison River, Mont. |
| 35. Wabash River and tributaries, Ind. | 87. Jefferson River, Mont. |
| 36. Pigeon River, Minn. | 88. Upper Yellowstone River, Mont., Wyo. |
| 37. Rainy River, Minn. | 89. Big Horn River, Mont. |
| 38. Vermilion River, Minn. | 90. Tongue River, Mont. |
| 39. Little Fork River, Minn. | 91. Cheyenne River, S. Dak. |
| 40. Big Fork River, Minn. | 92. Snake River, Wyo. |
| 41. Brule, Devil Track, Cascade, Poplar, Temperance, Baptism, Manitou and Beaver Bay Rivers, Minn. | 93. Clark Fork and Flathead Rivers, Mont. |
| 42. St. Louis River, Minn. | 94. Kootenai River, Mont. |
| 43. Sturgeon River, Mich. | 95. North Platte River, Wyo., Colo. |
| 44. Ontonagon River, Mich. | 96. South Platte River, Colo. |
| 45. Montreal River, Mich., Wis. | 97. Platte River, Sutherland and Tri County Projects Nebr. |
| 46. Bad River, Wis. | 98. Platte River near mouth, Nebr. |
| 47. Menominee River, Mich., Wis. | 99. Green River, Colo. |
| 48. Peshtigo River, Wis. | 100. Upper Colorado River, Colo. |
| 49. Oconto River, Wis. | 101. Dolores and San Miguel Rivers, Colo. |
| 50. Wolf River, Wis. | 102. Arkansas River, Colo. |
| 51. Fox River, Wis. | 103. Current River, Mo. |
| 52. Wisconsin River, Wis. | 104. White River, Mo., Ark. |

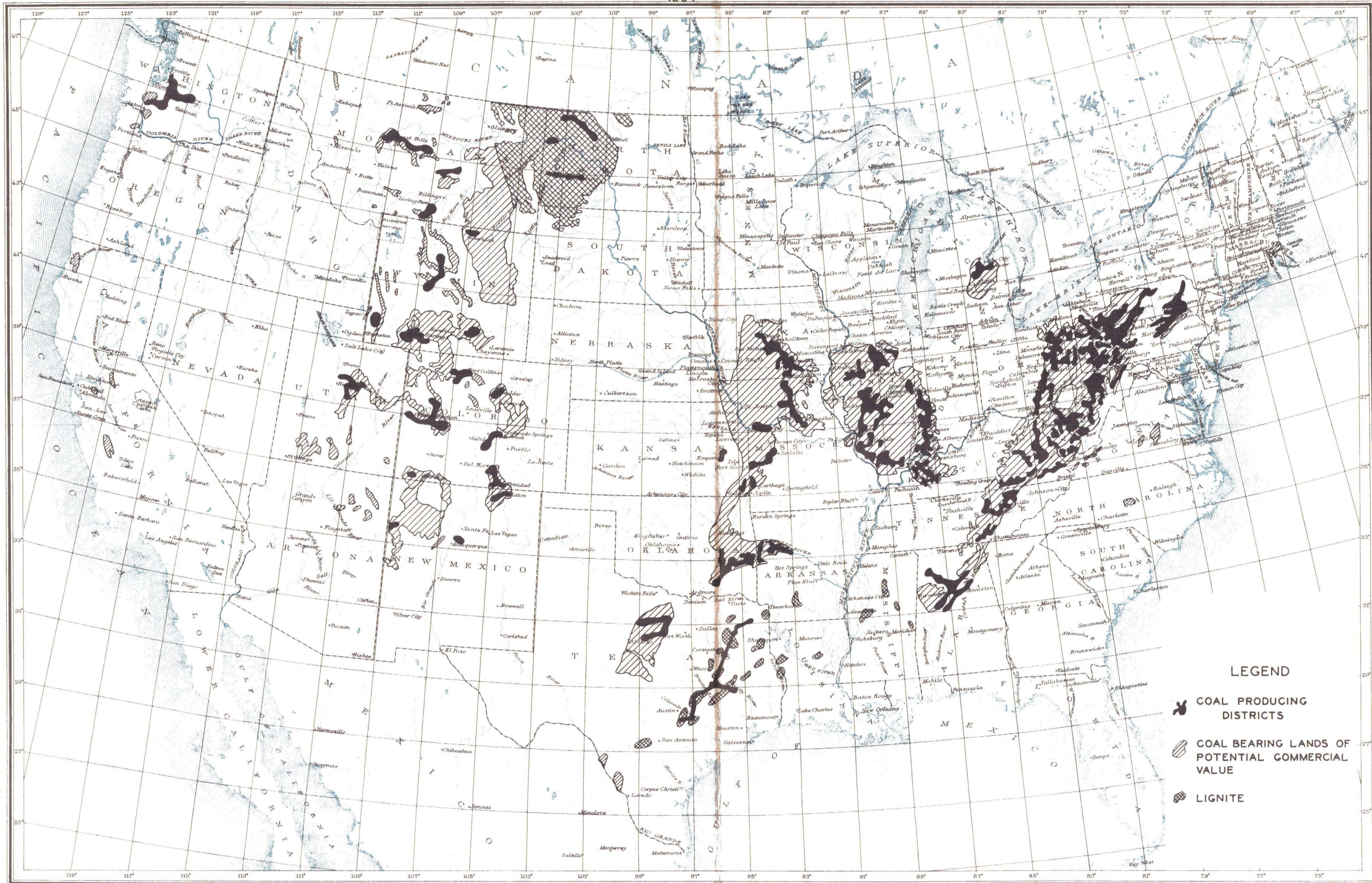
LOCATION OF UNDEVELOPED WATER POWER AREAS AND THEIR RELATION TO METROPOLITAN LOAD CENTERS OF THE UNITED STATES 1934

NATIONAL POWER SURVEY

FEDERAL POWER COMMISSION



Fig 11



LEGEND

-  COAL PRODUCING DISTRICTS
-  COAL BEARING LANDS OF POTENTIAL COMMERCIAL VALUE
-  LIGNITE

Fig. 13

ENGRAVED BY U.S.G.S.
Scale 1:11,875,000.
0 100 200 300 400 500 600 Miles

| Reference Number |
|---|
| 105. Grand River, Okla. (Arkansas Basin) |
| 106. Ouachita River, Ark. |
| 107. Red River, La., Ark., Tex., Okla. |
| 108. Calcasieu River, La. |
| 109. Brazos River, Tex. |
| 110. Guadalupe River, Tex. |
| 111. Rio Grande at Elephant Butte, N. Mex. |
| 112. Upper Rio Grande, N. Mex. |
| 113. Priest River, Idaho. |
| 114. Clark Fork, Wash. |
| 115. Columbia River and tributaries, Wash., Oreg. |
| 116. Snake River and tributaries, Wash., Oreg., Idaho, Nev. |
| 117. Yakima River, Wash. |
| 118. Cowlitz River, Wash. |
| 119. Willamette River, Oreg. |
| 120. Puget Sound Basin, Wash. |
| 121. Rogue and Umpqua Rivers, Oreg. |
| 122. Klamath and Trinity Rivers, Oreg., Calif. |
| 123. San Joaquin and Sacramento Valley, Calif. |
| 124. Humboldt River, Nev. |
| 125. Truckee, Carson River, Nev. |
| 126. Provo River, Utah. |
| 127. Green River and tributaries, Utah. |
| 128. Colorado River above Grand Canyon, Utah. |
| 129. Gila River, Ariz., N. Mex. |
| 130. Colorado River below Grand Canyon, Ariz., Nev. |
| 131. Colorado River at Parker Dam, Ariz., Calif. |
| 132. All America Canal, Calif. |
| 133. Little Colorado River, Ariz. |
| 134. Salt River, Ariz. |
| 135. Verde River, Ariz. |
| 136. Agua Fria River, Ariz. |
| 137. Hassayampa Creek, Ariz. |
| 138. Colorado River in Grand Canyon, Ariz. |

Figure 11 indicates pictorially the relative location of the principal undeveloped water power resources and important load centers. The areas of the shaded portions which designate the location of the water-power resources bear no relation to their magnitude. The following statistics and text describe in further detail the undeveloped power possibilities of the major streams of each zone.

Zone 1, Northeast Region

The 10 rivers of this zone having the largest potential undeveloped power resources, arranged in the order of magnitude, are:

| Reference number on map, fig. 11. | Estimated average annual output, thousand kilowatt-hours |
|--|--|
| 15. St. Lawrence..... | 5,724,000 |
| 23. } 24. } Susquehanna..... | 3,366,000 |
| 25. } 21. } Delaware..... | 1,530,000 |
| 22. } 6. Connecticut..... | 1,274,000 |
| 2. Kennebec..... | 1,082,000 |
| 26. Potomac (in Maryland. See also zones 2 and 3)..... | 1,053,000 |
| 20. Niagara..... | 870,000 |
| 1. Penobscot..... | 742,000 |
| 3. Androscoggin..... | 734,000 |
| 18. Black (in New York)..... | 680,000 |
| Total, 10 streams..... | 17,055,000 |
| Total for zone..... | 21,075,000 |

The potential energy from undeveloped water power in the first 4 of the above streams represents 56 percent of the total available in the zone. The output figure shown for the St. Lawrence represents that portion of the total available energy in the International Section, which would be allocated to the United States. The output shown for the Niagara represents energy which could be produced by developing additional head at Niagara Falls, utilizing the flow now allocated to the United States by treaty. These two major projects would provide large blocks of power at very high capacity factors. The majority of the remaining sites are adapted to the carrying of peak loads. Practically all developments are within transmission distance of load centers.

Zone 2, Middle West Region

The streams in the eastern section of this zone lie in a coal producing area where steam-generated power can be obtained at low cost, making difficult the justification of water-power plants except for peak power purposes or for power development incidental to flood control or improvement of navigation. The 10 rivers of this zone, having the largest potential undeveloped water power resources, arranged in the order of magnitude, follow.

| Reference no. on map, fig. 11. | Estimated average annual output, thousand kilowatt- hours |
|---|--|
| 30. Kanawha (in West Virginia. See also zone 3)----- | 4, 743, 000 |
| 29. Cheat (Monongahela Basin)----- | 1, 525, 000 |
| 26. Potomac (in West Virginia. See also zones 1 and 3)----- | 801, 000 |
| 28. Clarion (Allegheny Basin)----- | 629, 000 |
| 35. Wabash----- | 472, 000 |
| 104. White (in Missouri. See also zone 5)----- | 448, 000 |
| 58. } Iowa----- | 383, 000 |
| 59. } | |
| 47. Menominee----- | 376, 000 |
| 62. Gasconade (Missouri Basin)----- | 360, 000 |
| 56. Upper Mississippi (above Cairo, Ill.)-- | 357, 000 |
| Total, 10 streams----- | 10, 094, 000 |
| Total for zone----- | 13, 203, 000 |

Zone 3, Southeast Region

The 10 rivers of this zone having the largest potential water-power resources, arranged in order of magnitude, are:

| Reference number on map, fig. 11. | Estimated average annual output thousand kilowatt- hours |
|--|---|
| 78. Tennessee----- | 23, 800, 000 |
| 79. Cumberland----- | 3, 350, 000 |
| 71. Savannah----- | 2, 015, 000 |
| 68. } Santee----- | 1, 416, 000 |
| 69. } | |
| 70. } | |
| 30. New (Kanawha Basin. See also zone 2) | 1, 332, 000 |
| 65. Roanoke----- | 1, 315, 000 |
| 26. Potomac (in Virginia. See also zones 1 and 2)----- | 1, 163, 000 |
| 75. } Warrior and Tombigbee----- | 1, 137, 000 |
| 76. } | |
| 67. Yadkin-Pee Dee----- | 1, 032, 000 |
| 73. Chattahoochee----- | 755, 000 |
| Total, 10 streams----- | 37, 315, 000 |
| Total for zone----- | 41, 112, 000 |

The Tennessee Basin is by far the most important source of water power in this area, having a potential undeveloped output representing 58 percent of the total available in the zone. The figure given shows the output which could be obtained by a comprehensive development of the Basin and includes the estimated output of those projects under construction and proposed by the Tennessee Valley Authority. On some of the streams in this zone development will involve navigation and flood control, as well as power production.

Zone 4, Mountain and Plain States Region

This zone extends over a very large area of the western Mississippi Valley. Practically 85 percent of the water-power possibilities are located in the northwestern portion of the zone on the Missouri River and its tributaries, and on the upper headwaters of the Columbia River and the Colorado River in the Rocky Mountain area. Few power possibilities exist in the eastern and southern section of the zone where the major commercial and agricultural activities are located. The distance between the major water-power resources and the markets of the eastern section of the zone are beyond present economic transmission limits.

The streams of the zone arranged in the order of the magnitude of their potential power resources are listed below:

| Reference no. on map, fig. 11 | Estimated average annual output thousand kilowatt- hours |
|---|---|
| 84. } Upper Missouri----- | 4, 788, 000 |
| 85. } | |
| 86. } | |
| 87. } | |
| 93. } Upper Columbia----- | 3, 804, 000 |
| 94. } | |
| 88. } | |
| 89. } Yellowstone----- | 3, 275, 000 |
| 90. } | |
| 99. } | |
| 100. } Upper Colorado and Green----- | 2, 157, 000 |
| 101. } | |
| 95. } | |
| 96. } Platte----- | 1, 239, 000 |
| 97. } | |
| 98. } | |
| 92. Snake (Columbia Basin)----- | 571, 000 |
| 102. Arkansas (above Wichita. See also zone 5)----- | 103, 000 |
| 91. Cheyenne----- | 55, 000 |
| Total for 8 streams----- | 15, 992, 000 |
| Total for zone----- | 15, 992, 000 |

Zone 5, South Central Region

This is a relatively minor water-power zone, having but 2.3 percent of the total undeveloped water power of the United States. Much of the future development of water power in this area will be in connection with navigation, irrigation and water supply, or flood control. The Red and White Rivers account for about 65 percent of the potential energy output of the zone. Many of the potential developments are remote from any existing load center.

The streams of the zone arranged in the order of magnitude of energy possibilities are:

| Reference no. on map, fig. 11 | Estimated average annual output, thousand kilowatt-hours |
|--|--|
| 107. Red..... | 2,391,000 |
| 104. White (in Arkansas. See also zone 2)- | 1,739,000 |
| 105. Arkansas (below Wichita)..... | 770,000 |
| 111, } Rio Grande (above El Paso)..... | 603,000 |
| 112 } | |
| 106. Ouachita..... | 325,000 |
| 109. Brazos..... | 295,000 |
| 110. Guadalupe..... | 136,000 |
| 108. Calcasieu..... | 42,000 |
| Total, 8 streams..... | 6,301,000 |
| Total for zone..... | 6,301,000 |

Zone 6, Pacific Northwest Region

In the Pacific Northwest region is found the combination of relatively high mountains and heavy precipitation. In this zone, comprising Washington, Oregon, and Idaho, 41.4 percent of the undeveloped hydro energy of the Nation is located, representing a total of approximately 114 billion kilowatt-hours annually. The major portion of the power that may be developed is located in the Columbia River Basin. This basin includes all of eastern Washington and with its major tributaries, the Clark Fork, Snake, Willamette, Cowlitz, and Lewis Rivers, is potentially the largest water-power producing area in the United States. On this stream are now being constructed the Bonneville and Grand Coulee projects, which when developed to their ultimate capacity will have an installed capacity of 2,312,000 kilowatts and a potential annual output of 15 billion kilowatt-hours, which is included in the summaries throughout this section of the report. Considerable power has already been developed on the Spokane and Chelan tributaries and on the Snake River in Idaho.

The major basins of the zone arranged in order of the magnitude of undeveloped water power are listed below:

| Reference number on map, fig. 11 | Estimated average annual output, thousand kilowatt-hours |
|--|--|
| 113. } Columbia, including tributaries above | |
| 114. } Portland..... | 62,700,000 |
| 115. } | |
| 117. } | |
| 116. Snake River and tributaries..... | 17,510,000 |
| 120. Puget Sound Basin..... | 10,760,000 |
| 119. Willamette Basin..... | 6,530,000 |
| 118. Cowlitz River..... | 3,270,000 |
| Total, 5 basins..... | 100,770,000 |
| Total for zone..... | 114,200,000 |

Zone 7, Pacific Southwest Region

The undeveloped water-power resources in this zone comprise 23.2 percent of the total for the United States. These resources are located in two major basins—the Colorado River Basin, located mainly in Utah, Arizona, southern Nevada, and southeastern California, and the San Joaquin-Sacramento Valley Basin located in northern and central California.

The resources in the Colorado River Basin are located chiefly on the main stream, extending from Yuma, Ariz., at the southern end to the main branches of the Colorado in Utah. There are four sites within the Grand Canyon National Park in Arizona which account for 7.3 billion kilowatt-hours of the total estimated annual output of power potentialities of the basin. The output of the Boulder Canyon development, approaching completion, with a total ultimate capacity of over a million kilowatts and an output of approximately 5 billion kilowatt-hours per annum, has been included in the summary. The potential developments at the Parker Dam site and on the All-American Canal are also included. The potential power resources in this area are 200 or more miles from present major load centers.

Undeveloped resources of the San Joaquin-Sacramento basin are located in the streams on the west slope of the Sierra Nevada mountains. The major power streams within this basin are the Pit, Sacramento, Feather, Yuba, American, San Joaquin, and Kings. Distance to load centers varies from 100 to 250 miles.

The potential undeveloped resources of this zone by major basins in order of magnitude are:

| Reference number on map, fig. 11 | Estimated average annual output, thousand kilowatt-hours |
|---|--|
| 126-137 incl. Colorado Basin (outside of Grand Canyon National Park)..... | 21,900,000 |
| 138. Colorado Basin (inside of Grand Canyon National Park)..... | 7,300,000 |
| 123. San Joaquin-Sacramento Basin..... | 17,470,000 |
| 122. Klamath and Trinity Basin..... | 10,150,000 |
| * Total..... | 56,820,000 |
| Total for zone..... | 63,800,000 |

Relation of Undeveloped Water-Power Resources to Present Requirements

The relative magnitude of undeveloped water-power resources and present power require-

ments varies widely in the several zones. Tables 15 and 16 have been prepared to show this variation. Table 15 compares the estimated average annual energy available from undeveloped water power in each zone with the energy produced in the same zone in 1929 by the 215 major electric utilities of the United States. Table 16 is a similar comparison of the estimated potential capacity of undeveloped water power with the 1934 installed capacities of the same utilities.

The first of these tables shows that although more than 65 percent of the total 1929 energy production took place in zones 1, Northeast

power. The same conditions obtain in the eastern portions of zones 4 and 5, Mountain and Plain States and Southwest regions. The power requirements of zone 3, Southeast region, may continue as at present to be supplied largely from water-power plants, generation in fuel-burning plants being limited in general to the amount necessary to supplement hydro energy in periods of drought and to provide for most economical operation of power systems. Similar conditions may be experienced in zones 6 and 7, Pacific Coast regions.

In those zones in which relatively large loads have been developed and the predominant

TABLE 15.—Comparison of estimated annual output of undeveloped water power in the United States with 1929 power production of 215 major electric utilities

| Zone | Region | 1929 hydro production | | 1929 total production | | Estimated average annual output undeveloped hydro | | | |
|------|-------------------------|-----------------------|--------------------------------|-----------------------|--------------------------------|---|--------------------------------|-----------------------|-----------------------|
| | | 1,000 kilowatt-hours | Percent of United States total | 1,000 kilowatt-hours | Percent of United States total | 1,000 kilowatt-hours | Percent of United States total | Percent of— | |
| | | | | | | | | 1929 hydro production | 1929 total production |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 1 | Northeast..... | 8,795,080 | 28.20 | 28,463,253 | 30.29 | 21,075,000 | 7.65 | 240 | 79 |
| 2 | Middle West..... | 3,511,415 | 11.27 | 30,667,260 | 35.12 | 13,203,000 | 4.77 | 376 | 43 |
| 3 | Southeast..... | 6,830,733 | 21.92 | 8,758,058 | 10.04 | 41,112,000 | 14.90 | 602 | 469 |
| 4 | Mountain and Plain..... | 1,788,010 | 5.74 | 8,392,223 | 3.89 | 15,992,000 | 5.79 | 894 | 471 |
| 5 | Southwest..... | 66,805 | .22 | 4,514,543 | 5.18 | 6,301,000 | 2.29 | 9,432 | 140 |
| 6 | Pacific Northwest..... | 3,472,967 | 11.12 | 4,238,401 | 4.85 | 114,200,000 | 41.40 | 3,288 | 2,695 |
| 7 | Pacific Southwest..... | 6,713,394 | 21.53 | 9,261,279 | 10.63 | 63,800,000 | 23.20 | 950 | 689 |
| | Total..... | 31,178,404 | 100.00 | 87,295,017 | 100.00 | 275,683,000 | 100.00 | 884 | 316 |

region, and 2, Middle West region, the undeveloped water-power resources located in those areas could produce only 12.4 percent of the nation's potential undeveloped water-power energy. In contrast with this situation the 1929 energy production in zone 6, Pacific Northwest, was only 5 percent of the United States total (215 major companies) while 41.4 percent of all the potential energy available from undeveloped water power in the United States could be produced by projects located in that area. The corresponding figures for zone 7, Pacific Southwest, are 10.6 percent and 23.2 percent, respectively.

The potential energy available from undeveloped water power projects in both zones 1 and 2, Northeast and Middle West regions, is less than the 1929 requirements of those areas. It is probable that a large percentage of the

power requirements of both these regions will always be developed by other means than water source of energy is the fuel-burning plant, the construction of new water-power facilities can often be more easily justified than in zones of lesser development where energy from water power predominates at the present time. The annual load growths of the larger systems permit a more rapid utilization of new water power installations and a large proportion of capacity in fuel-burning plants presents favorable conditions for absorption of hydroelectric energy because of the possibility of substituting that type of energy for energy which would otherwise be produced in the fuel-burning plants. These factors are of especial importance in their bearing on the economic feasibility of large water-power projects such as the proposed St. Lawrence development.

TABLE 16.—Comparison of estimated capacity of undeveloped water power in the United States with 1934 installed capacity of 215 major electric utilities

| Zone | Region | Installed hydro capacity | | Total installed capacity | | Estimated potential capacity undeveloped hydro | | | |
|------|-------------------------|--------------------------|--------------------------------|--------------------------|--------------------------------|--|--------------------------------|-----------------|--------------------------|
| | | Kilowatts | Percent of United States total | Kilowatts | Percent of United States total | Kilowatts | Percent of United States total | Percent of— | |
| | | | | | | | | Installed hydro | Total installed capacity |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
| 1 | Northeast..... | 2,426,000 | 27.0 | 10,450,000 | 33.0 | 5,886,100 | 11.2 | 242 | 56 |
| 2 | Middle West..... | 1,095,000 | 12.3 | 10,416,000 | 33.0 | 3,604,600 | 6.8 | 329 | 35 |
| 3 | Southeast..... | 2,099,000 | 23.4 | 3,620,000 | 11.4 | 10,826,000 | 20.6 | 515 | 299 |
| 4 | Mountain and Plain..... | 344,000 | 3.8 | 843,000 | 2.7 | 3,431,300 | 6.5 | 996 | 407 |
| 5 | Southwest..... | 93,000 | 1.0 | 1,785,000 | 5.6 | 1,522,900 | 2.9 | 1,638 | 85 |
| 6 | Pacific Northwest..... | 1,183,000 | 13.1 | 1,576,000 | 5.0 | 15,664,000 | 29.8 | 1,323 | 994 |
| 7 | Pacific Southwest..... | 1,745,000 | 19.4 | 2,938,000 | 9.3 | 11,694,000 | 22.2 | 670 | 398 |
| | Total..... | 8,985,000 | 100.0 | 31,588,000 | 100.0 | 52,628,900 | 100.0 | 586 | 166 |

Note.—Installed capacities shown for each power region differ slightly from those shown in table 1, as the boundaries of the selected power districts do not in all cases conform exactly to zone boundaries.

VII. FUEL RESOURCES

By far the greater part of all electric energy generated in the United States is produced in fuel-burning plants. Figure 12 shows the relative amounts of electric energy generated in water-power and fuel-power plants for public use in the period 1919 to 1934, inclusive. In all these years except two, 1932 and 1933, power generated in fuel plants exceeded 60 percent of the total. In these 2 years the decrease was probably due to dropping off in total output

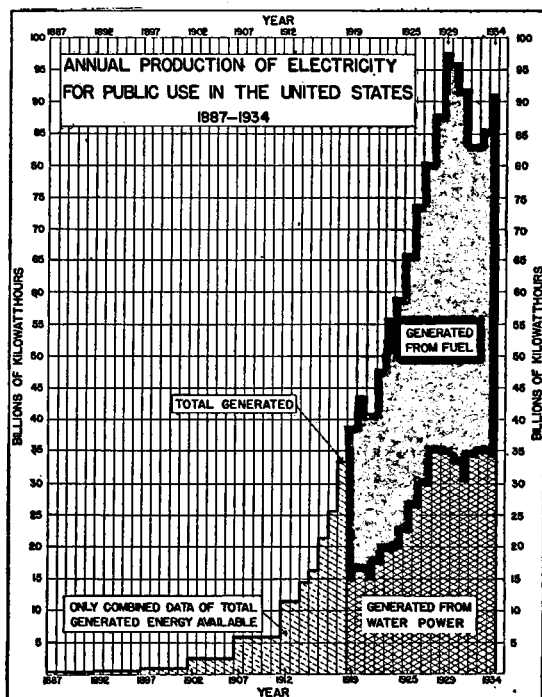


FIGURE 12.—Annual production of electricity for public use in the United States, 1887-1934.

with a fairly constant output from the water-power plants.

While comparable figures for industrial plants producing power for their own use are not available, it would appear that, according to the 1929 Bureau of Census reports, of the total installed horsepower of 20,155,397 falling in this class, only 1,559,618 horsepower, or 7.7 percent, represented the installed capacity of water-driven units, the remainder of 92.3 percent requiring the use of fuels.

All fuels can be used in producing power with equal facility. They thus compete one with

another solely on price and comparative investment in fuel-burning equipment. In the great industrial area lying east of the Mississippi River and north of the Ohio and Potomac Rivers, where 70 percent of the electricity of the country is produced, and including in its boundaries the major portion of the great Appalachian coal fields, coal is the predominant fuel.

The Southwest and the Pacific coast depend on oil and gas for their fuel. Along the Atlantic seaboard large quantities of oil are used, due to low water-transportation rates, but coal is also the important fuel in that area.

The distribution of use of fuels in utility power production for 1933 by zones is indicated in table 17.

Coal

Of the three natural fuels available, coal, oil, and gas, coal is the most abundant. It is found in mineable quantities in 31 States. Reserves are estimated at over 3,000 billion tons, of which only 25 billion have been mined. There are many kinds of coal with many diverse characteristics ranging from the graphitic anthracites, which have little or no fuel value, through the true anthracites, bituminous, lignites, to the youngest peat deposits.

There are three deposits of anthracite in the United States of commercial value, the largest of which is in eastern Pennsylvania. The other two are located in Colorado and New Mexico, and in Alaska. The only one of these deposits of importance in the production of power is the Pennsylvania field. There are 13 electric utility steam plants burning anthracite and using from 1,600,000 to 2,000,000 tons per year. Ten of these are within the limits of the Pennsylvania field and burn approximately 81 percent of the total used. Additional quantities are also burned in industrial power plants within this area and along the northeastern seaboard and by the coal producers themselves, but there are no data available as to these quantities. For the past decade the general trend of anthracite production has been downward. From a production of 93,339,000 tons in 1923, output declined to

OIL AND NATURAL GAS FIELDS WITH PRINCIPAL OIL PIPE LINES OF THE U.S.

-1934-

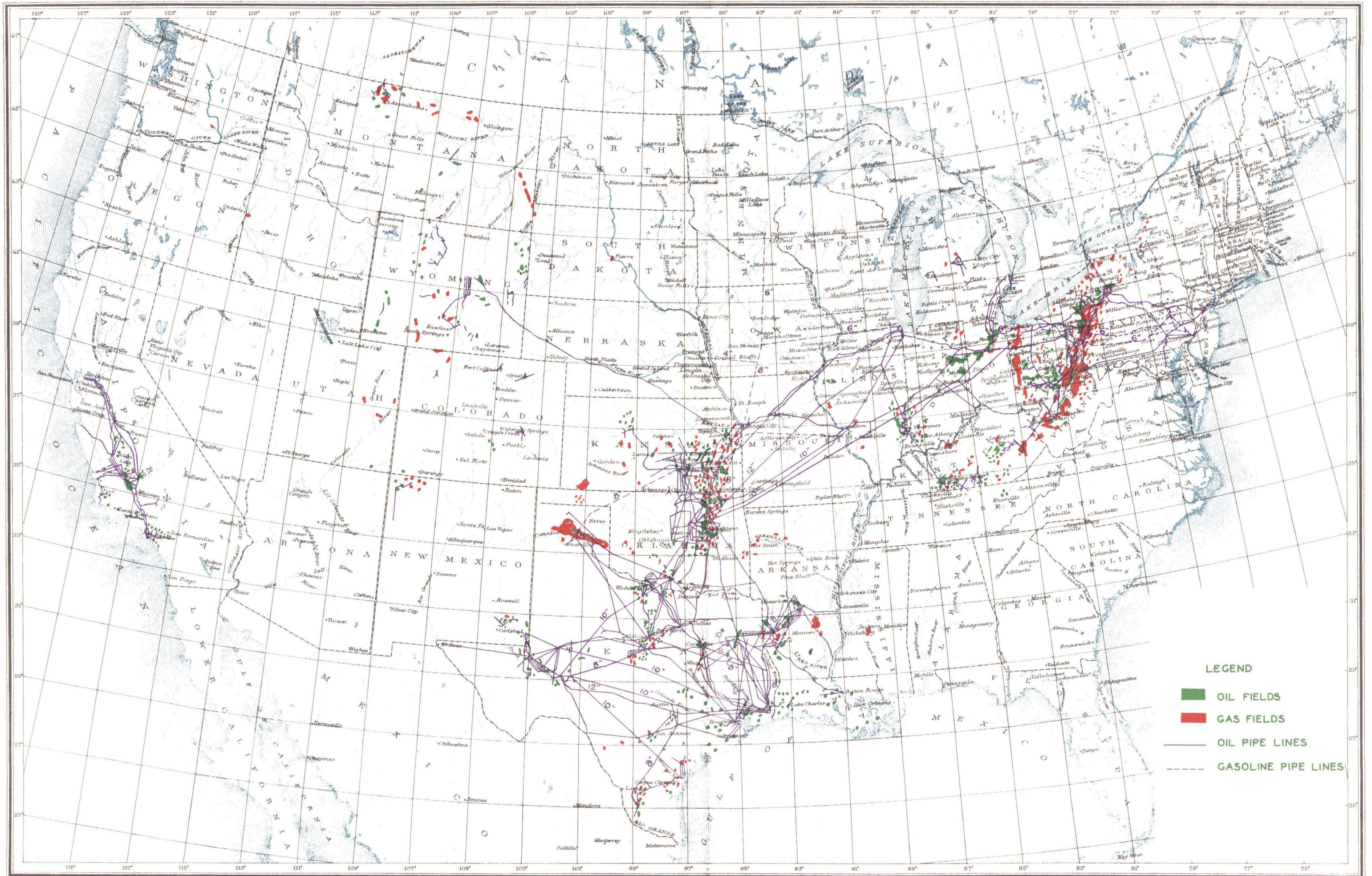


Fig. 14

ENGRAVED BY U.S.G.S.

Scale 1:1,275,000.

0 100 200 300 400 500 600 Miles

73,828,000 tons in 1929 and 49,541,000 tons in 1933. Its competitive position in the power field has been greatly weakened by the low

est production and the best quality of coals are found. It is in this area, also, that coal finds its greatest use as a power-producing agent.

TABLE 17.—Consumption of fuels in the production of electricity for public use in the United States, 1933

[Taken from United States Geological Survey Bulletins]

| Zone | Region | Coal | | Oil | | Natural gas | |
|------|--------------------------------------|------------|--------------------------------|-----------|--------------------------------|---------------------|--------------------------------|
| | | Short tons | Percent of United States total | Barrels | Percent of United States total | Thousand cubic feet | Percent of United States total |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1 | Northeast..... | 10,296,000 | 33.7 | 5,553,000 | 55.8 | 341,000 | 0.3 |
| 2 | Middle West..... | 16,871,000 | 55.2 | 658,000 | 6.6 | 13,000,000 | 12.7 |
| 3 | Southeast..... | 1,308,000 | 4.3 | 2,089,000 | 21.0 | 4,295,000 | 4.2 |
| 4 | Mountain and Plain..... | 1,262,000 | 4.1 | 455,000 | 4.5 | 14,095,000 | 13.7 |
| 5 | Southwest..... | 836,000 | 2.7 | 671,000 | 6.7 | 55,187,000 | 53.8 |
| 6 | Pacific Northwest..... | ..... | ..... | 75,000 | ..... | ..... | ..... |
| 7 | Pacific Southwest..... | 2,000 | ..... | 443,000 | 4.6 | 15,682,000 | 15.3 |
| | Total, United States..... | 30,575,000 | 100.0 | 9,944,000 | 100.0 | 102,600,000 | 100.0 |
| | Coal equivalent of consumed oil..... | 2,467,000 | ..... | ..... | ..... | ..... | ..... |
| | Coal equivalent of consumed gas..... | 4,120,000 | ..... | ..... | ..... | ..... | ..... |
| | Grand total..... | 37,162,000 | ..... | ..... | ..... | ..... | ..... |

NOTE.—In computing coal equivalents of consumed oil and gas the following conversion factors adopted by the Division of Power Resources, Water Resources Branch, United States Geological Survey, were used:
 4.03 bbl. oil equivalent to 1 ton of coal.
 24,900 cu. ft. gas equivalent to 1 ton of coal.

prices of other fuels prevailing in recent years. No great increase in use of anthracite coal as a source of central-station power may be expected.

The most important coal from the power standpoint is that classified as bituminous. It occurs in 5 principal fields with a total area of about 200,000 square miles. These 5 fields are generally indicated on Figure 13. The Appalachian field, with an area of about 70,000 square miles, extends in a general southwesterly direction from the western end of Pennsylvania through Ohio and West Virginia, eastern Kentucky, Tennessee, and northern Alabama. The northern interior field is located in the State of Michigan, and has an area of about 11,000 square miles. The eastern interior field runs in a southeasterly direction through Illinois, southwest Indiana, and western Kentucky. The western interior field runs in a southerly direction from Iowa through eastern Kansas, western Missouri, eastern Oklahoma, and western Arkansas. The southwest interior reaches in a southwesterly direction across the State of Texas, starting in the southern part of Oklahoma.

In a very general way, these coals become poorer as one travels from east toward the west. In the area east of the Mississippi River, and particularly in the Appalachian field, the great-

Steam-electric plants have usually been constructed near the load centers in order to minimize cost of transmission. In some cases where ample supplies of condensing water and coal are found adjacent to a concentrated load, plants have been established at mine mouths. This has happened principally in Pennsylvania and in the Ohio River Valley. A few plants located on the Susquehanna River near the anthracite fields have easy access to the coal fields and the mines, thus avoiding the long haul on low-grade fuel. Some conspicuous examples of steam plants located at or near bituminous mines are the Colfax and Springdale plants on the Allegheny River near Pittsburgh, the Windsor and Philo plants in Ohio, and the Dresser plant on the Wabash River near Terre Haute. In general, however, the fortunate combination of load, condensing water, and coal is rarely found.

Reduced coal consumption per unit of electric output has further strengthened the position of the steam-electric plant located at the load center against the mine-mouth plant. Using less fuel per unit obviously decreases the burden of transportation cost per unit. Based on present efficiencies of large steam-electric power stations and future possibilities of increasing their efficiencies, thus further reducing the coal

required to produce a kilowatt-hour of electricity, and on the large investments required for transmission lines, generally speaking it will cost less to haul the fuel to plants located near the load centers than to transmit the energy from mine mouth to plants.

Coal will probably continue to be the main source of fuel power in zone 1, Northeast region, and zone 2, Middle West region. Low cost of coal in zone 2, plus the limitation in potential water power, are controlling factors.

Oil

The principal petroleum deposits thus far developed are in Pennsylvania and the States immediately south and west along the Appalachian range, in Oklahoma, in Texas, and in California. Figure 14 shows the location of oil and gas fields and the main pipe lines of the United States. As a power-producing fuel for the production of electricity, oil now ranks below natural gas.

The major part of the oil used for fuel in power plants is a refinery byproduct, commonly known as "Bunker C", remaining after some of the lighter fractions have been reclaimed by

distillation, although some crude oil is used in areas adjacent to the oil fields. Known oil reserves are being rapidly depleted, which with control of production should increase prices, thus weakening its competitive position with other fuels in the production of power.

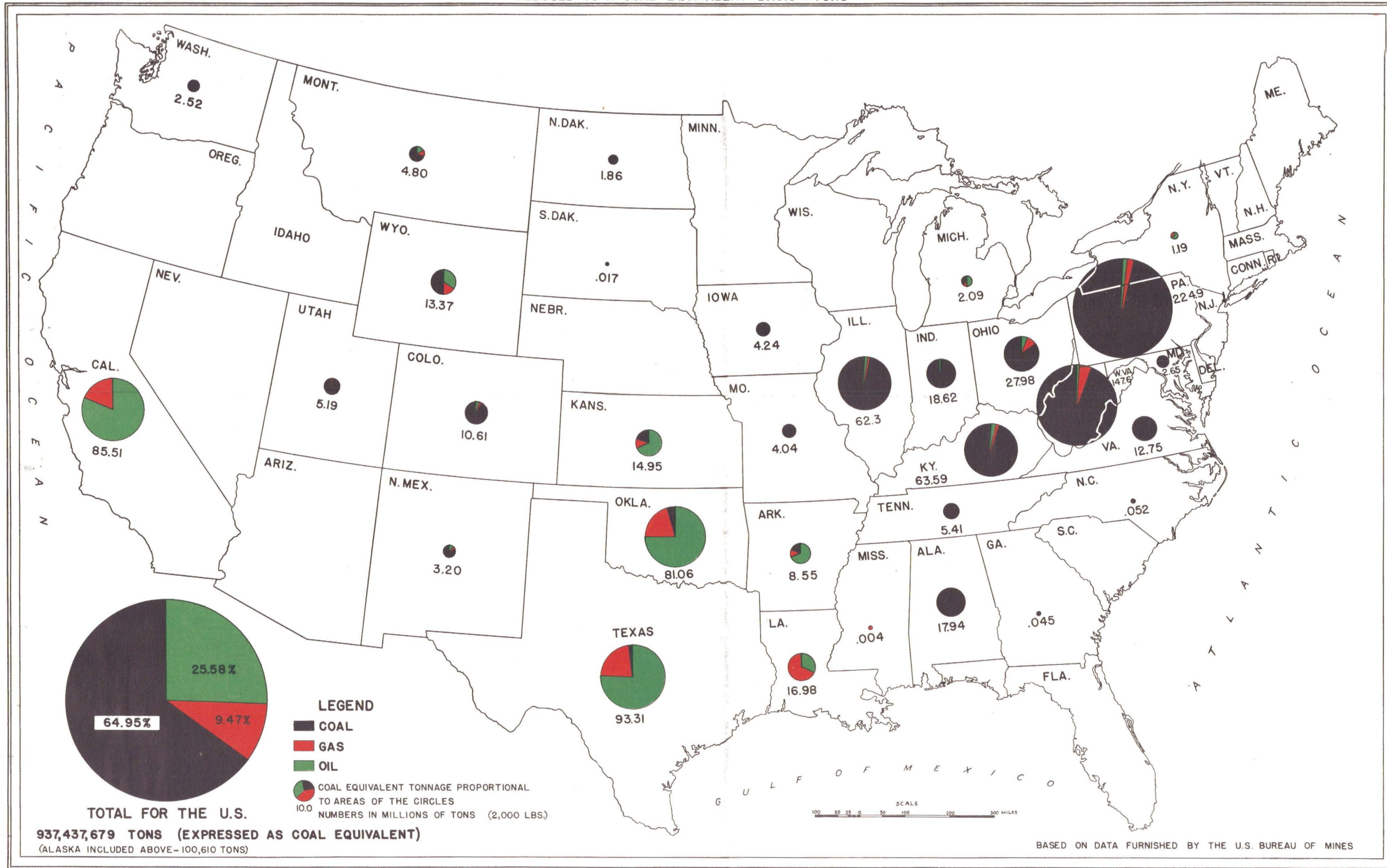
Natural Gas

The third of the important fuels is natural gas, although it represents a very small proportion of total fuels used in the production of power. It is an ideal fuel from the standpoint of flexibility of operation and simplicity and low cost of equipment used to burn it. Until recently, it was used principally for steam making in the areas adjacent to the natural-gas fields; however, developments in the art of producing and laying gas mains for long distances have brought natural gas into the industrial areas in greater quantities than the domestic market, which is the principal market, can absorb, particularly during summer months. This has brought about its use in increasing quantities in steam-power plants at great distances from the gas fields. The quantities used in each zone are shown in table 17.

PRODUCTION OF COAL, OIL AND NATURAL GAS BY STATES IN 1929
 REDUCED TO A COAL EQUIVALENT BASIS—TONS

NATIONAL POWER SURVEY

FEDERAL POWER COMMISSION



VIII. RELATION OF WATER AND FUEL POWER

Factors Affecting Development of Water Power

The location and extent of the Nation's undeveloped water-power resources have already been discussed in this report. From a commercial standpoint the question of utilization of these resources involves a study of the comparative economics of water and fuel power.

In many cases features other than the development of power, such as flood protection, navigation, irrigation, and water supply or public policy may dictate the construction of projects involving the development of water-power resources. In these cases power may be more or less incidental or a byproduct. However, the value of the power thus produced, and therefore the extent to which power may assist the financing of the development, will in general be measured on the comparative economic merits of water and fuel power.

The primary objective in supplying the power requirements of a system is that of producing power from dependable sources at a minimum cost. When additions to the system generating facilities are contemplated and both fuel power and water power are available, the selection of one or the other or a combination of both is governed by the requirement that the added capacity when combined with existing facilities must result in lowest production cost.

Water Power Is Both Competitive and Complementary

In some sections of the country, particularly certain sections in the Middle West, conditions unfavorable to economical development of water power have resulted in systems comprising for the most part fuel-burning plants. Where large power loads exist, steam-power plants predominate; while in the case of smaller isolated communities internal-combustion-engine plants have been found best adapted to service. In other sections, such as those served by the Washington Water Power Co. and Montana Power Co., the sole source of power is from water-power generating plants. More generally, however, where fairly large loads exist, lowest system generating costs have been found to

result from a combination of the two sources of power. Steam facilities predominate in some cases, while in others the bulk of the generating equipment is in water-power projects. The two sources of power are, therefore, in one sense competitive and in another complementary.

The determination of the economic advantage of one or the other source of power is dependent on the inherent characteristics of each which affect their costs and value to a power system. While these characteristics are more or less fixed, the conditions to which they must be applied, such as size and type of the load to be served, the cost of money and fuel, are constantly fluctuating. The changing nature of the problem makes it impossible to evaluate an undeveloped water-power project except for a certain set of conditions. Thus a project which cannot be justified from a cost standpoint today, may under conditions obtaining at some future date be found to be economical.

The value to a system of any additional source of power lies in the dependable capacity in kilowatts which that source will add to the system and its capability to produce kilowatt-hours which can be absorbed by and will meet the requirements of the load to be served. Aside from matters of broad public policy, the determination of whether water-power or steam plants should be constructed to meet the requirements of a given territory, necessitates the evaluation of many factors involving the characteristics of each source of power, the demand and characteristics of the load, and the resulting relative net costs. The definite answer to the question of which source of power should be developed requires, therefore, detailed knowledge of the facts in each case.

In order to assist in the better understanding of this important question, a general discussion of the major characteristics of water-power and fuel-power developments with a brief statement of the important differences follows.

Important Characteristics of Water-Power Plants

Most of the undeveloped water-power sites are located in sparsely settled territory, and in

general will require relatively long transmission lines, unless certain industries find it more economical to construct their new plants at or near the water-power sites rather than to expand their existing plants or locate at present industrial and commercial centers.

Water-power plants must be located where stream flow, head, topography, and geological conditions are found favorable. Although there are exceptions, suitable sites are seldom found near large metropolitan centers. Most of the existing and potential water-power developments on the Pacific coast and recent developments in New England are from 50 to 250 miles from centers of present developed power markets. The Pit River plants of the Pacific Gas & Electric Co., for example, are 220 miles from San Francisco, while the Leeving Creek plant of the Southern Sierras Power Co. is 330 miles from San Bernardino. Boulder Canyon is 270 miles from the center of the developed market which it is to serve. In New England the Comerford plant of the New England Power Association is 150 miles from its principal markets in Massachusetts. Even in the southeast region fairly extensive transmission lines must be built to dispose of the output of major projects.

The cost of water-power projects is difficult of determination without detailed information requiring very exhaustive field surveys. The cost per kilowatt of capacity ranges between wide limits. The lower limit seldom drops below \$100 per kilowatt; the upper limit is fixed by the value of the power to be produced.

A large part of the investment in a water-power project represents the cost of such basic elements as land, access to site, rights-of-way, dam, and regulating works, and is independent of the size of installation. The cost of the remaining elements such as water conduits, powerhouse, and generating equipment is generally proportional to the size of installation. The total cost per kilowatt of initial installation is, therefore, usually relatively high compared to the kilowatt cost of the ultimate installation for which the project is designed.

The output characteristics of water-power plants depend largely upon the water supply available. Precipitation in either rainfall or snowfall is not uniform throughout the year, and sometimes several years occur in succession when precipitation and run-off are much less

than the normal or average. Seldom is adequate seasonal storage possible, so that fairly wide fluctuations in output occur which require auxiliary service in the form of other water-power plants with large storage or fuel plants to make possible the most economical utilization of a proposed water-power plant.

The annual cost of water-power plants is practically fixed, the major portion representing interest, depreciation, and taxes on the development. Operating costs are relatively small and limited mainly to labor and maintenance, and also are of a fixed nature. This characteristic of the annual cost of water-power developments, differing quite widely from the cost characteristics of fuel plants, has a particular bearing on the determination of which type of plant is most economical for a given load.

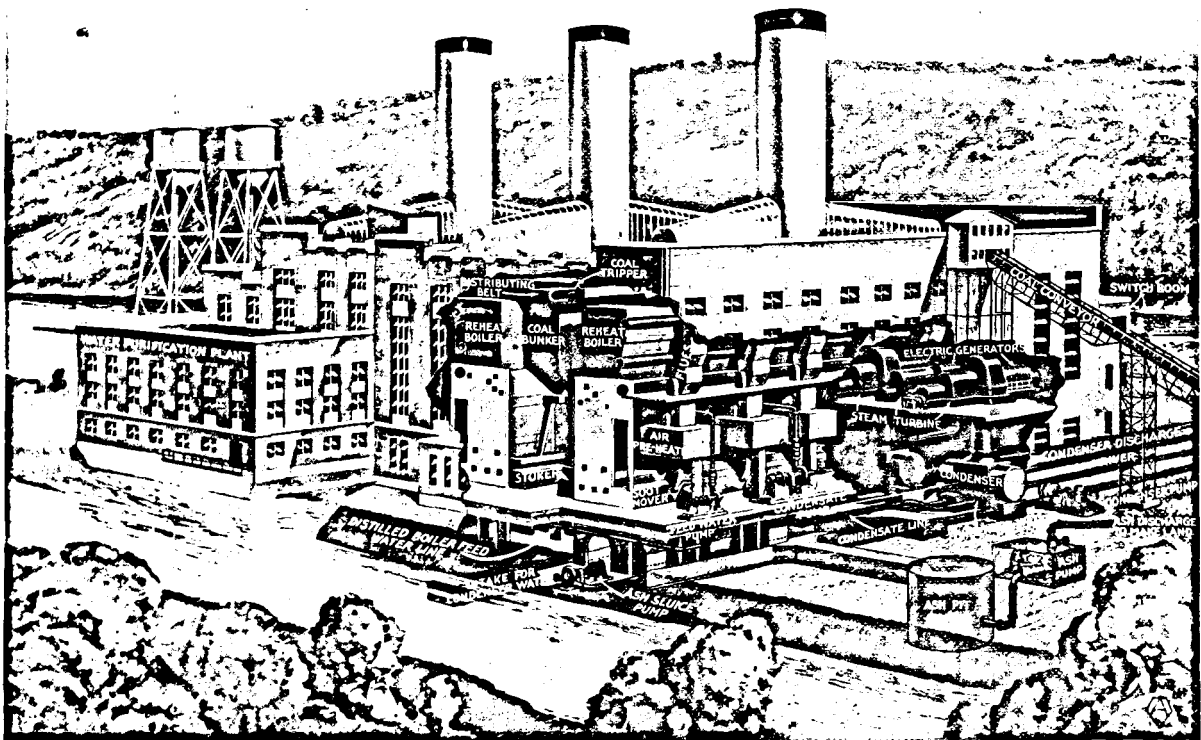
Important Characteristics of Fuel Plants

For the purpose of comparing fuel plants with water-power plants, the characteristics of large steam plants have been used.

The only physical limitation on the location of a steam plant is that imposed by the requirements for condensing water. Ample condensing-water supplies are usually to be found near metropolitan and industrial centers. Fuel can normally be transported by existing carriers at lower cost than electric energy can be transmitted over newly constructed transmission lines. For these reasons steam plants are generally located at or near important load centers where the bulk of the power is to be consumed. Extensive transmission lines requiring heavy investment and introducing hazards to dependable service are thereby avoided.

The capital cost of fuel plants is readily determined and can be fixed within fairly close limits. Companies submitting reports to the National Power Survey have furnished cost data on 78 plants each having an installed capacity of 25,000 kilowatts or over and constructed since 1920. A study of these cost figures substantiates the often-quoted estimate of \$100 per kilowatt as the average cost of modern steam plants.

The output of a steam plant and the dependable capacity which it makes available is limited only by the size of its installation. The extent to which the plant output can be absorbed



Courtesy of the American Gas & Electric Company.

MODERN STEAM ELECTRIC DEVELOPMENT.

The plant shown in this cut-away view represents a typical modern high-pressure steam-electric power development. Shown in this view are the coal conveyor which transports the coal to the stokers on which the coal is burned, the boilers, and steam turbo-generators. The intake from the river on which this plant is located is shown through which a large volume of water is passed to the steam condensers. The water purification plant in the left foreground produces water of a high degree of purity for use in the boilers.

by the power system depends on the characteristics of the system demand. The operation of a steam plant is flexible and its rate of output can at all times readily be adjusted to the system requirements. Except to the extent that fuel may be consumed at times of no output, to maintain the plant in a condition of readiness to serve, consumption of fuel occurs only when energy can be utilized on the system.

The cost of energy output from fuel plants is divided between a fixed charge and a cost varying with the energy produced. The fixed charges consist of interest, depreciation, taxes, and insurance, plus a fixed element of operating cost.

The cost varying with the energy output depends mainly upon the efficiency of the plant and the price of fuel.

An important factor of difference between water-power developments and fuel-power developments, which may not be readily apparent, involves the question of the degree of stability in annual cost. The water-power development once installed has practically a fixed annual cost. The cost of power from steam plants, however, is subject to the price of fuel, which past experience shows may vary widely over the period of the life of the plant.

Factors Favoring Water-Power Development

Since the investment for the same capacity in water-power plants is normally greater than that in steam plants, any reduction in interest rates tends to favor the development of water-power plants due to the proportionately greater reduction in annual charges on the water-power plant.

It is this fact that has warranted the common statement that "the time to build water-power plants is during a period of low interest rates and the time to build steam plants is during a time of high interest rates."

Development of major water-power sources by the Federal Government may, therefore, be justified in many cases where private development might be uneconomical.

There have been many developments in recent years which have made possible the construction of water-power plants which could not have been built a number of years ago. The technical developments in the art of designing dams has made possible the development of much higher dams than were possible

in the past; and the more economical use of materials in the structure, improved and new types of construction equipment, have made possible lower construction costs through greater speed of construction, cheaper handling of materials, and cheaper placing of concrete or earth. All these developments have reduced the first cost of the structures and likewise reduced the annual costs of the projects.

The design of hydraulic turbines had already achieved a high peak efficiency many years ago, and although developments since then have not increased the peak efficiency materially, they have increased the efficiency at average and part loads under actual operating conditions. New types of hydraulic turbines, particularly the adjustable-blade propeller runner, which is a modification of the earlier fixed-blade propeller runner, have made possible the development of water-power sites, especially those under variable heads, which could not be economically developed heretofore.

The interconnection of large systems has made possible more efficient utilization of existing water-power facilities, and the increased loads have made economical the development of some of the extremely large plants installed in recent years.

The factors which determine the economic relationship between steam and water power are constantly changing. The recent trend of these factors has been such as to favor the development of fuel power in many sections of the country. The development of huge fuel supplies and consequent lowering of fuel prices, the remarkable improvements in the art of steam-plant design and construction, with resulting improvements in fuel-plant efficiency, have been in this direction. While improvements in water-power practice have occurred coincidentally, the margin for improvements in this field has been more limited and the recent net balance of gain has been distinctly favorable to steam power. Reducing cost of money, particularly low costs to Federal enterprises and broad policies of conservation, tend to offset this trend. Future changes affecting this balance defy definite predictions. Gains in efficiency and lower construction costs will probably be obtained in both fields. The long-term trend in fuel prices has been one of increasing costs, and this trend is likely to continue in the future, particularly under improved labor conditions.

IX. INTERSTATE TRANSFERS OF POWER

Interstate Transfers of Power in 1933

More power crossed State lines in 1933 than was generated by all central stations in the entire country during 1913. The amount was in excess of 13 billion kilowatt-hours.

State lines, of course, do not constitute economic barriers, and the interconnected

networks which have grown up in the country have been developed in almost complete disregard of such political boundaries. A few States, the most notable example being Maine, have laws restricting the free interstate transmission of energy, but otherwise there are no restrictions on the free transmission of electricity across State borders.

TABLE 18.—*Interstate electrical energy transactions during 1933*
[Data taken from reports of 215 systems]

| Region and State | Thousands of kilowatt-hours | | | | | | |
|---|-----------------------------|--|--------------------------------|--------------------------|--------------------------------|----------------------------|------------------------------------|
| | Generated within State | Energy ¹ available for systems within the State | Received from outside of State | Received | | Delivered outside of State | Delivered as percent of generation |
| | | | | As percent of generation | As percent of energy available | | |
| Northeast: | | | | | | | |
| Maine..... | 759,000 | 759,000 | 39 | | | | |
| New Hampshire..... | 548,000 | 185,000 | 33,848 | 6.2 | 18.3 | 335,641 | 61.1 |
| Vermont..... | 399,000 | 136,000 | 26,036 | 6.7 | 19.2 | 288,757 | 70.8 |
| Masachusetts..... | 2,274,000 | 2,708,000 | 872,238 | 38.4 | 32.2 | 390,679 | 17.2 |
| Rhode Island..... | 442,000 | 565,000 | 270,984 | 61.3 | 48.0 | 163,604 | 37.1 |
| Connecticut..... | 1,032,000 | 1,116,000 | 136,150 | 13.2 | 12.2 | 49,224 | 4.8 |
| New York..... | 10,189,000 | 11,100,000 | 1,689,672 | 6.6 | 6.0 | 252,650 | 2.5 |
| Pennsylvania..... | 6,672,000 | 7,989,000 | 2,691,131 | 40.3 | 33.8 | 1,388,301 | 20.8 |
| New Jersey..... | 3,083,000 | 2,484,000 | 238,844 | 9.6 | 11.1 | 832,190 | 27.0 |
| Delaware..... | | 129,000 | 132,928 | | 103.0 | 4,870 | |
| Maryland..... | 1,726,000 | 1,136,000 | 1,093,077 | 63.3 | 96.3 | 1,687,306 | 97.7 |
| District of Columbia..... | 420,000 | 496,000 | 166,409 | 39.6 | 33.6 | 95,586 | 22.8 |
| Middle West: | | | | | | | |
| Michigan..... | 3,041,000 | 3,107,000 | 71,674 | 2.4 | 2.3 | 98,002 | 3.2 |
| Ohio..... | 5,618,000 | 4,781,000 | 572,625 | 10.2 | 12.0 | 760,326 | 13.5 |
| West Virginia..... | 1,557,000 | 1,609,000 | 527,713 | 33.9 | 32.8 | 901,353 | 57.8 |
| Indiana..... | 2,404,000 | 1,775,000 | 421,729 | 17.5 | 23.7 | 1,040,362 | 43.2 |
| Wisconsin..... | 1,804,000 | 1,750,000 | 166,725 | 9.2 | 9.5 | 254,275 | 14.0 |
| Illinois..... | 5,955,000 | 6,096,000 | 1,086,761 | 18.2 | 17.8 | 975,897 | 16.4 |
| Minnesota..... | 849,000 | 1,047,000 | 241,775 | 28.5 | 23.0 | 92,385 | 10.9 |
| Iowa..... | 621,000 | 780,000 | 223,404 | 36.0 | 28.6 | 83,613 | 13.5 |
| Missouri..... | 1,126,000 | 1,927,000 | 863,798 | 76.7 | 44.8 | 33,290 | .03 |
| Southwest: | | | | | | | |
| Virginia..... | 563,000 | 648,000 | 417,143 | 74.0 | 64.3 | 420,259 | 74.5 |
| North Carolina..... | 1,691,000 | 1,727,000 | 482,036 | 28.5 | 27.9 | 512,140 | 30.2 |
| South Carolina..... | 1,346,000 | 1,065,000 | 49,967 | 3.7 | 4.7 | 342,641 | 25.5 |
| Kentucky..... | 593,000 | 522,000 | 302,200 | 51.0 | 57.9 | 169,518 | 28.6 |
| Tennessee..... | 640,000 | 853,000 | 577,700 | 90.2 | 67.7 | 373,252 | 58.3 |
| Mississippi..... | 23,000 | 237,000 | 210,546 | 915.4 | 88.8 | 218 | 1.0 |
| Alabama..... | 1,413,000 | 1,284,000 | 137,463 | 9.7 | 10.7 | 551,780 | 38.9 |
| Georgia..... | 1,130,000 | 1,332,000 | 412,949 | 36.6 | 30.9 | 215,269 | 19.0 |
| Florida..... | 551,000 | 561,000 | 21,924 | 4.0 | 3.9 | 17,134 | 3.1 |
| Mountain and Plain: | | | | | | | |
| North Dakota..... | 102,000 | 75,000 | 2,491 | 2.4 | 3.3 | 28,993 | 28.4 |
| South Dakota..... | 44,000 | 68,000 | 26,393 | 69.9 | 39.0 | 3,609 | 8.1 |
| Nebraska..... | 428,000 | 396,000 | 1,477 | .4 | .4 | 46,231 | 10.8 |
| Kansas..... | 739,000 | 641,000 | 34,711 | 4.7 | 5.2 | 133,888 | 18.1 |
| Montana..... | 902,000 | 880,000 | 31 | | | 20,100 | 2.2 |
| Wyoming..... | | | 1,492 | | | | |
| Colorado..... | 340,000 | 321,000 | 465 | .1 | .1 | | |
| Southwest: | | | | | | | |
| Arkansas..... | 128,000 | 315,000 | 235,190 | 183.7 | 74.6 | 30,420 | 23.8 |
| Louisiana..... | 878,000 | 613,000 | 35,950 | 4.1 | 5.9 | 377,950 | 43.0 |
| Oklahoma..... | 635,000 | 699,000 | 85,762 | 13.7 | 12.4 | 40,058 | 6.4 |
| Texas..... | 2,195,000 | 2,211,000 | 61,365 | 2.8 | 2.7 | 58,860 | 2.7 |
| New Mexico..... | | | 4,102 | | | | |
| Pacific Northwest: | | | | | | | |
| Washington..... | 2,323,000 | 2,198,000 | 84,728 | 3.7 | 3.8 | 310,230 | 13.3 |
| Oregon..... | 911,000 | 866,000 | 149,800 | 16.4 | 17.3 | 208,954 | 22.9 |
| Idaho..... | 455,000 | 382,000 | 197,835 | 43.5 | 51.8 | 290,557 | 63.9 |
| Pacific Southwest: | | | | | | | |
| California..... | 7,923,000 | 8,421,000 | 166,889 | 2.1 | 2.0 | 78,348 | 1.0 |
| Nevada..... | | 59,000 | 59,267 | | 100.0 | | |
| Utah..... | 200,000 | 438,000 | 237,506 | 118.9 | 54.2 | 4,653 | 2.3 |
| Arizona..... | 220,000 | 228,000 | 8,811 | 3.1 | 3.0 | 75,908 | 2.7 |
| Total..... | 76,882,000 | 78,700,000 | 14,569,466 | 19.0 | 18.6 | 13,968,792 | 18.2 |
| Total, excluding States having interchange to a minor extent only²..... | 59,919,000 | 61,040,000 | 14,175,407 | 23.6 | 23.2 | 13,690,440 | 22.8 |

¹ As the data included in this tabulation are for the 215 large systems only, and as they involve transactions with smaller systems not included in the tabulation it is impossible to reconcile figures of Generated, Received, Delivered, and Available for Systems Within State.

² 617,905,000 kilowatt-hours included from Canada.

³ 26,000 kilowatt-hours included to Canada.

⁴ 5,056,000 kilowatt-hours included to Mexico.

⁵ 140,000 kilowatt-hours included from Canada.

⁶ 12,270,000 kilowatt-hours included to Mexico.

⁷ 17,000 kilowatt-hours included to Mexico.

⁸ Net balance received over international boundaries, 600,674,000 kilowatt-hours.

⁹ States excluded: Maine, Michigan, Florida, Montana, Colorado, Wyoming, Texas, New Mexico, California, Nevada, Arizona.

Data on interstate power transmission for 1933 have been compiled from reports submitted to the National Power Survey by the 215 larger systems of the country. These data, covering a very large percentage of the total interstate transmission of power, are presented in table 18. Although interstate transfers of power were probably greater than normal in certain parts of the country in that year because of reduced loads and greater distribution of hydroelectric energy, the data may be fairly indicative of the general situation.

Interstate Transfer of Power in New England

Interconnected power systems involving several States have been developed in many sections of the country, and as the technique of long-distance transmission is improved, it is reasonable to assume that these networks will be extended and reinforced. A typical example is New England. The States of Vermont, New Hampshire, Massachusetts, Connecticut, and Rhode Island constitute a single power area covered with a transmission network, possessing a considerable degree of coordination, planned for the major purpose of securing the most advantageous utilization of the output of water-power plants in conjunction with steam plants. This network extending across the State of Massachusetts, south into Rhode Island and Connecticut, and north into Vermont and New Hampshire, has made possible a more complete utilization of the water resources of the territory than could have been obtained otherwise. While many load centers within the area, due to difference in ownership and operating control, are not fully interconnected, still to a great extent power is produced where it can be generated at a minimum cost and transmitted across State lines to load centers. The water-power resources of the Deerfield and Connecticut River Valleys now feed, through the lines of the New England Power Association, the industrial area of central and eastern Massachusetts and Rhode Island, where the major part of steam power of the area is concentrated.

There was delivered outside the States of Vermont and New Hampshire amounts of energy equivalent to 71 and 61 percent, respectively, of the power produced within

these States. This was largely water power from the Searsburg and Harriman plants on the Deerfield River, and the Fifteen Mile Falls, Bellows Falls, and Vernon plants on the Connecticut River. Most of this power was exported to Massachusetts, and some was transmitted through Massachusetts to New York State, Connecticut, and Rhode Island. Massachusetts received from outside the State one-third as much as was generated within the State. There was imported into Rhode Island nearly two-thirds as much as was generated in that State. This power imported was largely water power during the high-flow season of the year, while during the low-flow season the steam plants exported power to Massachusetts to assist in meeting the need for power in that State.

Interstate Transfer of Power in the Middle Atlantic States

The eastern section of Pennsylvania, Maryland, Delaware, and New Jersey are also partially covered by a transmission network extending across State lines. As a result of these interconnections, power finds its way from the Conowingo water-power plant on the Susquehanna River in Maryland through Pennsylvania into New Jersey, from the Deepwater steam-electric station in New Jersey into and through Delaware to Pennsylvania and back into New Jersey. The other plants in the network also contribute to the exchange of power between Pennsylvania and New Jersey. A large part of the power supply of the Baltimore area is secured from the Safe Harbor and Holtwood water-power plants on the Susquehanna River in Pennsylvania and from the steam-electric plant alongside the Holtwood water-power plant.

There was imported into Pennsylvania 57 percent and exported 32 percent as much power as was generated in the State in 1933. Companies in Pennsylvania received from other States 2,263 million kilowatt-hours and delivered into other States 1,287 million kilowatt-hours. Maryland is probably the most striking example of disregard of State lines in the development of transmission systems and the interstate transfer of power. There were generated within the State, 1,726 million kilowatt-hours, received from outside sources, 1,094 million kilowatt,

hours, and exported, 1,690 million kilowatt-hours. In other words almost as much energy was exported as was produced within the State.

Interstate Transfer of Power in the South

Alabama, Mississippi, Georgia, and Tennessee are to an extent covered by an interconnected network owned by four separate operating companies which are under common holding-company control. In this network a considerable amount of power in excess of State requirements is generated in Alabama and exported to neighboring States.

Interstate Transfer of Power on the Pacific Coast

Utilities serving the Pacific coast are interconnected by lines of varying capacity. Present deliveries of power to and from California comprise a relatively small portion of that State's total generation. The interstate power transfers between California and Oregon, al-

though relatively small, normally amount to over 200 million kilowatt-hours annually. California plants, in turn, supply the major portion of Nevada requirements. With the completion of Boulder Canyon power development, import of power into California from Nevada and Arizona will ultimately total between 3 and 4 billion kilowatt-hours annually from this plant alone.

There is another group of systems lying between Portland, Oreg., Seattle, Wash., and Butte, Mont., among which there now exist interconnections sufficient to permit the flow of limited amounts of power across State lines. Transmission of power between eastern Washington and western Montana across Idaho is relatively extensive.

In Idaho, 455 million kilowatt-hours were generated in 1933, while an amount equivalent to 43 percent of the total generation was imported and an equivalent of 64 percent of the generation was exported to systems beyond the State border. The amount of power transmitted into Utah from Idaho in 1933 exceeded the total amount generated in Utah.

X. IMPORTANCE OF POWER IN NATIONAL DEFENSE

Effect of War on Power Requirements

The experience of the United States in the World War has shown that in such an emergency an adequate supply of electric power is absolutely essential. Col. Charles Keller, Corps of Engineers, United States Army, in his official report, "The Power Situation During the War", 1921, says:

"While it is difficult to say that any single resource is fundamental, it might well be argued that power supply comes very close to being so."

All of the major war materials or items of equipment rely on power for their production. Meeting the rapidly increasing requirements for power, which the production of these materials and equipment involves, is one of the most difficult of war-time procurement problems.

At the time the United States entered the war most of the existing spare generating equipment in many industrial areas had been absorbed by the demands of industry expanded to supply war orders placed by the Allied Governments.

Central-station output advanced from a total of 16.6 billion kilowatt-hours in 1914 to 22.7 billion kilowatt-hours in 1916, an increase of 6.1 billion kilowatt-hours, or 37 percent. A further increase of 6.8 billion kilowatt-hours occurred during the years 1917 and 1918, resulting in a total increase during the years 1915 to 1918, inclusive, of 12.9 billion kilowatt-hours, or 78 percent of the total national production during 1914.

In certain areas war demands for steel, chemicals, and equipment imposed rates of growth even in excess of this national average. In some districts these demands were met with great difficulty and with heavy expenditures and frequent interruptions to service, and in others it was totally impossible to produce power in the quantities required.

Due to our inability to quickly mobilize industry for war production, the full effect of a power shortage was not felt in this country until the winter of 1917-18, and during the year 1918, when many existing industries had been finally diverted to the manufacturing of war materials and new war industries had been established.

Conditions were particularly acute in the Buffalo-Niagara Falls region. Here the major power companies had previously supplemented their power supply with energy imported from Canada. The war-time increase in power requirements of Canadian industry required the curtailment of power exports.

The imminence of a power shortage was evident in other regions than the Niagara Falls district during the latter part of 1917, and by November of that year actual shortages had been developed in many places, including Pittsburgh and its environs; the eastern and central part of Ohio; the New England States, particularly Massachusetts, the southern portion of Vermont and New Hampshire; the State of New Jersey; Philadelphia and eastern Pennsylvania; Baltimore, Md., and Wilmington, Del.; the Pacific Coast; several locations in the Southern States; Norfolk and Hampton Roads; the western part of Virginia and the southern part of West Virginia, and even as far inland as Little Rock, Ark.

Causes of Power Shortages

These shortages were due to three principal causes. The first was lack of fuel. Inadequate transportation facilities and congestion of traffic made deliveries of fuel supply difficult, causing rapid depletion of stocks on hand. The second principal cause of shortage of power supply was the lack of generating capacity in central stations and industrial plants. The burden of the central stations was increased by additional demands from industrial plants whose own power-generating facilities were insufficient to meet the war-time level of production.

The third contributing cause was a shortage of water power due to extreme cold weather in the winter of 1917-18 and dry weather during the spring and summer of 1918.

Relief of Shortage During the World War

To meet the situation, the use of fuel was restricted by shutting down many old, small, and inefficient plants. Power plants were interconnected, thus taking advantage of diver-

sity in loads and making the surplus capacity of one district available for deficiencies of another. Water-power plants were interconnected in order to secure the maximum utilization of water power.

These steps, however, did not adequately provide for all requirements and, in fact, it is impossible to determine in certain districts what the power requirements would have been had capacity been available to supply them. The company at Niagara Falls had gone ahead with plans to build a steam plant at Buffalo as a substitute for the Canadian supply which had been withdrawn. Many utilities were unable to finance the construction of new plants or plant additions, and others who were in a financial position to do so were unwilling to invest in plants which it appeared would not be needed after the war was over.

There was originally no authority permitting the Government to advance money to construct new plants or to enlarge existing ones. This difficulty was later overcome, however, and plans were worked out by the War Finance Corporation enabling a few utilities to start construction, but not in time to complete needed installation before the end of the war. In one case, a new power plant was started on the Ohio River southwest of Pittsburgh near Wheeling, W. Va., by the cooperation of two companies and the United States Government. This plant, known as the "Windsor Plant", located at the mouth of a coal mine, was not put into service until after the end of hostilities.

When, in 1918, it appeared probable that the war would continue into 1919, plans were matured for extensive new power installations, and a bill (H. R. 12776) was introduced in the House of Representatives during the Sixty-fifth Congress, second session, which would have provided wide powers for the Government to construct power plants, to loan funds to enable private plants to extend capacity, to buy private plants, to construct transmission lines or pipe lines and to operate them, to requisition power output, to cancel private contracts for power, to form corporations to carry out such purposes. The bill carried with it an appro-

priation of \$200,000,000. It passed the House but had not passed the Senate at the time of the Armistice and was dropped.

Place of Power in Plans for National Defense

As a result of these war experiences, and as provided in the National Defense Act, the War Department now regularly collects data on the power-generating facilities and the transmission lines existing in the country in order to have available information to form the basis for mobilization at the very inception of a future conflict.

The importance of preparing a specific program for the control of electric power production in the event of another war has been fully demonstrated by past experience. Due to many factors that affect the situation it may be impossible in case of emergency to determine the exact amount of power needed, but it should be possible to determine in what areas or districts the greatest demand for power is likely to arise.

In view of the length of time required to construct large additions of generating capacity, consideration should be given to the maintaining of large reserves in these areas. The interconnections in each power district, as well as those between districts to permit of emergency supply from one district to another, should also be planned.

The construction of a large steam-electric generating station requires from 11 to 15 months from the time the ground is broken, but plans must be prepared considerably in advance. From 3 to 5 years are normally required to construct large water-power plants.

Water-power plants are a definite aid in national defense. Their operation is independent of fuel supply and transportation facilities and requires a minimum of manpower. Because of this and because of the length of time required to build them, water-power projects should be given consideration *now* and should be studied with a view to planned development to forestall a war-time shortage in power.

XI. SPECIAL PHASES OF THE SURVEY

Reference has been made in the Introduction to a number of special studies that are being conducted in connection with the National Power Survey. Among the most important of these are:

Cost of distribution of electricity.

Power in industry, present and future.

Power for railroad electrification, present and future.

Residential and domestic uses of electricity.

Rural electrification.

Interconnection and coordination of power facilities.

Cost of Distribution of Electricity

This study relates to the determination of the cost of distributing electrical energy from substations to the consumers' premises for different classes of service. It is being made under authority of Senate Resolution No. 80, Seventy-third Congress, first session, sponsored by Senator Costigan. It is also in accordance with President Roosevelt's Executive Order No. 6251 previously referred to, which authorizes and directs the Federal Power Commission to make a survey of the nation's power resources, including a study of the transmission, *distribution*, and utilization of electrical energy.

The object of this distribution study is to determine the cost of delivering the electric energy from the local substation to the customer, including handling his account. The scope of the study does not include determination of the cost of producing and transmitting energy to the distribution system.

The "cost of distribution" of electric energy from the local substation to the customer involves not only the cost incurred in the construction and operation of the distribution system, consisting of poles, wire, underground conduits and cables, transformer service and meters, but also cost of caring for customer complaints, commercial and new business expenses, together with taxes and general expenses incurred in connection with these items.

Surveys and investigations have been made of the distribution systems and the records of 11 private and municipal electric utility systems serving cities having, in general, a population of over 50,000. Among the major cities studied are Washington, D. C.; Los Angeles, Calif.; Portland, Oreg.; Seattle and Tacoma, Wash.; and Lansing, Mich. The costs of distribution in several smaller cities and in rural areas are now being studied.

The studies involve determination of capital invested in, or cost to reproduce, the distribution system, the operating costs incurred, and the allocation of capital and operating costs between classes of services, such as Residential, Commercial Light and Power, and Industrial Power. Throughout, care is being taken to determine costs from studies of practical operating systems.

This information, when completed and analyzed, will be covered by a subsequent report.

Power in Industry, Present and Future

The industrial survey, a feature of the National Power Survey, is a study of the present and probable future power requirements of large industries. Data have been obtained from major industries by means of report forms and personal visits of engineers. The information covers consumption of electricity over a number of years, number of installed motors and motor horsepower, details concerning industrial generating plants, the amount of electricity generated and purchased, the cost of generation, and the cost of purchased power.

The information is being collected by geographical areas so that the demand for electricity in such areas can be more accurately determined. This is of importance in working out any regional plan for power developments within a district or over extended areas.

Some industries, due either to location or the nature of their business and of their steam requirements, find it more advantageous to generate their own power, either in steam plants, using the exhaust steam for heating or process requirements, or in oil-engine plants.

Special studies are being made of the possibilities of interchange of power by these industries with electric utility systems. Such interchange has already been worked out in a number of cases. At the Deepwater Station in Deepwater, N. J., a steam plant has been installed in connection with a chemical plant of the E. I. du Pont de Nemours & Co. and power is generated partly for utility use, the exhaust steam being used in various chemical processes.

In the above case and other similar ones the electricity is generated as a byproduct at a very low incremental cost. The possibilities of such installations are dependent upon the requirements of the particular industry as well as the demands for power in the region. The effect of possible depressions on the industry, and consequent reduction in its demand for steam and power is an important factor to be considered in such cases.

The Survey is studying the increases in use of electricity in the production and refining of metals and the production of both organic and inorganic chemicals, together with electrothermal smelting, melting, refining, and heat treatment of metals and nonmetals. This use of electricity expanded rapidly during the World War period, and recent developments offer greater possibilities of commercial expansion in the future. There are many prospective changes in processes which will be treated in a special report on use of electricity by electrochemical and electrometallurgical industries. A report on the general industrial phases of the power situation is also under preparation and will be published later.

Power for Railroad Electrification, Present and Future

Attention is being directed also to the possibilities of electrification of main line steam railroads. Consideration of this important subject is being directed to the extension of some present electrified lines and to certain selected sections or divisions of other railroads which, either due to heavy mountain grades, tunnel conditions, or speeding up of traffic give promise of possible economic electrification.

The particular sections that are being studied are:

1. Atchison, Topeka & Santa Fe Railway, San Bernardino, Calif., to Winslow, Ariz.

2. Boston & Maine Railroad, Boston, Mass., to Rotterdam Junction, N. Y.

3. Chesapeake & Ohio Railway, Clifton Forge, Va., to Russell, Ky.

4. Delaware, Lackawanna & Western Railroad, Secaucus to Denville, N. J., and Dover, N. J., to Clarks Summit, Pa.

5. Denver & Salt Lake Railway, Denver to Bond, Colo.

6. New York Central Railroad, Croton to Buffalo, N. Y.

7. Norfolk & Western Railway, Roanoke, Va., to Bluefield, W. Va., and Jaeger to Williamson, W. Va.

8. Pennsylvania Railroad, Morrisville and Paoli to Harrisburg, Altoona, and Pittsburgh, Pa.

9. Reading Co., St. Clair and Tamaqua to Port Richmond and Shippensburg to Allentown, Pa.

10. Southern Pacific Co., Roseville, Calif., to Sparks, Nev., and Bakersfield to Los Angeles, Calif.

11. Union Pacific Railroad, Cheyenne, Wyo., to Ogden, Utah.

These and several other sections which offer special possibilities will be discussed in the forthcoming report on railroad electrification.

Residential and Domestic Uses of Electricity

The residential and domestic use of electricity is being investigated to determine its future possibilities. Studies are being made of trends of growth, effect of sales of appliances, and changes in rates, and the influence of present Federal and electric-utility activity in increasing the use of electricity.

The trend since 1929 is indicated in tables 3 and 5 and is illustrated graphically in figure 6, which is based on the statistics relating to the 215 major systems covered by this report. In the 4-year period, 1929 to 1933, the most severe part of the depression, both the total kilowatt-hour sales and the average use by domestic customers increased 25 percent. Despite economic conditions then prevailing, the 215 systems reporting these figures did not show a decrease in the number of domestic customers until 1933, when, due to the banking crisis and impairment of income and loss of savings of many people, the number fell off.

Rural Electrification

There are approximately 6,300,000 farms in the United States. Of these, 725,000 have central-station electric service. It has been estimated that an additional 2,400,000 families

living in rural areas and towns of 2,500 population or less do not have the advantages of electric service in their homes. The ratio of farms in any area to the total having electric service varies widely throughout the United States. Figure 16 indicates the ratio of electrified farms to the total farms for the various States. The States having the highest percentage of farms electrified are New Hampshire, Massachusetts, Rhode Island, Connecticut, New Jersey, California, Washington, and Utah, where more than 50 percent of all farms have electric service. The small size of farms and the proximity of rural to urban communities accounts for the high percentage of electrification in the Eastern States, while the extensive use of power for pumping purposes in connection with irrigation has assisted electrification of farms in the Pacific Coast States. Electrification of farms in the North Middle Central States and in the Southern States is generally very limited, being in many cases less than 5 percent of the total.

The study of rural electrification is being directed to a determination of the possibilities from a practical viewpoint of extending electric service to more of the farms in the United States at present without electric service. The extent to which electricity can be used on the farm has already been covered by various publications and is not being specifically dealt with in the National Power Survey. The energy consumption that can be expected from actual experience, the equipment used, the rates charged, and the methods and policies of power companies under which lines are constructed are being investigated. The study is also directed to the question of practical means by which more liberal extension of electricity to farms can be made possible.

Information is being obtained in cooperation with the Electric Rate Survey by means of report forms sent to private and municipal electric utilities. Data have been received from agricultural colleges and utility commissions. The Survey has been working in close touch with other Federal agencies and rural electrification authorities who have been carrying on surveys in various States. Through these means information available from every possible source is being collected so that a comprehensive analysis may be made with the object of presenting constructive and practical suggestions and recommendations. This phase

of the investigation, when completed, will be covered by a special report.

Value of Interconnection and Coordination of Power Facilities in Relation to the National Power Supply

The value of the interconnection of transmission systems and the coordination of sources of electrical energy has long been recognized both by the Government and the electric light and power industry. The industry has studied the problems and advantages of interconnection and coordination chiefly as applied to individual systems, while the Government in its previous studies has directed its attention to particular regions in which it had a special interest or in which the problems were particularly acute. Up to the present time there has been no official consideration of the possibilities of interconnection and coordination in relation to the national power supply.

The first official regional survey in which these questions were considered appears to have been that conducted by the War Industries Board relative to the area in which power generated at Muscle Shoals might be distributed. Later, in 1921, a similar survey of the region lying between Boston and Washington was undertaken by the Geological Survey under the authority of an act of Congress. This information was utilized and extended by the "North-east Super Power Committee" which reported in 1924. While these surveys did not result in any direct action by the Federal Government, their influence is clearly reflected in the relatively high degree of interconnection of transmission networks in the regions to which they related.

The vital importance of further studies of interconnection and coordination from both an engineering and economic standpoint is clearly revealed in sections III and IV of this report in which the adequacy of present power facilities and the surpluses and deficits of dependable capacity have been discussed. There it has been shown that critical shortages of power will exist in many districts when normal industrial activity is resumed. It has also been shown that a period of 2 years or more would be required to meet these shortages by the construction of large steam and hydroelectric plants. If, therefore, industry should resume its normal rate

of activity within a shorter period a serious crisis might arise which would tax the electric-generating facilities of the Nation to the utmost.

In view of this contingency it is of the highest public interest that thorough studies should be made of the possibilities of meeting this shortage in part by improving the interconnection and coordination of existing power facilities. Such studies are now being made in connection with the National Power Survey, the results of which will be published in due course.

While these studies, which are of a highly technical character, are incomplete they have gone far enough to show that interconnection as it exists today in the United States is not the result of any definitely planned program. Its growth has been relatively haphazard, handicapped by intercompany rivalry and prejudices and by artificial barriers, such as State lines,

prohibitory laws and a lack of uniformity in tax laws in adjoining communities. There are, of course, a number of well-defined areas in which interconnection is relatively far advanced: in New England, particularly Massachusetts and Connecticut; in southeastern Pennsylvania and New Jersey; in the South Atlantic States; in the Pittsburgh-Ohio industrial area; in the Chicago district; and in the States of California and Washington, but it would appear that in none of these regions are all of the benefits possible from a high degree of interconnection and coordination being secured. It is of great importance, therefore, both to the public and to the industry, that the possibilities of interconnection and coordination be thoroughly studied from a practical standpoint so that their results may be available in any emergency that may arise.

SECTION XII. NATIONAL POWER SURVEY

ITS RELATION TO FUTURE PLANNING BY GOVERNMENT AND INDUSTRY

It has been impossible in this interim report to do more than indicate the scope, methods, and purposes of the National Power Survey, as it is being carried out by the Federal Power Commission, and record some of its tentative findings and conclusions. Of the 19 months which have elapsed since the President directed the Commission to undertake this work, about 6 months were necessarily spent in preliminary inquiries and planning; about 10 months were required for the collection and compilation of basic data, leaving only about 3 months for analysis and the preparation of this report. The survey has been limited, not only in time, but also in resources, the total appropriation provided for this nation-wide inquiry being considerably less than many of the private utility systems have expended on surveys of their properties and markets.

Even with these limitations, enough has been accomplished, it is believed, to indicate the value of such a survey in relation to future planning both by the Government and the electric light and power industry and the great importance of maintaining currently up-to-date information regarding the Nation's power resources and requirements. When it is considered that a single large power project may involve the expenditure of \$100,000,000 or more which may be largely wasted if it is improperly located, badly designed, or incorrectly planned in relation to the large number of factors which have been briefly considered in this report, the economy of expending a small fraction of such a sum in securing and maintaining currently the information that is essential to sound planning would appear to be self-evident. When attention is directed also to the fact that savings of millions of dollars a year could be effected through suitable interconnection and coordination of the Nation's power facilities, the economy of such a procedure is strongly emphasized. When there is added the consideration that the safety of the Nation itself in time of war is dependent upon the existence of adequate power facilities which must have been installed before the out-break of hostilities, its vital importance from a

national standpoint would appear to be fully demonstrated.

Quite apart from these points in which the interest of the Federal Government is predominant, the National Power Survey has also a practical, tangible value to the public and private agencies which generate and supply electricity; to the many industries which are dependent upon the maintenance of a cheap and adequate supply of power; and to the consumers in urban and rural territories whose comfort and convenience are so vitally affected. Municipal plants as well as private companies require at all times adequate information regarding the power demands and facilities of the entire region in which they are located. The responsible heads of manufacturing industries need to know where they can best procure power under conditions that will meet the peculiar requirements of their individual factories. The consumer is entitled to assurance not only that he will be continuously provided with electrical energy but also that it will be secured at all times from the cheapest source that is reasonably available.

That such information will not only be carefully studied but practically applied is indicated by a consideration of the consequences of the survey conducted by the "Northeast Super-Power Committee", created in 1923 by general agreement among the Northeastern States and composed of Federal and State employees appointed by the governors and the President of the United States. The Federal Power Commission coordinated the information obtained and prepared the final report. Although the scope of this survey was limited, it is significant that the subsequent development of the industry in this area, as to the location and interconnection of transmission lines and the location of the larger steam and hydroelectric plants, has been substantially along the lines then recommended. There appears to be little question that large savings were effected which were not passed on to consumers because no adequate method of governmental control had been provided. As an indication of the possibilities of forecasting

as a basis for regional planning, it is interesting to note that this Committee's forecast of power requirements for the year 1930, which was made in 1924, proved to be accurate within a fraction of 1 percent.

The value of such surveys and the possibilities of accurate forecasting and sound planning will be greatly enhanced if the necessary information is regularly and continuously compiled.

Such information possesses the greatest value in times of emergency but, because of its complexity, highly technical character, and tremendous scope, many months are required for its compilation and analysis. The national interest would, therefore, appear to demand adequate provision for a continuous inventory of the power requirements and resources of the United States.

APPENDIX A—ROSTER OF STAFF

A LIST OF PRINCIPAL EMPLOYEES OF THE NATIONAL POWER SURVEY, THEIR EDUCATION, TECHNICAL TRAINING, EXPERIENCE, AND MEMBERSHIP IN PROFESSIONAL SOCIETIES

ADMINISTRATIVE DIVISION

Thomas R. Tate, Director; B. S. in-E. E., U. of Missouri.

Twenty-seven years' experience in design, construction, and operation of steam electric, hydroelectric, and internal-combustion generating stations, transmission lines and substations; electric, telephone, and gas valuation; power and transportation surveys and general consulting work. Registered Professional Engineer, New York; member A. I. E. E., S. A. M. E. and A. S. M. E.

Lester S. Ready, Chief Consulting Engineer; B. S. in E. E., U. of California.

Consultant on public-utility operation and regulation; 23 years' experience in operation and regulation of public and privately owned utilities; formerly chief engineer of California Railroad Commission and specialist on rates, valuations, water-power resources, and transportation problems; member A. I. E. E.

Ralph W. Martin, Executive Assistant; University of Chicago, National Institute, Northwestern University.

Ten years' experience in commercial organization, personnel management, public accounting, industrial development and executive administration.

Leshar S. Wing, Chief Engineer; B. S. in Mech. and E. E., South Dakota State College.

Nineteen years' experience in electrical design and general construction work; electric, gas, water, telephone, and transportation valuation and rate cases; special reports on power development, irrigation, and power applications. Registered Civil Engineer, California; member A. S. A. E. and associate A. I. E. E.

Emmett G. Craig, Chief Power Engineer and Asst. to Director; B. S. in C. E., C. E., Rutgers University.

Fourteen years' experience on construction, power studies, system design, economics of utility operating, utility finance, and securities; associate member A. S. C. E.

Claude E. Puffer, Economist and Asst. to Director; B. B. A., M. A., U. of Washington.

Seven years' experience in railroad traffic and rates, statistical and financial studies, and special research in public-utility regulation.

POWER REQUIREMENTS DIVISION

Percy H. Thomas, Chief of Division; S. B. in E. E., Massachusetts Institute of Technology.

Forty years' experience in design of electrical equipment for manufacturing companies; consulting engineer for American and foreign power and mining properties; and specialist on transmission lines. Registered Professional Engineer, New York; Registered Professional Engineer, N. J.; Fellow A. I. E. E.; member A. S. M. E.

Robert E. Moore, Chief Industrial Engineer; Pratt Institute.

Twenty-five years' experience in general industrial applications of power apparatus; power consultant in private engineering practice and in application of electric power to industries. Registered Professional Engineer, New York; Registered Professional Engineer, Michigan; associate member A. S. M. E.

Howard M. Van Gelder, Chief Electrification Engineer; M. E., Brown University.

Thirty-five years' experience in design and construction of power plants, industrial manufacturing plants, railroad electrification, and subway electrification, including supervision and inspection of contracts and placing of equipment in operation; member A. I. E. E.

Joseph P. Schaezner, Agricultural and Irrigation Engineer; B. S. in Agriculture, U. of Wisconsin.

Thirteen years' experience in project direction, rural electrification, vocational agricultural instruction, and community agricultural activities; member A. S. A. E.

James V. Alfriend, Jr., Electro-Chemical Engineer; B. E., Johns Hopkins University.

Eleven years' experience in application of electrical equipment to electro-chemical and electro-metallurgical industries; associate member A. I. E. E.

Richard L. Kimball, General Engineer; B. S. in E. E., Worcester Polytechnic Institute.

Eleven years' experience in railway electrifications.

Stanley W. Roland, Statistician; B. S. in E. E., U. of Wisconsin, M. S. in E. E., Harvard Engineering School.

Four years' experience as instructor in electrical engineering, four years in construction of power plants, and power sales engineering.

POWER RESOURCES DIVISION

Erich A. Mees, Chief of Division; B. S. in C. E., Rose Polytechnic Institute.

Twenty-four years' experience in design, superintendence, and supervision of construction of hydroelectric and steam power plants, water filtration plants, bridges, and industrial buildings; member A. S. M. E.

William G. Mervine, Chief Mechanical Engineer; Drexel Institute.

Seventeen years' experience in design, construction, and operation of steam electric power plants. Coauthor with Joel D. Justin of "Power Supply Economics." Registered Professional Engineer, Pennsylvania; member A. S. M. E.

Francis L. Adams, Civil Engineer; B. S. in C. E., U. of North Carolina, Mass. Institute of Technology.

Eight years' experience in hydroelectric, railway, and highway design and construction, valuation of public utilities, structural design and drafting, specification writing, and inspection; junior member A. S. C. E.

John D. Fitch, Hydraulic Engineer; S. B. in C. E., Mass. Institute of Technology.

Nine years' experience in field and office work in connection with the study, design, construction, maintenance, and testing of hydroelectric projects; associate member A. S. C. E.

Olcott L. Hooper, Hydraulic Engineer; S. B. in C. E., Mass. Institute of Technology, Northwestern U.

Twelve years' experience in design of water-supply and hydroelectric projects, construction supervision, and engineering management of public-utility properties, associate member A. S. C. E.

Carl O. Berglund, Hydroelectric Engineer; B. S. and B. A., State College, Sweden, Columbia Univ. Teachers College.

Twenty-three years' experience in general industrial engineering, design of hydroelectric and steam electric power stations, preliminary investigations, and research work.

D. N. Showalter, Hydroelectric Engineer; C. E., Lehigh University.

Eleven years' experience in design of dams and power plants; field survey of hydroelectric power plant sites.

Peter von Weymarn, Power Engineer; C. E. College of Civil Engineers in Petrograd, Russia.

Twenty-six years' experience in design, construction, and survey of water power, navigation, and irrigation projects, and power development; member A. S. C. E. and S. A. M. E.

RESEARCH DIVISION

Fayette S. Warner, Chief of Division; C. E., M. B. A., Rensselaer Polytechnic Institute; Ph. D., U. of Pennsylvania.

Sixteen years' experience in Industrial Research, instructor in the fields of Manufacturing Industries, American Government, Business and Government, and Regulation of Public Utilities at University of Pennsylvania; consulting engineer in valuation of public utilities; associate member A. S. C. E.

Joseph T. Silver, Chief Cartographic Engineer; B. S. Cooper Union.

Twenty-four years' experience in design of steam-electric and hydroelectric stations, substations, and transmission lines; and valuation engineering; member S. A. M. E. and associate member A. I. E. E.

Frederick Haag, Jr., Editor; B. S. in C. E., U. of Penn.

Sixteen years' experience in exploration and development of iron and coal properties, surveying, triangulation, mapmaking; rate investigations; surveys and publications; member A. M. S.

William L. Fairbanks, Economist; Eastman College.

Twenty-seven years' experience in U. S. Foreign Service, foreign trading, port development, rail and water transportation, commercial relations, and economic surveys.

L. B. Woll, Electrical Engineer; B. S. in E. E., E. E., Columbia U.

Five years' experience in electric motor design, testing, and power-plant operation; industrial engineering production and management problems; and statistical, economic, and financial research; associate member A. I. E. E. and S. A. M. E.

W. B. Moore, Civil Engineer; B. S. in C. E., Mass. Institute of Technology; M. S. in Transportation; Yale University.

Five years' experience in railroad design, economic studies, business management, and geodetic surveying; junior member A. S. C. E.

E. H. Dimmitt, Engineering Draftsman, B. in Arch., M. S. in C. E., Ala. Polytechnic Institute, Purdue.

Three months' experience in surveying and instrument work; member S. A. M. E.

T. C. Evans, Jr., Engineering Draftsman; B. S. in E. E., U. of North Carolina.

Two years' experience in maintenance of switches, relays, and transformers, and power surveys.

R. R. Sabine, Engineering Draftsman.

Eighteen years' experience as engineering draftsman.

Raymond B. Breinig, Engineering Draftsman; B. S. in E. E., Armour Institute of Technology.

Six years' experience in map drafting, statistical studies, transmission line design, and power-plant engineering.

Richard M. Kane, Engineering Draftsman; Mechanics Institute of Architecture.

Six years of experience in drafting including architectural, electrical, and map drafting, and illustrating.

DISTRIBUTION COSTS STUDY DIVISION

George H. Morse, Chief of Division; B. E. E., E. E., U. of Minnesota.

Forty-two years' experience, including Professorship of Electrical Engineering at U. of Nebraska; designer and consultant for electrical manufacturing companies; power specialist; consulting engineer on electrical work; and power survey for public service commission; fellow A. I. E. E.

Claudius E. Bennett, Distribution Engineer; B. S. in E. E., U. of Nebraska; M. S. in E. E., E. E., U. of Illinois.

Twenty-one years' experience in operation, design, and construction of hydroelectric plants, transmission lines, and distribution systems. Registered Professional Engineer in Illinois; member A. I. E. E.

Edgar S. Coffman, Distribution Engineer; Purdue University.

Six years' experience on appraisals of public-utility properties and valuations, participation in rate cases, and specialization in unit costs of electric distribution systems. Registered Professional Engineer in Indiana; associate member A. I. E. E.

William K. Hackmann, Distribution Engineer; B. S. in E. E., U. of Nebraska.

Six years' experience in requisition design on standard and special designs, particularly transformers and mercury arc rectifiers; associate member A. I. E. E.

Ellsworth F. Miner, Distribution Engineer; B. S. in E. E., Yale University.

Twenty-seven years' experience in testing and design of electrical equipment, construction, operation, and management of electric utilities, electric utility valuation and independent rate cases; member A. I. E. E.

Francis P. Quigley, Distribution Engineer; B. S. in E. E., U. of Pennsylvania.

Nine years' experience in design and construction of transmission lines distribution systems, lighting systems, and substations; industrial plant development; electrical appraisal work; member A. I. E. E.

Leon C. Shaver, Distribution Engineer; B. S. in M. E., Tri-State College of Engineering.

Eleven years' experience in rate structures, valuation of electric utilities, load dispatching, and operation of electric stations.

Samuel H. Thompson, Distribution Engineer; C. E., Reed College, Rensselaer Polytechnic Institute.

Thirteen years' experience in design and construction of bridges, buildings, equipment; installation, marketing, housing, advertising, domestic heating, technical and specification writing.

REVIEWING AND TABULATING SECTION

Robert H. Barclay, Chief of Section; Washington University.

Twenty-five years' experience as a consulting electrical engineer specializing in steam and hydroelectric-plant design and construction. Registered Professional Engineer in New York; fellow A. I. E. E.

Andrew H. Grimsley, Power Engineer.

Nineteen years' executive experience in the operation of electric and gas properties; the design and construction of hydroelectric and steam electric power plants, high-tension transmission lines, substations, and distribution systems; purchase and sale of electric and railway properties; studies of corporate structure and financing of public utilities; member A. I. E. E.

H. H. Houston, Electrical Engineer, A. B., Reed College, B. S. in E. E., M. S. in E. E., Mass. Institute of Technology.

Ten years' experience in design, construction, and valuation of power plants and transmission systems; associate member A. I. E. E.

George S. Green, Hydraulic Engineer.

Fifteen years' experience in field surveys, design, supervision, and management of construction of hydroelectric and steam electric power plants, dams, water supply systems, pipe lines, transmission lines, and pumping stations.

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