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ENERGY RESOURCES AND TECHNOLOGY

HEARINGS

BEFORE THE

SUBCOMMITTEE ON AUTOMATION AND ENERGY RESOURCES

OF THE

JOINT ECONOMIC COMMITTEE CONGRESS OF THE UNITED STATES

EIGHTY-SIXTH CONGRESS

FIRST SESSION

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ENERGY RESOURCES AND TECHNOLOGY

MONDAY, OCTOBER 12, 1959

CONGRESS OF THE UNITED STATES,
SUBCOMMITTEE ON AUTOMATION AND
ENERGY RESOURCES OF THE
JOINT ECONOMIC COMMITTEE,
Washington, D.C.

The subcommittee met at 10 a.m., pursuant to call, in the old Supreme Court room, the Capitol, Hon. Wright Patman (chairman of the subcommittee and vice chairman of the full committee) presiding.

Present: Representative Patman.

Representative PATMAN. The committee will please come to order. Mr. Widnall, representing the minority, is expected to be here any time. Some other members have engagements that will keep them out of Washington much of this week.

The Joint Economic Committee is directed by the Employment Act of 1946, section 5, to make a continuing study of matters relating to the promotion and maintenance of maximum employment and maximum production, economic stability and growth.

In connection with this responsibility the committee has, over the years, given continuing and intensive study to the instruments of public policy, especially monetary and fiscal measures, which can contribute to these ends. We have made also a number of studies and recommendations in such fields as commercial agricultural policy, Soviet economic growth, economic statistics, foreign economic policy, and others.

In the fall of 1955, through this subcommittee, we investigated and reported on the impact and significance to the stability and growth of the economy of automation and rapid technological change. The widespread and continued interest in that study is partially evidenced by the fact that the subcommittee hearings entitled "Automation and Technology Change" have just recently gone into a third printing for sale at the Superintendent of Documents, at the Government Printing Office.

The committee at that time concluded that the progress of technological change is so important to the economy that a continuing review is desirable from the standpoint of keeping the committee, Members of Congress, and the interested public informed of developments in this dynamic field.

In line with that recommendation, further hearings were held in the fall months of 1956 and 1957 on "Instrumentation and Automation" and "Automation and Recent Trends," respectively. We expect to come back to the problems of automation recurrently in the future.

In the set of hearings starting today, we are broadening the scope of inquiry a bit beyond machines, computers and electronics to cover the closely related problem of energy resources and technology. Automation is essentially an advanced stage of mechanization further replacing manpower and human brawn with machine power, thus conserving one form of energy.

Today's energy question is a corollary one involved in driving these machines more and more by the power inherent in fuels, atoms, or falling water rather than through human or animal muscle. In a sense, automation and energy—mechanization and power—may be said to supplement and even substitute for each other.

Our concern here with "energy" is primarily one of reviewing the adequacy of our resources and inquiring into the impact of technology on the production and efficient use of the energies required for sustaining economic growth. Special emphasis and attention will, accordingly, be given to prospective needs and prospective cost relationships among conventional energy sources—coal, hydro, oil, natural gas—together with the outlook for cost-reducing techniques and commerical production from newer, more romantic sources, including nuclear and solar power.

In a general way, these hearings should provide an updating of that part of the study made 7 years ago by the President's Materials Policy ("Paley") Commission and printed as volume III of the Commission's report "The Outlook For Energy Sources."

Our concern is primarily with the possibility of shortages and bottlenecks in our resource base and of the risk that energy technology may not keep pace with growth. We are planning five sessions to study such a variety of things as the estimated requirements and reserves of a variety of fuel and power sources which include coal, oil, gas, hydroelectric, the atom, the sun, shale distillation, et cetera.

In order to survey this broad and varied area in a few days it will be necessary, as far as possible, to avoid extended consideration of a number of items which, of themselves, might justify even more time than we can give to the overall problem.

We intend, therefore, to concentrate upon basic evidence rather than branch out into some of the collateral issues involving the terms of energy exploitation and distribution, important as these are. On the assumption that the national interest will be best served by an assured adequacy of reserves made available at a minimum cost and at the right time, the study will concentrate upon technology and broad economic considerations.

Among the things which we recognize as of utmost practical and political importance, but which we must pass over if we are to achieve our purpose this week, are such things as the issue of public versus private development of resources; the propriety and terms of import restrictions at this time; cartelization; the merits of the tax provisions respecting depletion allowances and discovery costs; the propaganda value of subsidizing development of the peaceful use of the atom; the related or incidental benefits of multipurpose hydroelectric installation.

These are all extremely important items. Our principal justification, I repeat, for passing them over at the present time must be one of the limits upon the time available and our conviction that this type of problem can be solved and will be solved by our people or by legislation as the occasion arises.

In any case, there are and will be other forums—perhaps future hearings of this subcommittee—for the discussion of these issues. If we can be assured, first, that a shortage of energy itself is not going to dampen our rate of growth and, second, that technology in the field of discovery, exploitation, and distribution of energy will continue with vigor as it has in the recent past, we can then concentrate better on the other problems.

I believe that the record which we will develop this week through these hearings will be of extreme importance and lasting value to the Congress and to the Nation in our thinking about this important ingredient of growth and economic stability. While all the members of the subcommittee nor of the committee as a whole could be in town at this particular time, I can, with confidence, assure the witnesses that the record will be studied very carefully by all of us.

After the testimony is taken, the record is printed and distributed not only to each member of this committee, but to all Members of Congress, and to libraries. They are given wide distribution. They are also offered for sale by the Government Printing Office.

Tomorrow we shall consider the problems of electrical energy from fuel and hydroelectric sources, and begin the study of the natural gas industry. On Wednesday our testimony will be devoted to the problems of the domestic oil and natural gas industries. Thursday will be devoted to the problems of the coal industry, and on Friday attention will be turned to the more romantic frontier of unconventional sources, such as nuclear and solar power.

The plan and schedule of hearings was set forth in an announcement of September 18, which, incidentally, I would like to have incorporated at this point. It will be incorporated here.

(The document referred to follows:)

CONGRESS OF THE UNITED STATES,
JOINT ECONOMIC COMMITTEE,
SUBCOMMITTEE ON AUTOMATION AND ENERGY RESOURCES,
September 18, 1959.

REPRESENTATIVE PATMAN ANNOUNCES HEARINGS ON U.S. ENERGY RESOURCES

Representative Wright Patman (Democrat, Texas), chairman of the Subcommittee on Automation and Energy Resources of the Joint Economic Committee today released the list of witnesses and the schedule of hearings on the anticipated needs for and adequacy of U.S. energy resources and the impact of technology on the production and efficient use of the energies required for sustaining economic growth. Special attention will be given to the overall prospective requirements and demand for energy from the conventional resources and to the outlook for commercial production from other sources such as nuclear and solar power.

The list of witnesses chosen from research organizations, Government bureaus, the oil and coal industries is attached. The hearings will be held October 12-16, 1959, inclusive, in room P-63, the old Supreme Court Chamber in the Capitol.

These hearings while closely related to some aspects of the full committee's current study of employment, growth, and price levels will be separate and distinct from it.

Members of the Subcommittee on Automation and Energy Resources are as follows:

Representative Wright Patman, Chairman

Senator Joseph C. O'Mahoney	Representative Henry S. Reuss
Senator John F. Kennedy	Representative Clarence E. Kilburn
Senator John Marshall Butler	Representative William B. Widnall

HEARINGS ON U.S. ENERGY RESOURCES

Monday, October 12, 10 a.m., Old Supreme Court Chamber, U.S. Capitol:
"Past Developments and Prospective Demand for Energy": Sam H. Schurr, director of energy and mineral resources program, Resources for the Future, Inc.
"The Future Supply of Energy Sources": Bruce C. Netschert, senior research associate, Resources for the Future, Inc.

Tuesday, October 13, 10 a.m., Old Supreme Court Chamber, U.S. Capitol:
"Electrical Energy from Fuel Sources—Present and Prospective": Philip Sporn, president, American Electric Power Service Corp.; president, Nuclear Power Group, Inc.
"Electrical Energy from Hydropower Sources—Present and Prospective": Francis L. Adams, Chief, Bureau of Power, Federal Power Commission.
"Prospective Demand and Supply in the Natural Gas Industry": Carl T. Kallina, Chief, Bureau of Rates and Gas Certificates, Federal Power Commission.

Wednesday, October 14, 10 a.m., Old Supreme Court Chamber, U.S. Capitol:
"An Analysis of the Domestic Oil Industry": Richard J. Gonzalez, treasurer (formerly economic adviser), Humble Oil & Refining Co.
"Conservation and Appropriate Role of Government in Developing Adequate and Competitive Energy Sources": W.J. Murray, Jr., commissioner, Railroad Commission of Texas.
"Problems and Prospects of the Natural Gas Industry": Arthur Kline, Commissioner, Federal Power Commission.
"The Status and Prospects of Oil-Shale Technology"; Russell J. Cameron, president, Cameron & Jones, Inc., Denver, Colo., and Rio de Janeiro, Brazil.
"World Petroleum Needs, Supplies, and Organization as Related to the Domestic Scene": Bernard N. Darbyshire, petroleum economist; member, interstate oil compacts subcommittee on foreign oil; adviser to "Migrol," Zurich, Switzerland, and Frisia Refining Co., Emden, Germany.

Thursday, October 15, 10 a.m., Old Supreme Court Chamber, U.S. Capitol:
"An Analysis of the Coal Industry": George A. Lamb, manager, Business Surveys, Pittsburgh Consolidation Coal Co.
"Coal Economics and Technology: Current Status and Prospects": William Schroeder, Department of Chemical Engineering, University of Maryland; formerly consulting engineeer, Pittsburgh Midway Coal Co.
"Coal and a National Fuels Policy": Joseph E. Moody, president, National Coal Policy Conference, Inc.; president, Southern Coal Producers' Association; treasurer and member, board of directors, American Coal Shipping Association.
"The Commercial Exploitation of Lignite and Subbituminous Coals": Veryl Hoover, general manager, Wyoming Division, Pacific Power & Light Co., Casper, Wyo.

Friday, October 16, 10 a.m., Old Supreme Court Chamber, U.S. Capitol:
"Problems and Future of Central-Station Nuclear Power": Walter H. Zinn, president, General Nuclear Engineering Corp.; formerly Director, Argonne National Laboratory (1946–56).
"The Economics of Nuclear-Energy Resources": Philip Mullenbach, vice president, Growth Research, Inc.; consultant, Nuclear Energy Study, Twentieth Century Fund, New York.
"An Analysis of the Domestic Uranium Industry": Gordon A. Weller, executive vice president, Uranium Institute of America.
"The Economics of Solar Energy": George O. Löf, solar energy consultant; research associate, Resources for Future, Inc., and University of Wisconsin.

Representative PATMAN. This morning is to be devoted to a survey of past developments, prospective demand, and future supply of energy as a whole as presented to us by the experts from Resources for the Future, Inc., a nonprofit privately supported research corporation.

The stated purpose of this organization—established in 1952 with the cooperation of the Ford Foundation—is to advance the development, conservation, and use of natural resources through programs of research and education.

Through the activities of its central staff and grants to other nonprofit institutions, Resources for the Future has established itself as an objective, thorough, and highlevel study group. Energy is, of course, but one of the fields with which the organization is concerned. Land use, minerals, and the increasingly serious concern about water resources are also within the purview of the organization.

Today we have Dr. Sam H. Schurr, chief of the Energy and Minerals Division, Resources for the Future, Inc., speaking primarily of prospective demand, and Dr. Bruce Netschert, as associate research economist of that organization and author of "The Future Supply of Oil and Gas," speaking primarily on the supply and reserves of energy sources.

We are glad to have you gentlemen. You may first be heard on your statement, and then after both of you have finished your papers, we will ask you questions. But we will not question you until each one has finished.

Dr. Schurr, I believe you are first on the program. You may proceed in your own way.

STATEMENT OF SAM H. SCHURR, DIRECTOR OF ENERGY AND MINERAL RESOURCES PROGRAM, RESOURCES FOR THE FUTURE, INC.

Mr. SCHURR. Thank you, Mr. Chairman. I appreciate the opportunity of appearing before the committee in these hearings.

PAST DEMANDS AND PROSPECTIVE DEMANDS FOR ENERGY

The materials which Mr. Netschert and I will present this morning summarize the approaches used and some of the results obtained in a major research project which has been underway at Resources for the Future for several years. Much of what is presented in our papers is now being made public for the first time. The full account, including the voluminous statistical appendixes underlying the analysis, will be published by the Johns Hopkins Press in 1960 in a book entitled "Energy in the American Economy, 1850–1975."

This research represents the work of many individuals. In addition to Mr. Netschert and myself, the main contributors were Vera Eliasberg, Joseph Lerner, and Hans Landsberg. Every effort has been made to do the research with complete objectivity; nevertheless, it must be recognized that the subject matter, particularly where future prospects are concerned, must depend to a substantial degree on judgment. However, even in making judgments, we have tried to do so on the basis of a complete consideration of the available facts and opinions, including the evaluations made by other students of the subject.

Our assignment here is to present materials which will help to establish the broad background relevant to the committee's subsequent consideration of individual energy materials—to provide, as is were, a perspective against which the individual fuels can be viewed. We therefore deal with energy materials in general—coal, oil, natural gas, etc.—and with the interrelationships among them. It is important that such a general view be presented because the fuels are to a very large extent substitutable one for the other in most applications.

A dominant note in the history of energy use in the United States is the fact of interfuel substitution, which in a much earlier time resulted in the decline of fuel wood and the rise of coal as our major energy source, and more recently, has seen oil and gas grow in relative importance at the expense of coal. Substitutability among energy sources is not absolute—for example, liquid fuels can not feasibly be replaced by coal in providing fuel for automobiles—but even in this application advances in technology which permit the production of liquid fuels from coal have established the technical, though not the economic, basis for such substitution. And in other ways, too, technology is widening the area of substitution.

The background we have been asked to cover includes both past developments and future prospects for energy in general. This assignment we have divided between us: my presentation will cover the history of energy consumption, and the prospects for consumption in the future, and Mr. Netschert will cover the prospects for future energy supply.

THE CURRENT LEVEL AND COMPOSITION OF ENERGY CONSUMPTION

A good place to begin my phase of the presentation is with the statistics on present-day energy consumption in the United States. The most recent annual data—for1958—are shown in table 1. In column 1 of the table the amounts are shown in the ordinary units of commerce—tons, barrels, etc. But by themselves these quantity figures are not as informative as we would like. Since they are not measured in common units, they cannot be added together to yield a total, nor is it possible to determine the relative importance of the different energy sources in the total. To add together heterogeneous commodities it is usually necessary to resort to their dollar value as the only available common denominator; however, in the case of the energy sources an alternative is available—namely, to translate them into common units of contained energy. The common unit which is ordinarily used for this purpose is the British thermal unit, or B.t.u. for short (defined as the amount of heat necessary to raise the temperature of 1 pound of water 1° F.)

TABLE 1.—*Energy consumption in the United States, by source, 1958*

	In conventional units	In B.t.u.'s (trillions)	Percentage of total
	(1)	(2)	(3)
Bituminous coal	367 million tons	9,607	23.1
Anthracite	19 million tons	483	1.2
Oil and natural gas liquids (NGL)	3⅓ billion barrels	18,658	45.0
Natural gas	10½ trillion cubic feet	10,995	26.5
Water power	148 billion kilowatt-hours	[1] 1,740	4.2
Total		41,483	100.0

[1] Converted at the prevailing rate of amount of fuel consumed per kilowatt-hour at central electric stations.

Source: Preliminary figures supplied by U.S. Bureau of Mines.

The quantity figures shown in column 1 are restated in B.t.u. terms in column 2, and a percentage distribution of the total is shown in column 3. Based on the B.t.u. measurement, we can see at a glance that oil, with 45 percent of the total, is by far the leading source of energy used in the United States; that natural gas is second with somewhat more than a quarter, that bituminous coal is close behind with 23 percent; and that water power with 4 percent of the total and anthracite with a little over 1 percent are of far smaller importance than the other three sources.

HISTORICAL CHANGES IN ENERGY USE

The current picture just presented is the product of a historical development which has included very great changes in the level and pattern of energy consumption, and in the relationship between energy consumption and other broad factors in the national economy. In our forthcoming book these changes are traced between 1850 and 1955, but in this paper, the statistics presented do not cover this entire period. For the most part they begin with either 1900 or 1920, and in general, are for 5-year intervals, rather than for all the intervening years.

Total energy consumption

Total energy use—i.e., the B.t.u. aggregate for all the mineral fuels and hydroelectric power—is shown in table 2 for the period 1900–1955. Column 2, which converts the figure to index number form, reveals that energy consumption in 1955 stood at more than five times the level of consumption in 1900, which is equivalent to an overall annual rate of growth of 3.1 percent.

TABLE 2.—*Total energy consumption in the United States, 1900–1955*

Year	B.t.u.'s (trillion) (1)	Index (1900=100) (2)	Percent change (3)	Average annual percentage rate of growth (4)	
1900	7,572	100.0	+95.5	1900–1910	6.93
1905	11,369	150.1			
1910	14,800	195.5	+33.6	1910–20	2.94
1915	16,076	212.3			
1920	19,768	261.1	+12.6	1920–30	1.19
1925	20,878	275.7			
1930	22,253	293.9	+7.3	1930–40	0.71
1935	19,059	251.7			
1940	23,877	315.3	+42.3	1940–50	3.59
1945	31,439	415.2			
1950	33,972	448.7	+16.9	1950–55	3.18
1955	39,729	524.7			

Source: "Energy in the American Economy, 1850–1975" (forthcoming publication of Resources for the Future, Inc.). Preliminary figures.

It is relevant to inquire whether this long-period increase has been reached through a relatively steady growth through time, because if this were the case there would be some support for the view that the average rate of growth which has characterized the past would be appropriate for estimating total energy consumption for future time periods.

Columns 3 and 4 of table 2, which deal with changes within decades, shed light on the question of regularity in growth. These figures indicate wide disparities in decade growth rates ranging from a 7 percent increase in 1930–40 to a 96 percent increase in 1900–1910. Not only is the range among decade changes considerable, but there is no evidence of a clustering around any particular percentage increase.

We conclude, on the basis of this and similar statistical evidence that the simple extrapolation of overall growth rates derived from past experience would be unwarranted in the projection of future energy consumption.

Total energy consumption per capita

What degree of regularity do historical changes in total energy consumption exhibit when they are converted to a per capita basis? Is the growth in energy consumption systematically related to the increase in the country's population? Statistics bearing on this question are presented in table 3.

TABLE 3.—*Per capita energy consumption in the United States, 1900–1955*

Year	Index number of per capita energy consumption (1900=100) (1)	Percentage change (2)	Average annual percentage rate of growth (3)
1900	100.0		1900–1910
1905	136.3	+61.0	4.88
1910	161.0		1910–20
1915	160.7	+15.9	1.49
1920	186.6		1920–30.[1]
1925	181.1	−2.7	(1)
1930	181.5		1930–40.[1]
1935	150.4	(1)	(1)
1940	181.6		1940–50
1945	225.8	+24.0	2.17
1950	225.1		1950–55
1955	241.6	+7.3	1.42

[1] Negligible.

Source: Energy in the American Economy, 1850–1975 (forthcoming publication of Resources for the Future, Inc.). Preliminary figures.

Column 1 shows that in 1955, the amount of energy consumed per person in the United States was almost 2½ times what it had been in 1900. But again, the decade changes (in columns 2 and 3) are instructive in showing that the United States has not followed a steady path in achieving the 55-year change. Energy consumption per capita grew by 61 percent in the decade 1900–1910, rose only 16 percent in the following decade, changed scarcely at all between 1920 and 1940, grew again between 1940 and 1955, but at quite different rates in the subperiods within the 15-year period.

Here, too, we conclude on the basis of this and similar evidence that the simple extrapolation of growth rates in total energy consumption per capita, drawn from past experience, would be unjustified in projecting future energy consumption in relation to an assumed growth in population.

Total energy consumption per unit of GNP

On a commonsense basis, one might expect that the relationship between the growth in energy use and the growth in the country's total output of goods and services—the GNP—would show a high order of regularity. Energy is so pervasive an ingredient in the production of all goods that it seems reasonable to expect that energy use should move in unison with overall production.

To test this commonsense belief we have divided total energy consumption by a series measuring GNP in constant (1929) dollars, and converted the results to index number form, as shown in column 1 of table 4. In column 2 the percentage changes in energy consumption per unit of GNP are shown for the successive 5-year intervals within the 55-year period. A quick scanning of these figures will indicate that the relationship between the input of energy and the total output of the economy has varied widely—from an increase of 20 percent in 1900–1905 to declines of 12 percent (1940–45) and 14½ percent (1920–25). It is obvious, too, that these extremes are not erratic departures from an otherwise parallel pattern of movement of the two series. The record of the relationship is, in short, marked by great diversity. There does not appear to be a typical rate of change over the long term for energy consumption per unit of GNP.

TABLE 4.—*Energy consumption per unit of gross national product (5-year intervals, 1900–1955)*[1]

Year	Index number of energy consumption per unit of GNP (1900=100) (1)	Percentage change[2] (2)	Year	Index number of energy consumption per unit of GNP (1900=100) (1)	Percentage change[2] (2)
1900	100.0		1930	118.0	1925–30 (+1.5).
1905	119.8	1900–1905 (+19.8).	1935	105.2	1930–35 (−10.8).
1910	132.2	1905–10 (+10.4).	1940	99.5	1935–40 (−5.4).
1915	134.2	1910–15 (+1.5).	1945	87.7	1940–45 (−11.9).
1920	136.0	1915–20 (+1.3).	1950	91.5	1945–50 (+4.3).
1925	116.3	1920–25 (−14.5).	1955	87.8	1950–55 (−4.0).

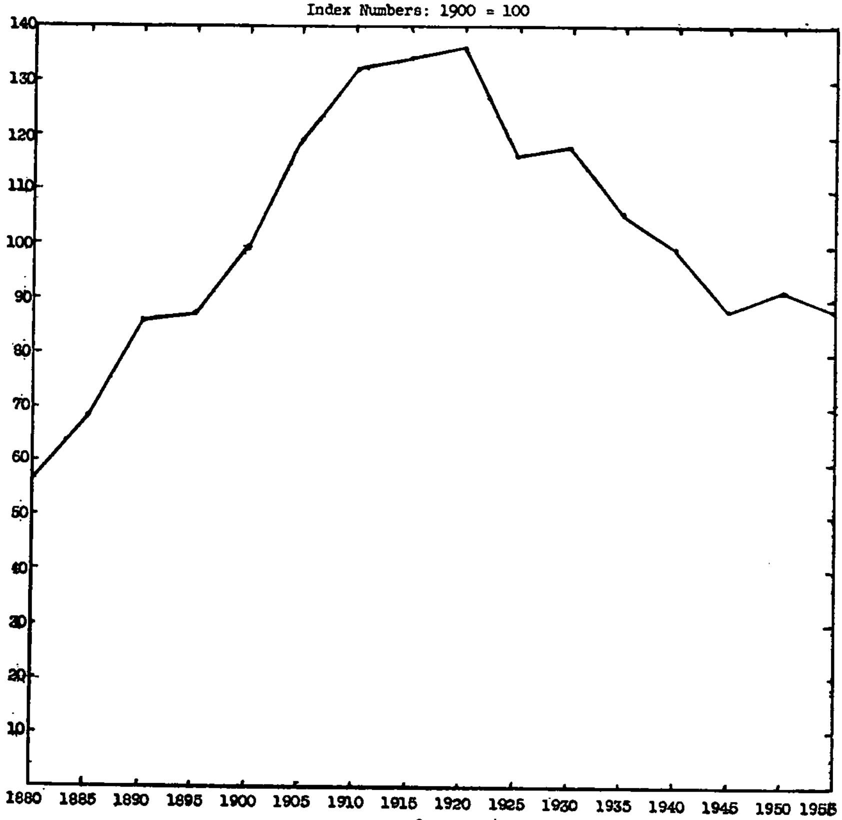
[1] GNP measured in constant (1929) dollars.
[2] The use of decade rates of change and of average annual rates by decades or 5-year intervals in this and other tables makes the results sensitive to the position which terminal calendar years occupy in business cycles. But the use of overlapping 5-year averages, based on annual data, confirms the 2 main findings: wide disparities in annual rates of growth or relative decline in energy use and a distinct reversal of the upward trend in energy input per unit of GNP around 1920.

Source: Energy in the American Economy, 1850–1975 (forthcoming publication of Resources for the Future, Inc.). Preliminary figures.

Despite this, however, the long-run record reveals what appears to be a definite pattern, consisting of two long-period swings divided by the 1910-20 decade. Figure 1, in which the relevant data are plotted, includes statistics back to 1880 in order more clearly to reveal the long swings. The record between 1880 and 1910 is one of persistent increases in the input of energy per unit of GNP; between 1920 and 1955 the record tends to be one of persistent decline in the ratio of energy to GNP. The decade 1910-20 appears, on the whole, to be transitional between the two diverse long-period movements. Beginning with 1880 when the long upward swing of energy relative to GNP started, the percentage increase to 1910 was 133 percent, equivalent to an average rate of increase of 2.9 percent per year. Between 1920 and 1955 the decline in the input of energy relative to GNP has been on the order of 35 percent, equivalent to an average rate of decrease of about 1.2 percent per year.

FIGURE 1 -- ENERGY CONSUMPTION PER UNIT OF GROSS NATIONAL PRODUCT*, 1880-1955 (five-year intervals)

Index Numbers: 1900 = 100



Source: Energy in the American Economy, 1850-1975 (forthcoming publication of Resources for the Future, Inc.). Preliminary figures.

* GNP in constant (1929) dollars.

Although hypotheses can be advanced to account for the long-run shifts, we are not in possession of a full explanation of the factors underlying these long swings in energy consumption relative to GNP. I believe it is worth while, nevertheless, to call this aspect of the historical record to your attention, because the clarity of the change in the relationship following the First World War, and the persistence of the decline since then provides some ground for the belief that in the future, too, total energy consumption will normally tend to grow at a less rapid rate than GNP.

However, this knowledge is still far from telling us at how much slower a rate than GNP energy consumption might be expected to grow. Reference to column 2 of table 4 indicates that the pattern of 5-year declines between 1920 and 1955 is quite erratic, and that although the direction is persistently downward, there are still brief spurts in which energy consumption relative to GNP rises. We conclude, therefore, that in projecting the future a simple extrapolation of total energy use declining at a fixed rate relative to GNP would also not be justified on the basis of the historical evidence.

Total energy consumption, by source

So far we have dealt with the historical development of total energy consumption—the B.t.u. aggregate of all mineral fuels and hydroelectric power. Now we turn to historical changes in the composition of the B.t.u. total in terms of the underlying energy sources. Table 5 [1] presents statistics on the quantities of the various fuels consumed for every fifth year between 1920 and 1955, and in order to allow quick comparison among them, the lower half of the table shows the quantities in index number form with 1920 equal to 100. In general, this table tells a familiar story, although the actual figures are not so well known.

Between 1920 and 1955, two of the energy sources, bituminous coal and anthracite, experienced absolute declines in the amounts consumed in the United States: Bituminous coal fell from 509 million tons in 1920 to 423 million in 1955, a decline of 17 precent, while anthracite fell from 86 million tons in 1920 to 24 million tons in 1955, a decline of 72 percent. The consumption of all the other energy sources, on the other hand, grew substantially over this 35-year period: Oil (including NGI), from 463 million barrels in 1920 to more than 3 billion barrels in 1955, an increase of about 565 percent; natural gas from 785 billion cubic feet in 1920 to almost 9 trillion cubic feet in 1955, an increase of more than 1,000 percent; and waterpower from 20 billion kilowatt-hours in 1920 to 120 billion kilowatt-hours in 1955, an increase of 500 percent. The last column of the foregoing table presents another aspect of the energy resource pattern—the amount of energy from all sources which reaches the energy consumer in the form of electricity. This, too, shows enormous growth over the 35-year period, from 57 billion kilowatt-hours in 1920 to 629 billion kilowatt-hours in 1955, an increase of more than 1,000 percent. This rate of growth is about the same as that achieved by natural gas in the same period; these two, natural gas and electricity, show a remarkable parallelism in their growth. (The electricity column is specially marked off in table 5 because it does not constitute a net addition to total energy supply. Instead it represents the conversion to another form of the primary sources listed.)

Although the description just provided deals wholly with the terminal years of the comparison, 1920 and 1955, it is evident from the statistics for the intervening years shown in table 5 that the trends described have been quite persistent. However, they have proceeded at different rates at different times, and have not been without certain short-run reversals, as, for example, the increase in bituminous coal and anthracite in the war years between 1940 and 1945.

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[1] Natural gas liquids (NGL) are included with oil in these statistics, because even though they are derived from natural gas, they are liquid fuels and, therefore, similar to oil products. At the present time, they are about one-tenth as important as oil products.

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TABLE 5.—*Energy consumption, by source, 1920–55 (5-year intervals)*

PHYSICAL UNITS

Year	Bituminous coal (million tons) (1)	Anthracite (million tons) (2)	Oil and NGL (million barrels) (3)	Natural gas (billion cubic feet) (4)	Waterpower (billion kilowatt-hours) (5)	Electricity generated (billion kilowatt-hours) (6)
1920	509	86	463	785	20	57
1925	499	64	743	1,150	27	85
1930	455	68	1,024	1,866	37	115
1935	356	51	984	1,854	44	119
1940	431	49	1,345	2,575	52	180
1945	560	52	1,772	3,741	87	271
1950	454	40	2,359	5,767	103	389
1955	423	24	3,080	8,700	120	629

INDEX NUMBERS (1920=100)

Year	Bituminous coal (7)	Anthracite (8)	Oil and NGL (9)	Natural gas (10)	Waterpower (11)	Electricity generated (12)
1920	100.0	100.0	100.0	100.0	100	100.0
1925	98.0	74.4	160.5	146.5	135	149.1
1930	89.4	79.1	221.2	237.7	185	201.8
1935	69.9	59.3	212.5	236.2	220	208.8
1940	84.7	57.0	290.5	328.0	260	315.8
1945	110.0	60.5	382.7	476.6	435	475.4
1950	89.2	46.5	509.5	734.6	515	682.5
1955	83.1	27.9	665.2	1,108.3	600	1,103.5

Source: "Energy in the American Economy, 1850–1975" (forthcoming publication of Resources for the Future, Inc.). Preliminary figures.

By converting the absolute figures just shown into their B.t.u. equivalents, it is possible to measure the changing relative importance within the total of the individual energy sources. The conversion to common units, and the derivation of percentage patterns, yields the picture of historical change shown in table 6.

TABLE 6.—*Specific energy sources as percentages of total energy consumption, 1920–55 (5-year intervals)*

Year	Bituminous coal (1)	Anthracite (2)	Oil and NGL (3)	Natural gas (4)	Water-power (5)	Total (6)	Electricity generation [1] (7)
1920	67.4	11.0	13.5	4.2	3.9	100	11.3
1925	62.6	7.8	20.5	5.8	3.3	100	10.7
1930	53.5	7.7	26.5	8.8	3.5	100	10.8
1935	48.9	6.8	29.7	10.3	4.3	100	11.8
1940	47.2	5.2	32.4	11.4	3.8	100	13.2
1945	46.5	4.2	32.0	12.6	4.7	100	14.7
1950	34.8	3.0	39.5	18.0	4.7	100	17.8
1955	27.8	1.5	43.8	23.1	3.8	100	19.7

[1] At the prevailing rate of amount of fuel consumed per kilowatt-hour at central electric stations.

Source: "Energy in the American Economy, 1850–1975" (forthcoming publication of Resources for the Future, Inc.). Preliminary figures.

Here we see clearly the really dramatic changes in the country's energy-use pattern which have characterized the past 35 years or so of our history. Coal was preeminent in 1920: bituminous coal and anthracite together accounted for more than three-fourths of all energy consumed, bituminous coal alone for more than two-thirds. Oil and natural gas together supplied less than one-fifth of the total in that year. In 1940 coal, although still in first place, was down to about half of the total, while oil and natural gas had risen to more than 40 percent. By 1950 coal was no longer in first place; oil with about 40 percent of the total was the most important source, bituminous coal was second with about 35 percent, natural gas third with a little more than half the relative importance of bituminous coal. The relative decline of coal and growth of oil and gas continued between 1950 and 1955, so that by the latter year oil's (including NGL) part in the total was about 44 percent and natural gas' share was close to one-fourth, not far below that of bituminous coal, which stood at 28 percent of the total. (Between 1955 and 1958, as we saw earlier, natural gas and bituminous coal exchanged places, with natural gas becoming the second most important energy source and bituminous coal dropping to third place.) Anthracite declined during this entire period almost to the point of becoming an insignificant factor in the total—from 11 percent in 1920 to 1.5 percent in 1955. Waterpower more or less maintained the same relative position—in the neighborhood of 4 percent of the total—over the entire 35-year period.

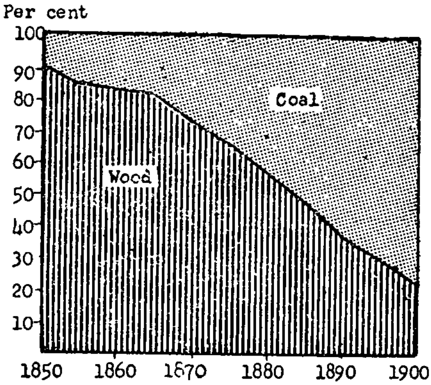
Another aspect of relative shares should also be noted. The share of the total which reached the energy consumer in the form of electricity started the period at 11.3 percent. In the 20 years between 1920 and 1940 it increased somewhat to 13.2 percent of the total. Between 1940 and 1955 its relative share grew rapidly so that by 1955 it stood at about one-fifth of all energy consumption.

The decline of coal

Within the longer perspective provided by statistics going back to 1850, it can be seen that the years during which coal was first among energy sources in the United States constituted a relatively short period—at least compared with other industrial countries. Coal contributed more than 50 percent of the total annual energy supply for about half a century, roughly from 1885 to 1940. It is interesting, too, in this longer perspective to observe that the rise of liquid and gaseous fuels and the displacement of coal roughly parallel the rise of coal and the decline of wood in the overall energy supply half a century earlier. The percentage shares of energy contributed by the principal sources changed as follows. (See figs. 2a and 2b.)

FIGURE 2-a
FROM WOOD TO COAL

(By 1900 other sources -- oil, natural gas and hydropower -- supplied 7½ percent of all energy consumed.)



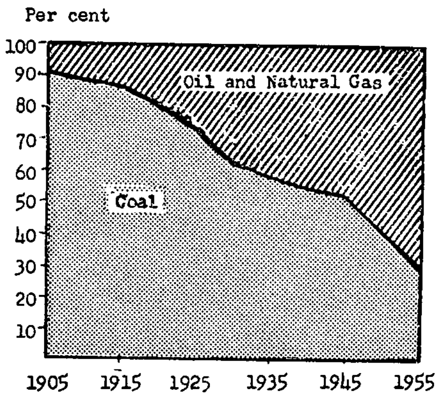


FIGURE 2-b
FROM COAL TO OIL AND NATURAL GAS

(By 1955 other sources —hydropower and fuel wood -- supplied 6 percent of all energy consumed.)

Source: Energy in the American Economy, 1850-1975 (forthcoming publication of Resources for the Future, Inc.). Preliminary figures.

Between 1850 and 1895, coal increased from 9 to 65 percent; wood declined from 91 to 30 percent.

Between 1910 and 1955, oil and gas increased from 9 to 65 percent; coal declined from 77 to 29 percent.

Thus within the past century the composition of the U.S. fuel and power base changed twice so markedly that the relative importance of the principal energy sources was completely reversed.

What light does the statistical record throw on the factors underlying the drop in the absolute and relative levels of coal consumption? To examine this question it is helpful to begin with statistics indicating the distribution of total energy use among the major consuming sectors. Such statistics are shown, for the year 1955, in table 7.

TABLE 7.—*Energy consuming sectors: Their relative importance in 1955*

	Percent
Total	100.0
Industry (mining and manufacturing)	39.2
Commercial	8.5
Households	18.6
Transportation	20.2
Government	4.6
Agriculture	1.8
Miscellaneous uses and losses	7.1

Source: "Energy in the American Economy, 1850–1975" (forthcoming publication of Resources for the Future, Inc.). Preliminary figures.

Three categories of use dominate the total: industry, households, and transportation. Industry is, of course, a highly heterogeneous combination of activities and is itself subject to a very large amount of internal change. Analyzing historical changes in the composition of the industrial aggregate and their effects on energy consumption is too big a task to undertake here. We may note, however, that the kind and amount of energy required per dollar value of product in different industries varies widely. For example: the smelting and refining of metals and the production of clay and glass products require many times as much energy per dollar of product as textiles and food products. Moreover, the form in which the energy is consumed differs among industries: aluminum production requires electric power; pig-iron production needs coke; natural gas is favored in the production of glass; food processing uses steam which can be produced from any fuel source, etc. The point to be noted is that since the growth of the economy involves different rates of growth for component industries, the growth of requirements for specific fuels is bound to be far from uniform. However, without untangling the factors involved, it is significant to observe the following result: between 1939 and 1954 (years in which censuses of manufactures were taken), a period during which the output of manufacturing industries more than doubled, the amount of coal consumed in manufacturing increased by less than 25 percent.

Transportation and residential uses, the other two major categories, are not as diverse as industry, and it is, therefore, possible to show more directly how coal's decline has been influenced by developments within these sectors. Table 8 shows coal consumption in these two declining consuming sectors, and also in electric utilities, which have been an important source of increased coal consumption.

TABLE 8.—*Coal consumption by selected consumer classes: Railroads, space heating, and electric utilities, 1940–55*

[Million tons]

	Railroads (1)	Space heating (2)	Electric utilities (3)
1940	85	[1] 124	49
1950	61	[1] 114	88
1955	15	[1] 68	141

[1] Including anthracite.

Source: U.S. Bureau of Mines.

During a period of general industrial expansion, coal consumed by the railroads declined by 70 million tons, and coal consumed for space heating purposes declined by about 55 million tons, a total decline of 125 million tons. Total coal consumption did not fall by nearly this much because there were offsetting increases in other consumption categories, mainly coal used by electric utilities, but, as we have seen, these increases were not large enough to keep the relative position of coal from declining sharply.

The story of what happened to take away coal's markets in railroads and in space heating is well known. Railroads were lost essentially as a result of technological advance in the form of diesel locomotives; space heating was lost essentially as a result of changing consumer preference for liquid and gaseous fuels which are cleaner and far more convenient to use. Thus, a coal industry which had already been losing much ground relatively since the 1920's, partly because of its technical inability to compete with oil in providing fuel for automobiles and trucks, began to lose ground rapidly both relatively and absolutely in applications in which it had previously been the primary fuel source.

However, a substantial portion of the market which coal has lost as primary fuel it has regained in the form of electricity. For example, the amount of electric power purchased by manufacturing industries has greatly expanded in recent decades, from 36.4 billion kilowatt-hours in 1929 to 102.8 billion in 1947 and 187 billion in 1954. And electric power utilities have provided a market in which coal consumption has expanded rapidly. To be sure, coal's relative importance as a fuel to electric utilities has declined from nearly nine-tenths of all fuels consumed by thermal powerplants in the early 1920's to seven-tenths in 1955. But over the same period generation of electric power by such plants rose by a very large amount (cf., table 5). Consumption of coal for this purpose increased about 3½-fold, from 37 million tons in 1920 to about 140 million in 1955, much of this increase taking place, as table 8 indicates, between 1940 and 1955.

The expanding market in this field is the more impressive if one considers the great advance in the efficiency of transforming fuel into electric power. At the beginning of this century nearly 7 pounds of coal were required to generate 1 kilowatt-hour. By 1920 this had decreased to 3 pounds; in 1950 it was 1.19 pounds; and in 1954, for the first time, slightly less than 1 pound.

ASSESSING FUTURE DEVELOPMENTS IN ENERGY CONSUMPTION

We now turn from the description and analysis of past developments to another phase of our broad energy study—the projection of future energy consumption. The future year to which these projections apply is 1975, but the exact year should not be taken literally.

Under the best of circumstances, estimating the future is a precarious occupation. When we examine a prediction of the long-run future of the economy we cannot reach a conclusion as to whether it is right or wrong; what we can do is try to determine whether it has been produced through the use of sound techniques, and whether it has made use of the best available current information. If it satisfies these requirements, we judge it to be an acceptable product, but at the same time we recognize that it will have to be changed as time goes by and as new information becomes available. Long-run economic estimates are, therefore, never definitive: they may be the best that can be done at a given time—say the best estimate we can make in 1959 of the 1975 situation; but it is very likely that the estimates made in 1959 will have to be changed if they are also to be the best which can be done at some future time—say, the best estimate that can be made several years from now of the 1975 situation.

Methods used in making the RFF consumption projections

What is a sound technique for projecting future energy requirements? We had occasion to observe earlier that the historical record reveals that energy consumption has not in the past been related in a systematic fashion to the passage of time, the growth in population, or the growth in GNP. We have concluded from this that the projection of the future in terms of general relationships of this type would be unwarranted. We have observed also that the historical record has been characterized by sharp shifts in the relative importance of different energy sources as components of the total. Faced with diverse movements of the kind which have characterized the past history of energy, it is impossible really to understand what brought them about except through a study of the detailed pattern of energy use through time, i. e., an examination of the impact on energy consumption of the changing structure of the national product, of changes in consumer preference (in part in response to price movements), of changes in technology, of changes in the efficiency of energy use, etc. And if, in order to understand the past it is necessary to probe into the detailed pattern of energy use in different economic sectors, it seems obvious that a projection of the future cannot be made with any confidence unless it too is based on a detailed picture of the expected behavior of energy consuming sectors and activities.

TheRFF approach to projecting energy demand is, therefore, along the following lines. In studying the future demand for energy we begin with projections of the overall growth of the national economy as reflected in estimates of broad economic magnitudes such as future population, and, in particular, GNP. Such estimates provide the economic framework within which our projections of the demand for energy are made.

Obviously, however, GNP estimates are only the beginning since the demand for energy arises not from the GNP, which is a statistical measure of the economy's total performance, but from the underlying activities in the economy in which men are employed and goods and services produced. An important reason for historical changes in the ratio of total energy to total GNP is that the relative importance of such activities changes over time. Some grow, others wane; new products appear, old products decline, etc. As the structure of output changes, so energy requirements per unit of total output (GNP) change, because of differences in the amounts of energy needed to produce a dollar's worth of various goods and services.

In the RFF projection changes in the structure of output are taken into account. We start by assembling information about the present distribution of energy consumption among different economic sectors and activities. Such informatin is then organized into a comprehensive framework accounting for all of the Nation's energy consumption.

Here energy is related to the uses in which it is consumed, and the amounts are expressed in common units (B.t.u.'s) as well as the ordinary units of commerce (tons, barrels, etc.). The assembly and organization of this information is a time-consuming task, and the results are far from ideal because detailed information on fuel uses is scattered and fragmentary and not always expressed in comparable or consistent terms.

After present energy consumption has been systematically accounted for, there are two further steps in our analysis of demand: (1) projection of future output levels for specific categories represented in the energy use pattern; and (2) estimation of possible future changes in the relationships between the energy these activities consume and their levels of output.

The second step requires attention to various aspects of the historical pattern and indicated future directions of the relationships between energy consumption and levels of output in specific activities, in particular (*a*) changes in the efficiency of energy use, and (*b*) movements in the relative importance of different fuels in supplying the demand for energy, as a result of such things as shifts in consumer preference and technological changes in fuel-using equipment.

The several operations described above yield projections of the future for particular fuels in specific activities and sectors and, when summed, yield also the total demand for particular energy sources as well as the grand total of projected energy use.

It should be noted that nuclear energy has been excluded from our calculations. Although there is every indication that nuclear energy will eventually become an important element in the energy position of the country, the uncertainties concerning the timing of this development are still very great. At the present time there is little more than conjecture on the matter of the place of nuclear energy in 1975, although it is quite clear that its role will not be important by that time. The estimates of conventional energy sources which we have developed can be used as background against which the possible impact of nuclear energy on the energy position in 1975, as projected by others, is examined.

Projections of 1975 energy consumption

Although the estimates which I am going to summarize were developed in considerable detail, and with much care and attention to all relevant information, I propose to skip over the details and just present the main findings. Let us look first at estimated total energy consumption. This total was, of course, not estimated as such, but is the result of adding together the estimates derived for the individual energy sources in particular uses. In table 9 the aggregate for energy consumption is compared with two other aggregates—GNP and population. Although in our judgment such aggregate relationships do not provide a dependable basis for making projections, they do offer a convenient means of summarizing results at the most general level.

TABLE 9.—*Energy consumption, gross national product, and population, 1955 and estimated 1975*

	1955 (1)	1975 estimates (2)	Percentage change, 1955–75 (3)
Energy consumption (in trillion B.t.u.'s)	40,079	75,288	+88
Gross national product (in billion 1955 dollars)	391	[1] 857	+119
Population (in millions)	165.3	[1] 233	+41
GNP per capita (in 1955 dollars)	2,365	3,678	+56
Energy consumption per capita (in million B.t.u.'s)	242.5	323.1	+33
Energy consumption per unit of GNP (thousand B.t.u.'s per 1955 dollar of GNP)	103	88	−15

[1] The overall economic assumptions within which the analysis is conducted were determined by the basic objective of testing the adequacy of resources. We have, therefore, assumed overall economic growth rates which are on the high side in order to test supply availability against requirements which are meant to be at the high end of a range of reasonable possibilities.

Source: "Energy in the American Economy, 1850–1975" (forthcoming publication of Resources for the Future, Inc.). Preliminary figures.

When the various energy commodities which have been separately estimated are added together in terms of B.t.u.'s contained, the total is found to grow by 88 percent between 1955 and 1975. Thus, the growth in energy consumption between the 2 years turns out to be more than twice as great as the assumed 41 percent increase in population, but falls short of the 119 percent increase assumed for GNP. On a per capita basis the assumed increase in GNP of more than 55 percent is found to require a 33-percent increase in energy consumption. Over the 20-year period, therefore, there is a resultant 15-percent decline in the quantity of energy consumption necessary to support a fixed amount of total national product (i.e., a constant dollar of GNP).

Comparison of these estimates with the historical record previously presented shows that, as in the past, percentage changes in total energy consumption do not move in unison with changes in population or gross national product. The one persistent trend that was noted in the historical record, for energy consumption to grow at a less rapid rate than the total national output, will continue in the future, according to these estimates.

Now we turn to the consumption of the individual energy sources, as summarized in table 10. Among the fuels, the highest rate of growth is estimated for natural gas—an increase of more than 100 percent between 1955 and 1975, from 9½ trillion cubic feet to almost 20 trillion cubic feet. The next highest rate of growth is for oil and NGL, with a 95-percent increase between 1955 and 1975—the absolute change being from 3 billion barrels in 1955 to almost 6 billion in 1975. Bituminous coal is next in line, increasing by almost 75 percent in the 20-year period from 1955 to 1975, with tonnage estimated to increase from 431 to 754 million short tons. Anthracite is the only one of the primary energy sources estimated to suffer an absolute decline—from 20 million tons in 1955 to 14 million tons in 1975, a decline of 30 percent. The fastest rate of growth, by far, is estimated, not for any one of the primary energy sources, but for electricity which shows a growth from 633 billion kilowatt-hours in 1955 to almost 2,000 billion kilowatt-hours in 1975, more than a 200-percent increase. Water power, a component of the electricity total, is estimated to grow by 120 percent.

TABLE 10.—*Energy consumption, by source, 1955 and estimated 1975*

	1955 [1] (1)	1975 (2)	Percentage change, 1955–75 (3)
Bituminous coal (million tons)	431	754	+74.9
Anthracite (million tons)	20	14	−30.0
Oil and NGL (million barrels)	3,034	5,923	+95.2
Natural gas (billion cubic feet)	9,614	19,881	+106.8
Hydropower (billion kilowatt-hours)	120	265	+120.8
Consumed as electricity (billion kilowatt-hours)	633	1,966	+210.6

[1] Estimates of 1955 aggregate consumption of the various energy commodities and sources differ somewhat from those used in the historical tables. We have passed over the virtues of complete consistency in order to use data which were, for one reason or another, more suitable for projection work in the one instance and for historical analysis of time series in the other. In table 5 consumption represents apparent disappearance, calculated from production, net foreign trade, and net changes in stocks. In this table, on the other hand, the consumption of each energy commodity or source was built up from reported or derived statistics which purport to measure the actual quantities which went into specified consuming sectors and activities. The sources of the differences are explained in our full report.

Source: "Energy in the American Economy, 1850–1975" (forthcoming publication of Resources for the Future, Inc.). Preliminary figures.

These findings, when compared with the historical record, continue one of the characteristic aspects of the development of the U.S. energy consumption—the disparate rates of growth of the different sources. However, there is a sharp contrast between the individual growth rates registered during the historical periods examined earlier, and these estimates of the future. This difference—and a very significant one—is to be found in the fact that the future growth rates for oil, natural gas, and bituminous coal are not nearly as far apart as they were in the past. Thus, between 1920 and 1955 and between 1940 and 1955, when oil and natural gas expanded rapidly, bituminous coal experienced absolute declines in tonnage, while between 1955 and 1975 bituminous coal is estimated to grow substantially, with a percentage increase only about 20 percent below that for oil and about 30 percent below that for natural gas. This change is clearly visible in table 11 which compares percentage changes in the consumption of coal, oil, natural gas, and electricity for selected years between 1920 and 1955, and between 1955 and the estimates for 1975.

TABLE 11.—*Comparative changes in consumption in various fuels for selected years*

[In percent]

	1920-40 (1)	1940-55 (2)	1920-55 (3)	1955-75 (4)
Bituminous coal	−15	−2	−17	+75
Oil and NGL	+190	+129	+565	+95
Natural gas	+228	+238	+1,008	+107

Source: "Energy in the American Economy, 1850-1975" (forthcoming publication of Resources for the Future, Inc.). Preliminary figures.

The factors accounting for this abrupt change in trends are imbedded in the myriad of items entering into our detailed estimating procedures. However, it is possible to identify one set of circumstances which provides much of the explanation for the reversal in the bituminous coal trend and for what, by the standards of recent history, must be called a remarkable closeness in the expected rates of growth of bituminous coal, oil, and natural gas. One important element in this outcome is the high rate of growth estimated for electricity between 1955 and 1975. This high growth rate, which reflects the ever-growing use of electricity in industry and the home, is estimated to produce a substantial effect on coal, because much of the growth in electricity generation is expected to be fueled by bituminous coal in the future, just as it has been in the past. In the past, though, the growing use of coal by electric utilities could not offset the great tonnage losses experienced by coal in railroad locomotive power and in space heating. (This is evident from the statistics presented earlier.) However, the major inroads of gas and oil into coal's railroad and residential markets have already been achieved. The further inroads into these markets to be expected in the future will no longer be large enough to offset coal's estimated greatly expanded use in connection with the growth of electric power generation. Hence, the substantial increase for bituminous coal compared with its decrease in the past. The same factors explain the estimated slowing down in the rate of increase for oil and natural gas; no longer can these fuels benefit as much as they have in the past from coal's loss of customers in railroading and household use. The major gains have been realized, and consequently their growth in the future is expected to be less rapid than in the past.

However, it is important to remember that the reversal in the trend for bituminous coal depends, in the final analysis, on its ability to hold on to a very large share of the electric utility market. According to our estimates electricity production (including nonutility generation) will account for 60 percent of the consumption of coal in 1975, compared with 37 percent in 1955. Thus, anything which seriously cuts into the use of coal for generating electricity, as, for example, atomic energy might do (not before 1975, but probably in the years following), could according to these estimates throw the industry once again into its previous pattern of decline.

CONCLUDING REMARKS

The historical record summarized in this paper bears testimony to the remarkable flexibility of the energy resources base of the United States in meeting the country's needs for fuel and power during a period of rapid growth and economic transformation. This country has moved with relative ease from wood to coal, and from coal to oil and gas as major energy sources in response to the changing needs and wants of industry and the American people. It is doubtful that the history of any other industrial nation would show as great a transformation in the composition of the energy base as 75 to 100 years of American history have witnessed. Today, as in the past, we draw heavily on a variety of fuels, drawn mainly from domestic sources. Such flexibility in meeting the country's needs has been a source of strength in both war and peace.

The purpose of our study is not just to chronicle these changes, but to answer the question whether the U.S. resource base can continue to provide abundant and flexible supplies of energy in the future. It is basically in connection with this question that our analysis of the future was undertaken. In my presentation I have drawn the picture of what our demands may be in 1975. Because our interest has been in testing the adequacy of our energy resource base we have geared these demands to an estimated high rate of economic growth. Thus, the assumed 4 percent annual average growth rate for GNP, within which our demand analysis was conducted, is at the high end of what is currently viewed as the range of reasonable prospects. The next question is whether our energy resource base can satisfy these demands, and, if so, at what cost. Mr. Netschert's paper, which summarizes the analysis of supply contained in our book, is devoted to this subject.

APPENDIX TABLE I.—*Coal, oil, and natural gas: Prices and price indexes, 1900–1955 (average values at point of production)*

Year	Bituminous coal			Anthracite			Crude oil			Natural gas		
	Average price, dollars per net ton [1]	Index (1947=100)	Index relative to all wholesale prices (1947=100)	Average price, dollars per net ton [1]	Index (1947=100)	Index relative to all wholesale prices (1947=100)	Average price, dollars per barrel [2]	Index (1947=100)	Index relative to all wholesale prices (1947=100)	Average price, cents per cubic foot [3]	Index (1947=100)	Index relative to all wholesale prices (1947=100)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1900	1.04	25.0	66.0	1.49	20.6	54.4	1.19	61.7	162.8	7.1	118.3	312.1
1901	1.05	25.2	67.7	1.67	23.1	62.1	.96	49.7	133.6	5.7	95.0	255.4
1902	1.12	26.9	67.8	1.84	25.5	64.2	.80	41.5	104.5	5.7	95.0	239.3
1903	1.24	29.8	74.3	2.04	28.3	70.6	.94	48.7	121.4	5.7	95.0	236.9
1904	1.10	26.4	65.7	1.90	26.3	65.4	.86	44.6	110.9	5.7	95.0	236.3
1905	1.06	25.5	62.8	1.83	25.3	62.3	.62	32.1	79.1	5.0	83.3	205.2
1906	1.11	26.7	64.0	1.85	25.6	61.4	.73	37.8	90.6	4.6	76.7	183.9
1907	1.14	27.4	62.3	1.91	26.5	60.2	.72	37.3	84.8	5.1	85.0	193.2
1908	1.12	26.9	63.4	1.90	26.3	62.0	.72	37.3	88.0	5.2	86.7	204.5
1909	1.07	25.7	56.5	1.84	25.5	56.0	.70	36.3	79.8	5.0	83.3	183.1
1910	1.12	26.9	56.6	1.90	26.3	55.4	.61	31.6	66.5	5.3	88.3	185.9
1911	1.11	26.7	61.0	1.94	26.9	61.4	.61	31.6	72.1	5.6	93.3	213.0
1912	1.15	27.6	59.2	2.11	29.2	62.7	.74	38.3	82.2	5.7	95.0	203.9
1913	1.18	28.4	60.3	2.13	29.5	62.6	.95	49.2	104.5	5.8	96.7	205.3
1914	1.17	28.1	61.1	2.07	28.7	62.4	.81	42.0	91.3	6.1	101.7	221.1
1915	1.13	27.2	58.0	2.07	28.7	61.2	.64	33.2	70.8	6.1	101.7	216.8
1916	1.32	31.7	54.9	2.31	32.0	55.5	1.10	57.0	98.8	6.1	101.7	176.3
1917	2.26	54.3	68.5	2.85	39.5	49.8	1.56	80.8	101.9	6.8	113.3	142.9
1918	2.58	62.0	70.1	3.40	47.1	53.2	1.98	102.6	115.9	8.1	135.0	152.5
1919	2.49	59.9	64.1	4.14	57.3	61.3	2.01	104.1	111.3	8.2	136.7	146.2
1920	3.75	90.1	86.6	4.85	67.2	64.6	3.07	159.1	152.8	9.4	156.7	150.5
1921	2.89	69.5	105.6	5.00	69.3	105.3	1.73	89.6	136.2	10.1	168.3	255.8
1922	3.02	72.6	111.3	5.01	69.4	106.4	1.61	83.4	127.9	11.1	185.0	283.7
1923	2.68	64.4	95.0	5.43	75.2	110.9	1.34	69.4	102.4	10.0	166.7	245.9
1924	2.20	52.9	79.9	5.43	75.2	113.6	1.43	74.1	111.9	9.3	155.0	234.1
1925	2.04	49.0	70.2	5.30	73.4	105.2	1.68	87.0	124.6	9.4	156.7	224.5
1926	2.06	49.5	73.4	5.62	77.8	115.4	1.88	97.4	144.5	9.5	158.3	234.9
1927	1.99	47.8	74.3	5.26	72.9	113.4	1.30	67.4	104.8	8.8	146.7	228.1
1928	1.86	44.7	68.6	5.22	72.3	110.9	1.17	60.6	92.9	8.9	148.3	227.2
1929	1.78	42.8	66.7	5.22	72.3	112.6	1.27	65.8	102.5	8.2	136.7	212.9
1930	1.70	40.9	70.3	5.11	70.8	121.6	1.19	61.7	106.0	7.6	126.7	217.7
1931	1.54	37.0	75.2	4.97	68.8	139.8	.65	33.7	68.5	7.0	116.7	237.2
1932	1.31	31.5	72.1	4.46	61.8	141.4	.87	45.1	103.2	6.4	106.7	244.2
1933	1.34	32.2	72.5	4.17	57.8	130.2	.67	34.7	78.2	6.2	103.3	232.7

See footnote at end of table

APPENDIX TABLE I.—*Coal, oil, and natural gas: Prices and price indexes, 1900–1955 (average values at point of production)*—Continued

Year	Bituminous coal			Anthracite			Crude oil			Natural gas		
	Average price, dollars per net ton [1]	Index (1947=100)	Index relative to all wholesale prices (1947=100)	Average price, dollars per net ton [1]	Index (1947=100)	Index relative to all wholesale prices (1947=100)	Average price, dollars per barrel [2]	Index (1947=100)	Index relative to all wholesale prices (1947=100)	Average price, cents per cubic foot [3]	Index (1947=100)	Index relative to all wholesale prices (1947=100)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1934	1.75	42.1	83.4	4.27	59.1	117.0	1.00	51.8	102.6	6.0	100.0	198.0
1935	1.77	42.5	78.8	4.03	55.8	103.5	.97	50.3	93.3	5.8	96.7	179.4
1936	1.76	42.3	77.6	4.16	57.6	105.7	1.09	56.5	103.7	5.5	91.7	168.3
1937	1.94	46.6	80.1	3.81	52.8	90.7	1.18	61.1	105.0	5.1	85.0	146.0
1938	1.95	46.9	88.5	3.92	54.3	102.5	1.13	58.5	110.4	4.9	81.7	154.2
1939	1.84	44.2	85.0	3.64	50.4	96.9	1.02	52.8	101.5	4.9	81.7	157.1
1940	1.91	45.9	86.6	3.99	55.3	104.3	1.02	52.8	99.6	4.5	75.0	141.5
1941	2.19	52.6	89.3	4.26	59.0	100.2	1.14	59.1	100.3	4.9	81.7	138.7
1942	2.36	57.5	86.3	4.50	62.3	93.5	1.19	61.7	92.6	5.1	85.0	127.6
1943	2.69	64.7	93.1	5.06	70.1	100.9	1.20	62.2	89.5	5.2	86.7	124.7
1944	2.92	70.2	100.1	5.57	77.1	110.0	1.21	62.7	89.4	5.1	85.0	121.3
1945	3.06	73.6	103.1	5.90	81.7	114.4	1.22	63.2	88.5	4.9	81.7	114.4
1946	3.44	82.7	101.3	6.83	94.6	115.9	1.41	73.1	89.6	5.3	88.3	108.2
1947	4.16	100.0	100.0	7.22	100.0	100.0	1.93	100.0	100.0	6.0	100.0	100.0
1948	4.99	120.0	110.8	8.17	113.2	104.5	2.60	134.7	124.4	6.5	108.3	100.0
1949	4.88	117.3	114.0	8.38	116.1	112.8	2.54	131.6	127.9	6.3	105.0	102.0
1950	4.84	116.3	108.7	8.90	123.3	115.2	2.51	130.1	121.6	6.5	108.3	101.2
1951	4.92	118.3	99.3	9.51	131.7	110.6	2.53	131.1	110.1	7.3	121.7	102.2
1952	4.90	117.8	101.7	9.36	129.6	111.9	2.53	131.1	113.2	7.8	130.0	112.3
1953	4.92	118.3	103.6	9.67	133.9	117.3	2.68	138.9	121.6	9.2	153.3	134.2
1954	4.52	108.7	95.0	8.52	118.0	103.1	2.78	144.0	125.9	10.1	168.3	147.1
1955	4.50	108.2	94.3	7.86	108.9	94.9	2.77	143.5	125.0	10.4	173.3	151.0
	1900=100											
1955	------------	432.8	142.9	------------	528.6	174.4	------------	232.6	76.8	------------	146.5	48.4

Source: "Energy in the American Economy, 1850–1975" (forthcoming publication of Resources for the Future, Inc.). Preliminary figures.

[1] Average values, f.o.b., mines.

[2] Average value at well.

[3] Average value at well. For years prior to 1922, for which only value at point of consumption is available, estimated assuming the same ratio between the 2 values as in 1922.

Representative PATMAN. Thank you very kindly, sir.

We will forgo asking you questions on your statement until after Mr. Netschert has completed his testimony.

Mr. Netschert, we will be glad to hear from you.

STATEMENT OF BRUCE C. NETSCHERT, SENIOR RESEARCH ASSOCIATE, RESOURCES FOR THE FUTURE, INC.

Mr. NETSCHERT. Thank you.

THE FUTURE SUPPLY OF ENERGY SOURCES IN THE UNITED STATES

In this discussion I propose to observe certain limits that reflect the scope of the studies that have been undertaken at Resources for the Future. Only the conventional energy sources—coal, crude oil, natural gas, and hydropower—will be covered; and the future period considered will be from the present to 1975. These limitations may seem arbitrary, but they are consistent with the approach and conclusions of our work. As is already apparent from Mr. Schurr's presentation, for example, the conventional energy sources will continue to dominate the energy use pattern, at least for the medium-term future.

I should also make clear that I am not going to provide independent, original estimates, based on technical research, of the remaining natural stocks of energy sources in the United States. What I will give you is the results of a critical analysis of existing authoritative estimates, an analysis employing new perspectives and concepts.

The fundamental determinants of future energy supply are (1) the natural stock of the energy sources available for exploitation, (2) the technology with which they can be developed and utilized, (3) the level of demand, and (4) foreign supply, as a supplement to domestic supply if one is considering the U.S. position only. I propose to look at supply ex demand—that is, to ascertain not what will or would be produced, but what could be produced. This restricted definition of supply should be kept in mind during what follows. Foreign supply is likewise excluded, since in my work my interest was in future domestic supply, not total supply.

THE U.S. RESERVE POSITION AS CURRENTLY STATED

A useful starting point is provided by the most recent authoritative estimates of the national reserves of the respective energy sources, which are summarized in table 1. By themselves, of course, these figures are rather meaningless; they are all large absolute numbers, but they cannot be directly compared with each other. The practice in the oil and gas industry is to compare the reserve figure with the current level of annual production to obtain a "life index," or the ratio of reserves to production. Let us see the results of using this technique with all four energy sources.

TABLE 1.—*Most recent authoritative estimates of national reserves of the conventional energy sources*

Energy source	Reserve quantity	Source of estimate	Date of estimate as of—
Crude oil	30.5 billion barrels	American Petroleum Institute	Dec. 31, 1958
Natural gas	254 trillion cubic feet	American Gas Association	Do.
Coal	950 billion short tons	U.S. Geological Survey	Jan. 1, 1953
Hydropower	90 million kilowatts	Federal Power Commission	Jan. 1, 1958

Applying the 1958 annual production figures for coal, oil, and gas to the respective reserve estimates, the life indexes are 12.7 for oil, 22.9 for gas, and 2,200 for coal. Oil reserves, that is, are 12.7 times the 1958 rate of production. A similiar calculation can be made for hydropower, although as a renewable resource the concept of current hydroelectricity production as a using up of reserves does not apply. In this instance the nearest relevant measurement is the ratio of developed and installed hydro capacity to the total including both developed and undeveloped. About 28 million kilowatts of capacity were developed and installed as of the beginning of 1958, making a total, together with undeveloped, of 118 million kilowatts. Thus, just under one-quarter of that total is dveloped.

Again, however, these figures are not, by themselves, meaningful. Since the life index for gas is almost twice that of oil, are we, as a nation, twice as well off in gas as we are in oil? Can the enormous figure for coal be compared at all to those of oil and gas? It is obviously necessary to look behind the reserve figures, to see how they are derived and defined, if we are to understand their meaning.

The term "reserves" in the oil and gas industry is commonly understood to mean "proved reserves," which are rigidly defined by the industry as the quantities of oil and gas that are known to exist in underground reservoirs and which can be recovered with present technology under current cost-price conditions. The industry compiles the national total from individual field data, and so the "reserves" of oil and gas are very clearly defined.

In contrast, there is no official definition of what the term "reserves" means with respect to coal, although the individual mine operator uses the term for his own mine in much the same fashion as the oil industry—the quantity of coal known to be in place and which can be recovered with current technology at current costs and prices. Moreover, there is no total of individual coalfield reserves compiled by industry. The U.S. Geological Survey has, however, made an estimate of coal "reserves" based on a State-by-State compilation of estimates of coal in place made, in turn, by State Geological surveys. These "estimated total reserves remaining in the ground" (covering all ranks, from lignite to anthracite) amount to 1.9 trillion tons, just double the "recoverable reserves" figure listed in table 1. Since current recovery averages 50 percent of the coal in place, the Survey applies this 50 percent factor to the total to obtain the "recoverable reserves." Thus, in contrast to the oil and gas industry practice, which is to count only the oil and gas that can be currently recovered economically, the "recoverably reserves" of coal include some that would be uneconomic at present, although physically feasible to recover.

The Federal Power Commission hydropower estimate is for the undeveloped portion of the "hydroelectric power resources"of this country. This includes sites that are not currently economic to develop, hence conceptually the figure is closer to the coal figure than to the others in table 1, but the criteria on which it exceeds the current economic limit are not given.

It is clear from the foregoing that the four estimates have no common conceptual basis and cannot and should not be directly compared. The term "reserves" has a different meaning for oil and gas on the one hand and coal on the other, The oil and gas "reserves" constitute a working inventory for the industry, Yearly additions to these reserves occur through the discovery and proving of new quantities of oil by new wells and by revisions based on new, additional data. In the coal industry, although individual coal companies may block out new reserves for their own operations, such activity bears no relation to the Geological Survey figure, which is based on the knowledge of the stock of coal in the ground and which is changed only by the resurvey, by a State, of its own coal stock. And in the hydropower field, the Federal Power Commission figure is changed by the acquisition of new data, compiled by any competent source, concerning hydrosites for which no data or obsolete data were previously available.

In the literature on future domestic energy supply this lack of a common conceptual basis for the same terms in different energy fields has been a source of compound confusion by the frequent failure to recognize its existence and by the common practice of using the terms "reserves" and "resources" interchangeably, with no explicit definition of their meaning. The situation is doubly unfortunate because of the conclusions that are frequently reached. Failure to understand the specific meaning of the terms has led to many commonly quoted authoritative statements that the natural stock of energy sources available at present costs is rapidly becoming exhausted, or, in the extreme case, that actual total and complete exhaustion is only a matter of a few decades. Whether energy costs actually will rise is, of course, a question that will be settled only by the passage of time. But any consideration of the future will yield more dependable conclusions if it employs terms that are clear in their conception and clean in their definition. In the following paragraphs I would like to present a new approach that has been worked out at Resources for the Future in an attempt to cut through the present terminological tangle.

A NEW TERMINOLOGY FOR CONSIDERING THE FUTURE SUPPLY OF ENERGY SOURCES

You will recall that at the beginning of my remarks I stated that the level of technology was one of the fundamental determinants of future energy supply. One thing that is abundantly clear in the record is the constant progress in technology that has occurred to date, thereby increasing our ability to develop and utilize portions of the natural stock that were hitherto unutilizable economically Many of the oil and gas discovery wells of today would have been classified as dry holes as recently as a decade or so ago.

The oil and gas would have been found, but the occurrence would have been classified as noncommercial, since the techniques for developing that type of occurrence did not yet exist. Similarly, some coal companies now own coal reserves that are being mined by the recently developed auger technique. A decade or more ago this same coal would not have been counted as reserves by the owner because it was too deeply buried to strip mine it and too shallow to mine by underground methods.

If there is one aspect of the future on which there is no disagreement it is that we can expect continued technological progress. This implies that material not now counted in "reserves," or "recoverable reserves" is likely to be included in such "reserves" of the future. Clearly, then, any attempt to estimate the portion of the natural stock that will be utilizable in the medium- and long-term future must allow for improved technology to the extent that this is possible. One cannot consider the future in terms of the present alone. The definition of "reserves" used by the producers of coal, oil and gas is a wholly justifiable basis for measuring their working inventory of material in situ, but it simply will not serve for more than the near-term future. This is equally true from the economic aspect. "Reserves" mean present costs and prices; but suppose there is reason to consider the possibility of higher costs and prices in the future?

Yet if future technology, costs and prices are to be considered in assessing the utilizable portion of the natural stock, the question immediately arises, at what level? Why should any specific assumptions be better, on a priori grounds, than any other? The implication of this question is that once you have passed the limit of what prevails here and now, whatever assumptions you make are essentially arbitrary.

There is, however, one level that is not arbitrary and which is given by nature—the natural stock afforded by the environment. It is possible to conceive of the total natural stock of an energy source that exists in the environment (say, the earth's crust within the boundaries of the United States), including both what is known and what is unknown, and regardless of cost-price considerations and technological feasibility. This concept I have called the "resource base." In the present context the resource base is absolute; it comprehends everything and its definitional limits are "clean"—that is, there is no question of what is or is not oil, gas, or coal (or, for that matter, potential hydropower).

Leaving aside for the moment the question of quantifying the resource base, the immediate advantage it provides is an outer limit for considering the natural stock. There can be no larger quantity than the resource base under any economic or technical criteria. At the other end of the scale there already exists the nearby limit in the "reserve" concept as used by industry. It is between these two limits, of the here and now on the one hand and the environmental absolute on the other, that the natural stock of any energy source becomes meaningful in any look at the future. I have called the concept of the natural stock between these two limits the "resources" of an energy source. It should be noted that in going up the scale, these concepts are successively inclusive; that is, resources include reserves, the resource base includes everything.

The concept of resources concerns the level of the natural stock lying between the reserve level and the resource base. The resources of a specific energy source may be defined according to any criteria that are judged relevant. Thus, one may wish to define oil resources as the quantity available at costs twice as high as present; or, using physical criteria, one may define coal resources in terms of the quantities available down to the 5,000-foot depth, in seams as little as 1 foot thick, and with a 50 percent ash content.

This answers the question raised previously. There is no preferred or best level at which to take account of technology, costs and prices, just as there is no specific level at which resources will be utilized over the long term. But the longer the future period under consideration, the broader are the applicable technical and economic limits, the less restrictive are the physical criteria that are pertinent, hence the larger the quantity of resources that obtain.

It is, of course, obvious that the resource base and even the resources, under some definitions, may be impossible to quantify. It is not the intent of this terminology, however, to provide necessarily quantitative estimates. Rather, its value lies in the perspective in which it places existing estimates of the natural stock. It provides clearly and unambiguously for the consideration of conditions other than those currently prevailing in assessing the future. The usefulness of this terminology and the gain it affords will, I hope, become apparent in the examination of existing coal, oil, and gas estimates to which I now turn.

A CRITICAL SURVEY OF CURRENT FUTURE SUPPLY ESTIMATES OF ENERGY SOURCES

Crude oil

Attempts by industry experts to measure the future domestic supply of oil have yielded several estimates of the "ultimate reserves" of crude oil in this country, meaning all oil that has been produced to date, plus current proved reserves, plus the oil awaiting discovery to be added to those reserves. The more authoritative are based on geological data relating the known occurrence of oil to the volume of rock in the sedimentary basins in which it is found; others are modifications of these original attempts, are based on discovery trends, or are accompanied by little or no explanation of their derivation. The estimates range from 140 to 250 billion barrels and, allowing for the 60 billion barrels of cumulative production through 1958, mean that from 80 billion to 190 billion barrels would remain.

Implicit in the estimates, however, is the "proved reserve" definition, which has an important and highly misleading influence on the results. At present only one-third of the oil actually found in place can, on the average, be recovered economically; thus the 30 billion barrels of present proved reserves count only one-third of the oil actually being discovered. The oil estimated to be awaiting recovery in the "ultimate reserve" figures is on the basis of this current recovery ability; that is, the only oil counted is that which could be recovered under present-day circumstances. By extrapolating into the future under the proved reserve concept, the estimates therefore not only ignore the 200 billion barrels (including the accumulation from past actual discoveries) presently known to be in the ground but not counted; in addition they implicitly assume that future discoveries will yield only one-third of the oil actually found. This denies, by implication, that it will be possible to produce a higher percentage of the oil actually discovered in the future than can be produced from the oil actually discovered today.

Although the "ultimate reserve" estimates have this shortcoming, since they quantify future discovery prospects they offer the fascinating and useful possibility of inferring from authoritative opinion a rough approximation of the crude oil resource base in the United States. The estimates assume the present recovery capability of only one-third, hence imply the existence of three times as much oil in the ground. Accordingly, it is appropriate to multiply the estimates by 3 to obtain an equivalent figure near the resource base level. By subtracting from this resource base equivalent the cumulative production to date, one obtains an estimate of the oil in the ground potentially available for recovery (i.e., including proved reserves, the currently unrecoverable content of known reservoirs, and the total content of undiscovered reservoirs). A rough average of the results of this operation on each of the ultimate reserve estimates indicates an inferred potential availability of 500 billion barrels.

I want to emphasize that I am not suggesting that this is the total of what will actually be found and produced in the future. But this is the indicated order of the resources against which future technology can be applied. The important gain is the perspective this puts on prospects for the medium-term future, say, to 1975. The ultimate reserve estimates have engendered the widespread belief that the peak producing capacity of the domestic oil industry will be reached before 1975, or even within the next 5 years, because of the comparatively small magnitude of the quantity of oil remaining to be discovered. This belief has been reinforced by statistics showing that the "drilling return" (the quantity of oil added to proved reserves for each foot of drilling by the industry) is declining sharply.

A complete discussion of this pessimistic viewpoint is not possible here, since it involves opinions on and interpretations of such diverse items as the meaning of drilling statistics, discovery prospects within the country as a whole, and the use of the typical life production curve of an individual field as an analog to the life production of the industry as a whole. I will merely summarize some of the reasons for disagreeing with the pessimistic view.

There is no a priori basis for ascribing the currently increasing difficulty of discovery to a deteriorating resource position. It is all too easy to say that if we find less than we used to it is because there is less to be found. To do this is to assume that we are already probing for oil in all its possible occurrences, both areally and in depth. On the contrary, leading oil geologists have repeatedly called attention to the large potential oil-bearing areas (such as the Atlantic Coastal Plain) still unexplored, the possibilities of further intensive work in known oil-bearing areas, and the potential at depth in both known and unexplored areas.

What seems more likely is that we are pushing hard on the limits to our present discovery capabilities. With present techniques it is becoming more difficult to find new oil. But will discovery technology cease development henceforth? It does not require a dramatic breakthrough to justify the expectation of improved discovery ability in the future. Merely a continuation of the steady improvement in known techniques should be sufficient, for it is after all, a compound growth.

For the medium-term future there is a more important reason for disagreeing with the pessimistic viewpoint. This is the more than 200 billion barrels of known but currently unrecoverable oil. Newly developed techniques of increasing recovery, such as in situ combustion and miscible phase displacement, give every indication of vastly improving overall recovery levels (pilot operations have approached 100 percent recovery), and the incentive to apply these new techniques to the hitherto unrecoverable oil that has no discovery costs would appear to be strong indeed. Early evidence of the growth in these new techniques, together with the increasingly rapid expansion of older methods (such as waterflooding), indicates the possible explosive growth of such secondary production. By 1975 the "secondary jackpot" could be contributing substatially to overall production. In addition, the application of the improved methods to new discoveries would also increase producing capacity.

It is therefore concluded that the domestic oil industry could meet the projected demand level in 1975 given by Mr. Schurr, and that this could be done at no higher constant dollar costs due to resource depletion. The latter statement is based not only on the expectation of future technological progress, but on the demonstrated ability of the industry to date to offset the increasing physical difficulties, such as greater depth without increasing costs. Statistical evidence of this ability is provided by the industry's drilling cost surveys and by the reports of individual company experience in the literature.

Natural gas

Natural gas is never considered in terms of "ultimate reserves," since the large proportion of earlier discoveries that was wasted will never be known quantitatively and can only be crudely estimated. The equivalent estimates for natural gas are all in terms of "total future supply" (i.e., current proved reserves plus the quantities available for future discovery that could be produced under current conditions). Such estimates are always related to total future crude oil supply (derived from an estimate of ultimate reserves), in recognition of the fact that oil and gas are geologically associated. The relation is expressed as the "gas-oil ratio,"which assumes that for each barrel of proved reserves of crude oil discovered the proved reserves of gas will be augmented by so many thousand cubic feet. The gas estimates thus have a double basis, and because the two assumptions of crude oil supply gas-oil ratio are compounded, there is considerable variation in the results.

The published estimates of total future natural gas supply range from 500 to 1,200 trillion cubic feet. There is little point in converting these to a resource base equivalent, for the current recovery level of between 80 and 90 percent means that the difference between the two bases is in all probability within the margin of error of the total future supply estimates.

This leaves the gas-oil ratio as the crucial element. Available data offer a choice of several ratios, but without becoming involved in a discussion of the relative merits of the possible ratios that can be used it appears that the ratio of gas to oil in annual discoveries (of proved reserves) is the most useful in a situation in which none of the ratios can be a true measure of the ratio of occurrence in nature.

The ratio in annual discoveries in turn offers three possibilities: the ratio in total discoveries, the ratio in "extensions and revisions," and the ratio in "new fields and new pools in old fields." The second concerns the development of known occurrences, hence does not refer to true "discoveries." The third is closer to the true "discovery" situation in that it represents the results of wildcatting, or drilling on the basis of either indirect evidence of hydrocarbon occurrence or no evidence at all. The first merely reflects the proportion of the two types in the total.

As shown in table 2 and figure 3, there has been wide variation in the three series in the period for which statistics are available, both from year to year and between individual series. Again without going into detail, it appears that the consistently higher ratio in new fields and pools and the rapid rise in that series are due to either the depth factor, the rising value of natural gas, or both. There is strong evidence to indicate that the gas-oil ratio rises with depth, and, as wildcats lead the way to deeper producing horizons, it would be expected that the discovery ratio in new fields and pools would be higher and would rise faster. At the same time, the increasing value of gas has stimulated the search for gas alone, the successful results of which would also tend to increase the ratio.

TABLE 2.—*Gas-oil ratio in "discoveries" of proved reserves*

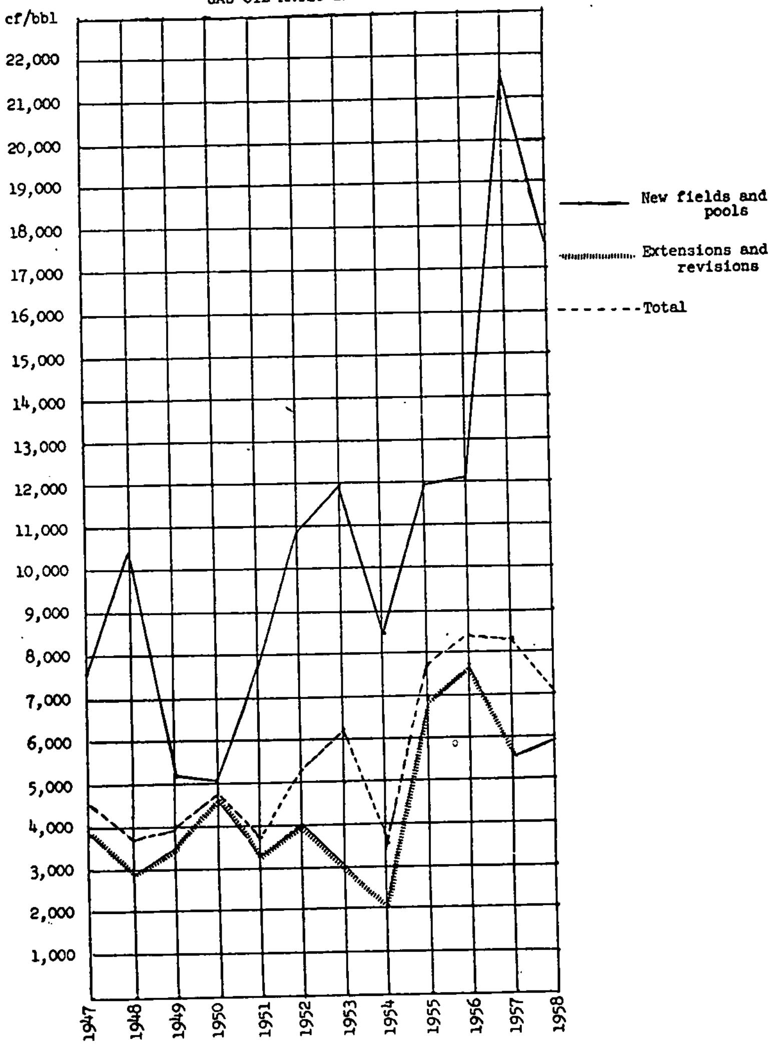
[Cubic feet per barrel]

Year	Extensions and revisions	New fields and pools	Total discoveries	Year	Extensions and revisions	New fields and pools	Total discoveries
1958	5,838	17,828	7,285	1951	3,233	7,808	3,637
1957	5,535	21,622	8,296	1950	4,591	5,093	4,702
1956	7,664	12,064	8,355	1949	3,509	5,180	3,976
1955	6,812	11,991	7,666	1948	2,874	10,414	3,662
1954	2,025	8,479	3,462	1947	3,749	7,656	4,455
1953	4,944	11,969	6,205				
1952	3,966	10,900	5,218	Average	4,562	10,917	5,577

Source: Annual proved-reserve estimates of American Petroleum Institute and American Gas Association.

FIGURE 3

GAS-OIL RATIO IN DISCOVERIES OF PROVED RESERVES



Regardless of the relative influence of the price and depth factors on the data, it is reasonable to assume that the gas-oil ratio will be higher in the future than in the past (although not necessarily higher than at present). The ratios used in the published estimates of future gas supply vary from 3,333 to 7,500 cubic feet per barrel, with 6,000 as the most commonly used figure. In our work a ratio of 7,000 cubic feet per barrel was chosen as a conservative expression of the belief that the ratio will be higher in the future than it has been in the past.

It remains to apply the ratio of 7,000 cubic feet per barrel to our own estimate of 500 billion barrels as the oil available for future recovery. Since the ratio is derived from data based on the proved reserve concept, however, the oil figure must be converted back to a proved reserve basis. This means the figure of 500 billion barrels must be divided by 3 (the reverse of the resource base conversion), which yields a figure of 167 billion barrels. Multiplying this figure by 7,000 gives 1,169 trillion cubic feet of gas, or 1,200 trillion in round numbers. In this instance our conclusion is the same as that of the highest previous estimate, but with the feeling that it may well be conservative rather than overly optimistic.

With respect to the implications of this for the medium-term future, the general conclusions on producing capacity and costs are the same as those for crude oil. The projected demand level in 1975 for natural gas given earlier by Mr. Schurr could be met without any increase in constant dollar costs. The discovery prospects are better, and the same cost data apply.

Coal

As noted earlier, there is only a single estimate of the natural stock of coal remaining in the United States: the State-by-State compilation, by the Geological Survey, of estimates of coal in place. The figure for each State varies from generalized estimates made many years ago to recent estimates made by State surveys under a reappraisal program begun by the U.S. Geological Survey after World War II. Of the 32 States in which coal occurs, one-half are represented by figures based on recent, detailed work, and one-half by the earlier, cruder figures.

The 1.9 trillion tons in the estimate includes many seams not now being mined, hence it is obviously greater than any figure that would represent the total "reserves in place" counted by coal mine operators. It is thus not a figure for national coal reserves, on either an in-place or recoverable basis, corresponding to the oil and gas industry reserve figures (although the Survey labels it as total "reserves").

At the same time, the Survey's estimate is not at the level of the resource base concept. The data are restricted to certain physical limits—viz, a depth of 3,000 feet, a minimum seam thickness (for high-rank coal) of 14 inches, and a maximum ash content of 33 percent. This means that some coal known to exist is not counted because the seam thickness is too small or the ash content too high (like the oil that is not counted because it is currently unrecoverable). In addition there is the unknown quantity of coal that may lie below 3,000 feet—unknown because there is no incentive to probe for coal resources at depth.

Since the currently unrecoverable portion of the stock in place is already included, and lacking any basis on which to estimate future coal discoveries (if, indeed, they will be of any significance) it is not possible to extrapolate to a resource base equivalent. Yet because of its relatively wide environmental limits, the national coal resource figure is considerably closer to the resource base than are the oil and gas figures. With due allowance for the large error inherent in the estimate (even the 6 percent of the total that is most fully delineated as "measured reserves" is subject to a 20-percent error) it can be said that the amount of coal available for exploitation in this country is on the order of at least 2 trillion tons.

Such resources are clearly enormous, and in purely quantity terms there is no question about the ability of the coal industry to meet any conceivable demand for many decades. In the absence of a national reserve figure, however, there is no way of obtaining even an approximate idea as to what portion of those resources would be available at current costs. One can resort to the dictum that in the extractive industries the richest resources are always exploited first, and that the effects of depletion over time are therefore seen as a decline in the quality of the remaining resources. But, like many generalizations, this is little more than a truism; it is of no help for any particular time period. The problem can be approached, however, from the direction of technology. It can be demonstrated that through improved mining and "preparation" techniques the coal industry should be able to cope with whatever decline in resources quality might appear before 1975.

One area of rapid recent technological advance is strip mining, in which productivity per man-day currently averages about 22 tons, versus 9 tons in underground mining. For most of the postwar period strip mining has accounted for one quarter, or slightly less, of total annual coal production. The recent development of supergiant shovels, together with such refinements as the bucket-wheel excavator, point toward an increase in strip mine output as a percentage of the total, hence toward an increase in overall productivity. (Some observers voice concern over the adequacy of "strippable reserves." But the new technology itself demonstrates how open ended these "reserves" are. Current equipment can handle overburden up to 120 feet in thickness. Only a few years ago, 80 feet was the maximum feasible thickness.)

But the greatest opportunities for improved productivity lie underground. Here a true technological revolution is underway in the form of the continuous mining machine. Introduced around 1950, the continuous miner now accounts for approximately 20 percent of total underground production. The reduction in manpower with continuous miners, and the consequent rise in productivity of the manpower retained, has been dramatic. At present, however, the use of the machine is still in the early commercial stage; it is being used in mines and with auxiliary equipment, such as haulage, that were not designed to take advantage of it. When, in a few years, mines designed for the continuous miner are producing an appreciable percentage of total underground coal output, the really large results in terms of overall industry productivity should be obtained. The most optimistic in the industry speak of a doubling or tripling in the productivity level.

Another possible advantage of the continuous miner is an improvement in the recovery level. Although the new technique is still too recent to determine unequivocally whether it will permit greater average recovery (the details must be forgone here), better mine layout and full-seam mining alone would appear to promise some gains.

"Preparation," the other area in which technology promises important gains, consists in the utilization of various techniques to reduce the proportion of impurities in the mined coal, and thus provide a delivered product of higher quality. Advances in preparation to date have made it possible, for example, to supply coke ovens with a satisfactory raw material produced from coal resources of lower and lower quality (higher sulfur and ash). Some 60 percent of all bituminous coal mined is now treated in preparation plants, and the technique is thus available on a large scale to deal with the problem of declining resource quality.

Whether progress in preparation technology will lead to the utilization of lower grade resources, or whether a decline in resource quality will generate advances in that technology, is immaterial. What is significant here is that the cost benefits accruing from more efficient mining techniques should allow for increased preparation costs, stemming from the use of lower grade resources, without a net increase in total coal cost at the mine.

But this is not all; there are in addition possibilities of actually reducing the cost of delivered coal. As shown in table 3, during the last 20 years transportation costs as measured by data for class I railroads were never less than half of production costs, and have recently been rising from their postwar low. In view of the complexity of the subject of rail freight rates, it is fortunate that it is unnecessary to project future rates as a means of considering the future course of coal transportation costs. It is merely necessary to look at two other aspects of coal transportation: (*a*) competing forms of haulage and (*b*) its elimination.

TABLE 3.—*Average rail revenue per ton of bituminous coal hauled, as percentage of average mine value in the United States, 1936–58*

Year	Average value per ton, f.o.b. mine (1)	Average revenue per ton hauled on class I railroads (2)	(2) as percentage of (1) (3)	Year	Average value per ton, f.o.b. mine (1)	Average revenue per ton hauled on class I railroads (2)	(2) as percentage of (1) (3)
1958	$4.86	$3.58	73.7	1946	$3.44	$2.27	66.0
1957	5.08	3.57	70.3	1945	3.06	2.20	71.9
1956	4.82	3.45	71.6	1944	2.92	2.21	75.7
1955	4.49	3.24	72.2	1943	2.69	2.30	85.5
1954	4.51	3.23	71.6	1942	2.36	2.31	97.9
1953	4.92	3.33	67.7	1941	2.19	2.22	101.4
1952	4.90	3.35	68.4	1940	1.91	2.22	116.2
1951	4.92	3.16	64.2	1939	1.84	2.23	121.2
1950	4.84	3.09	63.8	1938	1.95	2.27	116.4
1949	4.88	3.00	61.5	1937	1.94	2.17	111.8
1948	4.99	2.74	54.9	1936	1.83	2.25	123.0
1947	4.16	2.49	59.8				

Source: U.S. Bureau of Mines Minerals Yearbooks.

Table 4 and figure 4 demonstrate the clear trend over the past decades toward water and truck transport of coal at the expense of rail transport. Economics and geography make it most unlikely that these competing forms would ever supplant rail transport, but it is clear that higher freight rates for coal would tend to shift more of its movement to trucks and barges, as these were given a competitive advantage of additional specific hauls. In addition, there looms on the horizon the threat of unconventional transport means. The successful operation of the first commercial coal pipeline, at considerable savings over corresponding rail costs, has generated interest in additional projects of this kind, and the long-distance conveyer belt for coal continues to remain a practical possibility.

TABLE 4.—*Percentage of total production of bituminous coal and lignite moved by the various transport means in the United States, 1939–58*

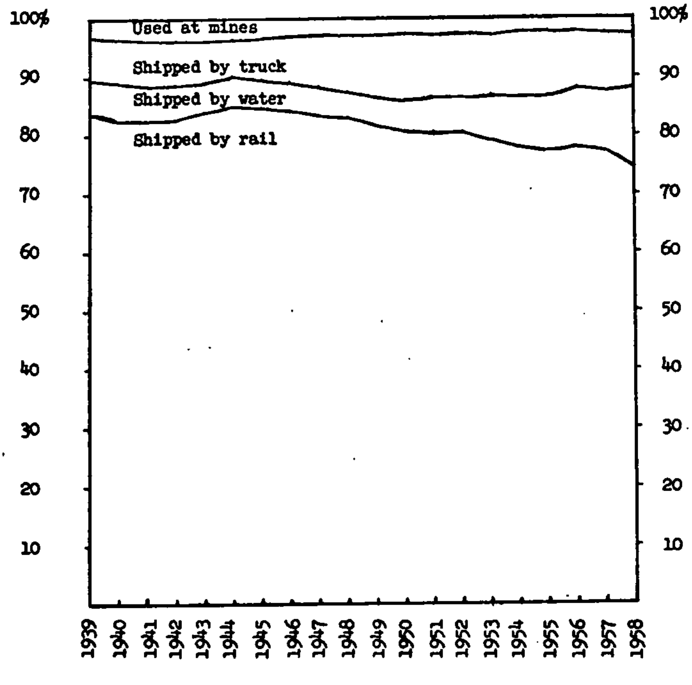
Year	Shipped by rail	Trucked to rail	Total rail	Shipped by water	Trucked to water	Total water	Trucked to final destination	Used at mines [1]
1958	----------	----------	74.5	----------	----------	10.7	12.3	2.5
1957	----------	----------	77.2	----------	----------	10.4	10.2	2.2
1956	----------	----------	77.9	----------	----------	10.1	9.9	2.1
1955	(2)	(2)	76.6	(2)	(2)	10.2	11.1	2.1
1954	(2)	(2)	78.1	(2)	(2)	8.4	11.4	2.1
1953	73.5	5.7	79.2	7.2	0.6	7.8	10.3	2.7
1952	74.2	6.3	80.5	5.6	.3	5.9	10.8	2.8
1951	74.3	6.4	80.7	5.4	.2	5.6	10.9	2.8
1950	72.7	8.1	80.8	5.1	.2	5.3	11.3	2.6
1949	72.2	9.2	81.4	4.7	.3	5.0	10.9	2.7
1948	73.2	9.9	83.1	4.2	.3	4.5	9.7	2.7
1947	74.3	9.3	83.6	4.4	.3	4.7	8.9	2.8
1946	75.5	8.9	84.4	4.4	.2	4.6	8.0	3.0
1945	76.7	8.2	84.9	4.5	.3	4.8	7.2	3.1
1944	76.9	8.2	85.1	4.9	.2	5.1	6.5	3.3
1943	78.7	5.3	84.0	5.0	.1	5.1	7.2	3.7
1942	79.8	3.1	82.9	5.7	.1	5.8	7.7	3.6
1941	80.5	2.2	82.7	5.6	.3	5.9	7.8	3.6
1940	81.5	1.1	82.6	6.2	.2	6.4	7.7	3.3
1939	82.9	1.0	83.9	5.3	.3	5.6	7.5	3.0

[1] Includes delivery to nearby destination by conveyer or tram.
[2] Not available.

Source: U.S. Bureau of Mines Minerals Yearbooks.

FIGURE 4

PERCENTAGE OF TOTAL PRODUCTION OF BITUMINOUS COAL AND LIGNITE MOVED BY THE VARIOUS TRANSPORT MEANS IN THE UNITED STATES, 1939-1958



The elimination of coal transport refers to its use at the mine mouth by a central power station or by an industrial plant for which the cost of power is a prime consideration. Both types of development are already taking place, the utility use of mine powerplant location especially spurred by advances in power transmission technology through the use of extra high voltage. In brief, the traditional barrier of high cost in "sending coal by wire" is now being pierced by the growth of the electric utility industry. Very large central stations and the transmission of large blocks of power make the economics of the mine-mouth station ever more attractive. Again, to the extent that this development occurs, the average cost of delivered coal in the economy is held down. If it is on a sufficiently large scale, that cost could actually be lower.

With respect to the 1975 demand projection for coal in the preceding discussion, there is, of course, no question whatever of the physical feasibility of satisfying that demand. The foregoing analysis leads to the conclusion that this should be possible at no higher, and perhaps even at somewhat lower, constant dollar cost.

Hydropower

The discussion of hydropower in the same context as the mineral fuel resources requires considerable attention to definitions and technical detail because of the very different nature of this energy source. It is, therefore, necessary to devote some space to an explanation of how hydropower can be satisfactorily brought within the reserve-resources-resource base terminology.

The task has been immensely simplified by the recent development in Europe of a new conceptual approach and terminology for the consideration and measurement of hydropower resources.[1] Beginning at the environmental level, the absolute maximum hydropower potential of a country can be conceived as the total quantity of water flowing in its streams times the vertical distance the water descends. This concept of total flow times head is the "theoretical hydroelectric potential." Within the theoretical limit is a second concept, the "technical potential," representing the total hydropower resources that can be developed with a given state of technology (and allowing for the losses in flow and head because they cannot be fully captured and utilized). And within this limit, in turn, there is a third conceptual limit, the "economic potential," or the total hydropower resources that can be developed with a given level of technology under given relative cost conditions.

It is immediately evident that this approach to hydropower resources is extraordinarily close to the approach to the fuel resources developed at Resources for the Future. The theoretical hydro potential corresponds to the resource base; the technical potential is the equivalent of resources defined in technological terms; the economic potential is the same as the reserves of a mineral fuel. One can thus discuss hydropower in the same context as the fuels despite its totally different nature as an energy source.

Let us now look at the hydropower resource estimate of the Federal Power Commission in this context. According to the Commission,

[1] See, for example, United Nations Economic Commission for Europe, Committee on Electric Power, "Hydroelectric Potential in Europe and Its Gross, Technical, and Economic Limits" (Geneva: United Nations, 1953).

the "hydroelectric power resources" of this country amount to 118,096,000 kilowatts, of which some 28 million kilowatts are developed and installed, the remaining 90 million kilowatts being undeveloped. Since the total includes sites that are not currently economic to develop, the estimate does not pertain to the "economic potential" or reserve level. On the other hand, it is not really at the "technical potential" level either, for it is not complete in its coverage of all sites that could be developed with current technology. The FPC's figure is merely the summation of all sites for which data are available, and specifically excludes small powersites of less than 2,500 kilowatts potential. In many respect, then, the FPC hydro figure is like the Geological Survey coal figure. It goes beyond the reserve level, but is not a complete resource figure because it does not have complete coverage even within its own definitional limits. And, as with coal, the authoritative hydropower estimate does not represent the ultimate resource total of the country. Hydropower resources are at least as much as the estimate, and certainly something more. Just how much more is, again, impossible to say.

In hydropower, as in coal, the absence of a reserve figure makes it difficult to relate future development to costs. Again the generalization that the higher the proportion of developed resources within total resources, the higher the marginal costs are likely to be, has been commonly applied. At the current level of just under 30 million kilowatts installed capacity, only one quarter of the FPC (understated) resource total has been developed. There is no a priori reason why development beyond the 25 percent (or lower) level should bring into play such sharply rising marginal costs that the pace of development is severely reduced. Yet the specter of much higher marginal costs has clearly been in the minds of those who have attempted to project future levels of installed capacity. A survey of all published estimates of installed hydro capacity in 1975 reveals an implied growth rate of 3.5 percent per annum from the base year of each estimate to 1975. Table 5 shows, in contrast, the rates of growth over selected periods from 1926 to 1961 (1961 capacity was obtained by adding to current capacity those additions expected to be on line by the end of 1961).

Table 5.—Average annual growth rates of hydropower capacity, selected periods, 1926–61

	Percent		Percent
1946–58	5.5	1926–58	4.5
1935–45	4.3	1958–61	8.0

It is clear from table 5 that the authors of the estimates of 1975 capacity expect a considerably slower growth rate in the future than has prevailed in the past, the implication being that the remaining underdeveloped hydro sites will be more costly per kilowatt to develop (perhaps even progressively so) than those previously developed. The extent to which growth subsequent to the time of the estimates has exceeded the expectations contained within the estimates is revealed by obtaining the implied growth rates in the estimates for the period 1961–75. For this period the average implied rate is 2 percent per annum.

In both instances, the general expectations appear to be a growth rate not only lower than any prevailing in the past three decades, but very much lower than the current rate. The clear inference is that the increasing cost of the remaining undeveloped resources should begin to make itself felt strongly in the coming decade or so. To what extent is this position warranted?

Again, it appears that indicated technological advances in power site development and utilization are not taken sufficiently into account. The costs for projects that may not be developed for a decade or more are estimated on the basis of current technology. Admittedly, the engineer is in no position to do anything else—he cannot allow himself the luxury of estimating costs under future, unknown conditions. But the fact that this is done is apparently overlooked by those appraising the future course of hydro development.

In the field of design and construction there is some authoritative opinion that cost savings can be realized through less reliance on the gravity dam (and the tendency to overdesign it), and bolder exploitation of the arch dam, as is being done abroad. Rapid development is already occurring in techniques of underground rock excavation that should reduce previous cost estimates on some projects. The recent French development of the "bulb," or immersed Kaplan turbine offers important possibilities in the very low head range.

The most important development, however, is the pumped-storage technique, employing the recently perfected reversible pump turbine. All evidence points to a rapid, widespread adoption of this technique, which increasing utility system and unit size makes ever more attractive. As larger and larger steam units are built, at higher cost per kilowatt of capacity, the need for obtaining a high plant factor becomes more urgent as a means of keeping down the cost per kilowatt-hour. It is desirable, in other words, to utilize such a plant as close to capacity as possible as continuously as possible. This is complicated, however, by daily and seasonal variations in demand that result in peaks appreciably higher than the average.

Pumped storage offers an especially attractive means of coping with this problem. Surplus, offpeak energy is fed to the pump, which raises water to a modest sized storage reservoir. During peak periods the pump is run as a turbine and the water is released from the reservoir. The stored energy, minus some losses, provides additional capacity to the system when it is needed, at lower cost than could be provided by conventional peak power sources. This advantage is especially significant for the large nuclear powerplant, where operation at close to 100 percent plant factor is essential if it is to be economic.

Pumped storage offers opportunities at a wide range of hydrosites because of its great flexibility. It is attractive in almost any size installation and at a host of locations where conventional hydro would be infeasible. Since all it needs is an arrangement of two reservoirs (which do not need to be large) between which to shuttle a given quantity of water, it can actually provide hydro capacity at sites where no natural bow exists. (This raises questions concerning the measurement of hydropower resources, but it is believed these can be dealt with satisfactorily.)

Still another area in which technological advance seems likely to contribute to the development of hydropower and to hold costs down is that of power transmission. Transmission of large blocks of power at extra high voltage—500,000 volts or more—is now clearly in the offing within the next 15 years. Extra high voltage transmission significantly extends the range over which electricity can be economically transmitted, and this together with the increased flexibility provided by extra high voltage interconnections, suggests that hydrosites should become economic that have heretofore been considered unpromising.

The foregoing leads to the conclusion that continued development of the remaining hydropower resources of this country should continue through 1975, at no appreciable increase in constant dollar costs. Present indications point to a range of 60 million to 70 million kilowatts of installed capacity by 1975. The implied growth rates in the lower figure are 4.1 percent per annum from 1958 to 1975, and 3.3 percent from 1961. The upper figure is meant to indicate the possibilities of pumped storage if this technique is exploited on a wide scale. The implied growth rates are 5.1 percent and 4.5 percent. It will be noted that according to table 5 this would constitute no great departure from past medium- and long-term growth rates, in contrast to the marked decline anticipated in other projections. None of this should be construed, however, as meaning that hydropower is destined to become more important in the total energy picture. Relative to overall energy consumption, hydropower will continue to be minor, allowing for significant regional differences.

CONCLUSIONS

The findings of this phase of our work on future energy supply can be summarized as follows: All conventional energy sources should continue to be available, at least through 1975, at no appreciably higher constant dollar cost. This is based on the finding that the natural stocks of these energy sources are higher than is generally estimated, and that the significance of technology as a dynamic element in cost determination has been underrated. Making allowance only for advances already underway, technology should be able to cope successfully with any deterioration of resource quality that may arise.

In juxtaposition with the preceding presentation by Mr. Schurr, this general conclusion means that the projected demand levels for 1975 for each of the energy sources *could* be met entirely from domestic sources at no significant increase in constant dollar cost. The italics are meant to emphasize that this is in no sense a prediction that we will be self-sufficient energywise. From the resource point of view, it appears possible. What will happen depends on political decisions and administrative decisions in both Government and industry that are not considered here.

A few words are in order on the implications of these findings for other energy sources. If the conclusions are correct, the burden of atomic energy growth falls entirely on that industry, at least in the medium-term future. If other energy costs do not rise, then atomic energy costs must close the present cost gap by coming down to conventional energy costs if this new power technique is to become an important element in the energy economy. Thus, atomic energy would appear to be limited to a minor role in the period through 1975.

Much the same can be said with respect to oil shale. Shale oil appears to be already marginal, at least as a gasoline source, and a shale oil industry should be in existence on a small scale before 1975.

The only area of potential significance for solar energy within total energy consumption in this period appears to be saline water conversion. Judgment on this must await the results of the current test program of the Department of the Interior on various desalinization methods. In other solar energy applications, even allowance for large-scale use does not result in significant effects on the overall energy pattern; either the application is severely restricted by climatic and other limitations, viz, solar house heating, or the quantity of energy involved in the specific application is very small, viz, the so-called solar battery.

Representative PATMAN. Since World War II, what have been the trends in relative prices of energy from the various sources reduced, let us say, to a common denominator, such as B.t.u. or horsepower, Mr. Schurr?

Mr. SCHURR. I have nothing in my statement on this subject, but our full study includes statistics bearing on the point. I should, therefore, like to insert the relevant statistics into the record as an appendix to my full statement.

(The material referred to appears at pp. 23, 24.)

Let me answer your question in a somewhat longer context, but taking into account the specific question you raised.

Over a long period of time, say the period from 1900 to the present time, if you consider the various energy sources, and if you deflate their prices by an index of wholesale prices so that you express them in what you might call constant dollar terms, you have an increase in bituminous coal of about 40 percent, an increase in anthracite of about 75 percent, a decline in oil of about 25 percent, and a decline in natural gas of about 50 percent. This refers to the long period between 1900 and 1955, and to the prices of these fuels at the point of production, as deflated by the index of wholesale prices.

These long-term changes in which you have bituminous coal and anthracite rising considerably and oil and natural gas declining—the greatest decline being for natural gas—are in sharp contrast to the period following World War II.

Between 1947 and 1955, again deflating price at point of production by the Wholesale Price Index, there has been a decline in bituminous coal of about 6 percent, and a decline of about 5 percent in anthracite, while crude oil has risen by about 25 percent and natural gas by about 50 percent. So you get a quite different picture, whether you are looking at the very long period or looking at the period since World War II.

I might mention, in passing, that it is interesting to observe that over the very long period the relative decline in the consumption of coal, both bituminous and anthracite, has been accompanied by a relative rise in the price of these fuels at the point of production, while the relative increase in the consumption of oil and natural gas has been accompanied by a relative decline in their prices. Although I didn't mention prices in my presentation, it is quite likely that the consumption trends which were described have been influenced by the fact that the prices over the long run have behaved in that way.

Representative PATMAN. Thank you, sir. Do you think that we may anticipate increases or decreases in the real cost per unit of energy in the areas with which you are familiar?

Mr. NETSCHERT. I would say in answer that it partly depends on the period which you are talking about. I can say that it is my firm conclusion that for the period 1975, with which I was dealing, that there should be no appreciable or significant increases in constant dollar costs of any of these energy sources. But what happens thereafter is much less certain because it depends on the technological side on developments that are totally unforeseeable at the present time; that is, the technology in the period following 1975 will be determined by things that we do not yet know about.

However, in the coming decade or so we can pretty well see what the general trend in level of technology will be because it will be determined by what is already in existence and by what is emerging. So I must make a distinction between periods.

Representative PATMAN. This next question is: What are the most promising opportunities for cost reduction in the field with which you are familiar?

Mr. NETSCHERT. Did you say what are the most promising?

Representative PATMAN. The most promising opportunities for cost reduction in the field with which you are familiar.

Mr. NETSCHERT. In the field of oil, improved recovery, I would say, is the most promising opportunity. It appears possible to raise the average recovery level drastically over the coming decades by new methods that are now emerging and into the pilot stage. When you have a current average recovery of one-third and you find that it is possible—in certain restricted cases, to be sure—to approach 100 percent recovery under the proper conditions, it gives you a very wide margin within which to work, technologically.

So this would be the area I would say for oil. For coal, I would say the main area is in the application of a continuous mining machine so as to obtain its full productivity possibilities. As yet, there is really no use of the machine under conditions which will take optimum advantage of the large gains in productivity that it can afford.

It has not yet been used, for example, on a large scale in mines that were opened up, developed, and laid out for its use.

Representative PATMAN. Mr. Schurr, since there has been such an increase in the cost of natural gas, I believe you said about 50 percent during the period discussed by you, do you anticipate similar comparable increases in the future?

Mr. SCHURR. Well, the increase in price at point of production that took place since the end of the war has largely been in response to the widening geographic area of use of natural gas, and reflects, to a considerable extent, the fact that for a long period of time this was a fuel which, in terms of its energy content, was actually undervalued compared to other fuels, largely because of the fact that it had limited distribution possibilities. By price in terms of energy content I mean the price of natural gas per million B.t.u.'s, compared with the price of other fuels on the same basis.

To a considerable extent, this undervaluation of natural gas in terms of its energy content has been overcome, and it seems to me that increasingly natural gas will run into serious problems of competition from other fuels, if, for example, the pattern of price change during the past 10 years or so were to be continued for very long into the future.

So I would say that my guess is that a limit will be set on price rises in natural gas by the competitive influence of alternative fuels.

Representative PATMAN. Thank you, sir.

Mr. Netschert, I think this is along the line of questions I want to ask you.

What, in your opinion, would you say are the factors limiting or deterring further development of cost reduction in the field with which you are familiar?

One thing that deters further cost reduction in oil and gas is the fact that it is more difficult to make new discoveries than it use to be. I have already said that I think this difficulty is being met and can be met—that we are holding the line and will continue to hold it. But to get a real cost reduction would require, I think, a dramatic breakthrough in discovery technology; whereas we should be able to hold the line against cost increases on this account through better integration and pursuit of existing techniques. We seem to be in the mature phase and approaching the end of a cycle in discovery technology, in the sense that the dramatic early results of geophysical techniques are no longer beeing duplicated. I do not mean by this that we can expect no more significant results from current techniques; on the contrary, as I point out in my prepared statement, there is still plenty of opportunity for significant discoveries by more thorough probing of known petroliferous areas and the thorough testing of possibilities in areas such as the Atlantic Coastal Plain.

Representative PATMAN. Mr. Schurr, what, if anything, needs to be done or can be done to strengthen the energy position of the United States?

Mr. SCHURR. Well, the position looks pretty strong to me. I would say that perhaps the outstanding conclusion that one comes to, after studying the American position historically, is that we have been unusually well off. The ability of the United States to undergo what amounts to two complete changes in its major energy sources in the space of 100 years, in the first place going from wood to coal and then later from coal to oil and gas is remarkable. These changes, in response to changing consumer wants and industrial needs, were accomplished with relative ease so far as strain on our resource base is concerned.

If this is contrasted with the situation in Western Europe and the United Kingdom, where there has not been anything like this kind of change, and where serious energy resource problems have nevertheless been encountered, one is impressed with the fact that the situation here, historically, has been very good.

The analysis that we have made of the remaining energy resource potential of this country persuades me that there is no reason to expect that the position is not going to be strong in the future. The resource analysis that Mr. Netschert was not able to cover in his oral presentation but which is summarized in his full statement is, I believe, quite persuasive in showing that the available resources of oil, natural gas, coal, and water power are quite adequate for the medium-term future as we see it. In addition, there are technological advances affecting new resources, oil shale for example, which we have in reserve to meet future problems.

I don't see, in short, a resource problem here for the medium-term future. There are other aspects of the question that one could get into, of course. The development of atomic energy, for example, is very often thought of not just in terms of the American energy position, but in terms of the contribution that the United States could make to the rest of the world, so far as new technology affecting energy is concerned.

Viewed from this broader standpoint, there is perhaps something that should be done. But not in terms of our domestic position; rather, in terms of considering what it is that the United States might want to give to the world in the way of leadership in an important, new technological field.

Representative PATMAN. You don't think any additional public policy is necessary along that line, and you think we are getting along all right?

Mr. SCHURR. Along which lines, sir?

Representative PATMAN. Along the lines of strengthening our fuel resources in the future. That is, are we doing so well that you don't think we need to adopt any additional public policies?

Mr. SCHURR. This is really outside the subject matter of what we have actually studied. I wouldn't be able to answer in terms of any special study we have given to the question. But it seems to me that in terms of the U.S. energy resource position as such, there are no special policy problems that present themselves. There are many problems from other standpoints.

Representative PATMAN. Mr. Moore?

Mr. MOORE. Would you comment on table 4 of your presentation, which shows a declining index number of energy consumption per unit of GNP and give us some idea of your explanation as to why that might have happened? Is it perhaps the rising importance of services in the GNP, or what would be your interpretation?

Mr. SCHURR. That is a very interesting matter, and I think it is both the earlier rise and the subsequent decline in the index of energy relative to GNP that are of interest.

We haven't got a complete or tidy explanation, but we do have a feel for some of the factors that seem to have been involved. The earlier period of rise in energy relative to GNP, running from 1880 to about 1900–1920, probably is explained in good measure by the fact that the country was industrializing at a rapid rate during that period of time, and that the composition of national output was probably changing in the direction of industries that were heavy consumers of mineral fuels per unit of output.

The subsequent decline reflects, I think, a slowing down in this trend toward the growing importance of heavy industry. I think you probably have an element of it in singling out the growth of services. But, in addition, there has been growth in other economic activities that aren't as intensive in their energy requirements as, let us say, heavy manufacturing industry is.

Another aspect of it, of course, is the increase in the thermal efficiency with which fuels are utilized. There has been a continuing improvement in this respect. I perhaps ought to make clear that what we are measuring is what you might call the raw B.t.u.'s; that is, the energy contained in the fuels. But with the passage of time, there are many instances in which the raw B.t.u.'s are applied with greater efficiency because of technological advances in extracting useful energy from fuels. An example is electric utilities where there has been (as indicated in my full statement) a substantial increase in the efficiency with which fuels are converted into electricity. Factors of this kind are bound to produce a decline in the input of raw energy relative to national output.

Still another factor which is involved is this. I believe that in other hearings before this committee you have had materials presented in which a similar trend of increasing efficiency following World War I in the output of the economy relative to the input of labor and capital has been pointed out. Those findings were based on studies made by the National Bureau of Economic Research. I think that the decline in energy input relative to GNP reflects, to a certain extent, the general improvements in economic efficiency which lie behind the productivity increases in labor and capital that have, in other hearings, been brought to the attention of this committee.

Those are some of the factors. They don't add up to a tidy package, and I have made things sound simpler than they really are, but it is elements of this kind which have been at work.

Mr. MOORE. I notice that in your tables on oil you referred to "natural gas liquids." Are they an important element in the statistics on oil?

Mr. SCHURR. Their quantitative importance in consumption is about 10 percent that of oil in 1955, which is the base year we have used for our projections. They are growing in importance as a percentage of the total. In our projections, their quantitative importance in consumption is about 15 percent that of oil in 1975.

Their growth has been substantial in recent years. They have been produced for a long time, but they have become quantitatively significant in the total only in the recent past.

Mr. MOORE. This is because of an improving technology?

Mr. SCHURR. That is right, for recovering and handling these materials.

Mr. MOORE. Apart from the propaganda aspects and our understandable desire to keep ahead in all sorts of technology, does not the fact that in this country we have relatively low-cost reserves of coal, oil, and gas lessen the pressure for early commercial utilization of atomic energy in this country as compared to other countries?

What I have in mind is: Is it possible that we might view with less concern the earlier installation of atomic commercial power in other countries because we are not as pressed as they are for cheap sources?

Mr. SCHURR. Well, I would say that viewing it entirely from the standpoint of America's own needs, we are certainly under no pressure to develop commercial atomic power. Certainly we don't have anything like the same pressures in that regard that Great Britain must feel, where the problem of coal supply has been difficult, and where any move away from coal means dependence on foreign sources of oil. We are not faced with that kind of a problem, as far as we can see from our analysis of the available information.

If one wants to view the atomic energy development problem wholly in that context, then the answer to your question, it seems to me, is pretty clear. We just don't face energy resource pressures. But we all know, of course, that the question of atomic energy development is viewed also in broader terms, which involve a range of quite different considerations.

Representative PATMAN. Thank you, gentlemen, very much for your appearance. I assume it will be all right if a member of the committee who is not here, after seeing the testimony and reading it, desires to ask a question, you will each be willing to answer it for the record when you correct your testimony.

Mr. SCHURR. Yes.

Mr. NETSCHERT. That is correct.

Representative PATMAN. A transcript will be furnished each of you.

Tomorrow we have first the "Electrical Energy From Fuel Sources—Present and Prospective," by Philip Sporn, president of American Electric Power Service Corp. Then "Electrical Energy From Hydropower Sources—Present and Prospective," by Francis L. Adams, Chief of the Bureau of Power, Federal Power Commission, and a third witness speaking on "Prospective Demand and Supply in the Natural Gas Industry," Carl T. Kallina, Chief, Bureau of Rates and Gas Certificates, Federal Power Commission.

Again, thank you, gentlemen.

Without objection, we will stand in recess until tomorrow morning at 10 o'clock, to meet here in this room.

(Whereupon, at 11:25 a.m. the subcommittee recessed, to reconvene at 10 a.m., Tuesday, October 13, 1959.)

ENERGY RESOURCES AND TECHNOLOGY

TUESDAY, OCTOBER 13, 1959

CONGRESS OF THE UNITED STATES,
SUBCOMMITTEE ON AUTOMATION AND ENERGY RESOURCES
OF THE JOINT ECONOMIC COMMITTEE,
Washington, D.C.

The subcommittee met at 10 a.m., pursuant to recess, in room P-63, the Capitol, Hon. Wright Patman (chairman of the subcommittee and vice chairman of the committee) presiding.

Present: Representative Patman.

Representative PATMAN. The committee will come to order.

We have as our witness this morning Mr. Philip Sporn, president of the American Electric Power Co. Mr. Sporn, we are glad to have you. You may proceed in your own way.

STATEMENT OF PHILIP SPORN, PRESIDENT, AMERICAN ELECTRIC POWER CO.

Mr. SPORN. Thank you, sir. I will present my prepared statement, but any time the Chair wishes to interrupt, I will be glad to stop and accommodate myself to the desire of the Chair.

Representative PATMAN. Thank you.

Mr. SPORN. I welcome the invitation of this committee to present the results of some of my work and study in the field of energy and electric energy.

I am an engineer by profession. I was chief engineer of my company from 1932 to 1945, executive vice president from 1945 to 1947, and have been president since 1947. In these capacities I have had responsibility for the engineering work of my company and have necessarily been engaged in the study of energy in general and, particularly, the conversion of fuel energy to electric energy.

In the last decade, our work on high-voltage transmission has resulted in our company's constructing the first 345,000-volt transmission line in this country, in 1953. More recently, in 1958, we completed construction of the first steam-electric generating unit in the world to operate at supercritical temperature and pressure. Also, for more than a dozen years now, I have been working intensively on various aspects of atomic energy, especially those that affect the power industry.

I have divided my testimony into three parts. In the first I have tried to give my views on the role of energy and of electric energy in the United States. The second part is a brief review of the recent history of the development of energy use in this country and a projection of energy use to 1975 and 2000.

In my final section, the effort has been to summarize the technological changes in the electric power industry and their effect on the cost and growth in use of electric energy for the past quarter century and to describe what appear to me to be likely areas for future development.

In addition to the condensed testimony which I prepared on these matters, I have also prepared a much longer paper covering the same ground in more detail to offer for the record.

Representative PATMAN. Your full statement will be received and printed in the record. You may proceed with your oral summarization.

Mr. SPORN. Thank you. I also want to point out that in the course of my presentation this morning, the abbreviated presentation, I shall refer to a series of tables and charts, of which there are some 18 tables and 10 charts and 1 figure in the detailed statement that I have presented. But I shall bring to the particular attention of the committee this morning only 2 of those 18 tables and only 2 of the 10 charts.

Representative PATMAN. They, too, will be inserted as part of your remarks.

Mr. SPORN. Thank you.

PART 1. THE BASIC ROLE OF ENERGY AND OF ELECTRIC ENERGY IN THE UNITED STATES

Although fuel and power play an important role in a modern industrial economy, they do not play the decisive part frequently assumed for them. In the generation of electric power, for example, the cost of fuel in the United States is neither the largest item of cost nor the determinant of the use of electric energy. In a modern powerplant, fuel cost represents at most only 55 percent of the total cost per kilowatt-hour on the plant bus bars (table I, see p. 61), and this high percentage occurs only in the unusual case of almost 100 percent plant factor, or 8,500 hours of operation per year, and a fuel cost of 40 cents per million B.t.u.; this is a fuel cost equivalent to almost $10.50 per ton of coal, which is close to the upper limits of the range of fuel costs in this country. At the more usual plant factor of 50 percent, or 4,380 hours of operation annually, and still with the expensive fuel of 40 cents per million B.t.u., fuel cost represents less than 40 percent of the total cost of power at the bus bar; this percentage diminishes sharply when transmission and distribution to the ultimate consumer are added. Capital costs, maintenance, and other expenses apart from fuel are major cost components even in electric energy at the bus bar.

When we look for the influence of fuel cost on use—that is, on the willingness and ability of consumers to buy electric power—it becomes difficult to discover any substantial effect, if we ignore for a moment that special group of industries which use power more or less as a raw material. By and large, there is little regional correlation between fuel cost per kilowatt-hour and kilowatt-hour sales per capita (table II, see p. 62). For example in the east north central region of the United States, fuel costs are twice as high and kilowatt-hour sales per capita almost one-third higher than in the west south central region of the country. In general, the use of electric energy is determined by complex economic and noneconomic factors, only one of which is the cost of electric energy and of the primary fuel for its generation. Much more important factors in determining the establishment and expansion of energy-consuming industries are markets, transportation costs, location of raw materials for processing, and so on. Rarely is it true to say that the cost of electric energy determines the character of an economy.

The conclusion is sometimes drawn that the availability of a low-cost, indigenous supply of energy results in a high income, but the cause-and-effect relationships are not so simple. High income results from the application to production of large quantities of capital equipment which require energy. Income and energy consumption—not production—are thus interrelated via the intermediary of capital and numerous economic and noneconomic forces which determine capital development. Although high per capita income is usually accompanied by high energy consumption, it is not necessarily accompanied by the production of large quantities of energy within the national boundaries (table III, see p. 63). Where other favorable factors are present, energy resources can be, and are, imported. This is clear when we realize that a large part of the world's fuel reserves is located in the less developed areas, while several of the most advanced industrial countries have little domestically available fuel resources.

Table III (see p. 63) illustrates the point I have been making. The table lists a representative group of countries, descending in order according to income per capita. Alongside the column showing income per capita are two others showing energy production and energy consumption per capita. In every case the high-income countries ($800 or more per capita) consume more fuel than they produce; in every case the low-income countries (with the exception of Brazil) produce more energy than they consume.

The same conditions obtain among the States of the United States. This can be readily observed by listing them in order of per capita income and then comparing the energy production of each with the others (table IV, see p. 64). With the exception of California and Illinois, which are in the top 10 States in both per capita income and energy production, the major fuel producing States rank low in per capita income, and the 2 States leading in per capita income produce almost no energy.

The pervasive use of electric energy characterizes modern industrial society—but again such power is only one among a multitude of factors important in attaining material wealth. This is shown by comparing the cost of electric energy with the value of product added for the 20 industry groups of U.S. manufacturers (table V, see p. 65); only a very few of these industry groups does expense for power exceed 4 percent of value added by manufacture. For all the groups taken together, the average is less than 2 percent. Only among the industries where electric energy tends to enter into production much as a raw material—such as in aluminum reduction—is the expense for power significant relative to the total value of product added (table VI, see p. 66).

An existing or potential supply of low-cost energy may catalyze other forces necessary to bring about industrialization and may encourage the use of energy-consuming capital equipment, but this is not an inevitable consequence. Among the numerous factors that determine the extent to which machinery, and thereby electric energy, will be applied to production, the availability of capital is crucial. The cost of energy-consuming equipment far exceeds the cost of the electric energy required for its operation and the capital cost of the energy-producing facilities. This relationship applies equally to an electric shaver with an annual consumption of 1 kilowatt hour and of a gaseous diffusion plant with an annual consumption of 17-billion kilowatt hour (table VII, see p. 66).

The same general pattern appears when we look at electric power utilization in the home and on the farm (tables VIII and IX, see pp. 67, 68). Even here the availability of capital is an important determinant. I do not mean to minimize the role which low-cost electric power has played in the rapid growth of residential consumption of electric energy; nor do I minimize the key part which electric power has played in taking the drudgery and isolation out of farming and bringing in their place all manner of conveniences formerly associated only with urban life. But I do want to show that cost of power is not the decisive factor. When a refrigerator, for example, costs $400 to $450 in capital outlay and the power to operate it only about $15 a year, it is clear that what primarily determines whether a family obtains the appliance and consumes the power necessary for its operation is the cost of the appliance and not the expense of the power to run it.

On the farm the rising consumption of electric energy—however important in making farm life attractive—does not account for the increased productivity which is the outstanding fact of recent agricultural history in the United States. This productivity increase is attributable primarily to the increase in the use of mobile farm machinery and tractors which consume liquid fuels. And in the case of the farm, as in that of the urban home, the expense for power is a small item as compared with the cost of the power-using appliances and equipment.

In sum, the role of energy and electric energy becomes significant only when a host of complex economic, social, and political forces have created the environment in which it is possible to harness inanimate energy resources.

PART 2: THE HISTORY OF DEVELOPMENT OF ENERGY USES IN THE UNITED STATES IN RECENT YEARS AND PROJECTIONS TO 1957 AND 2000

If we could view the development of electric energy generation by nuclear fissure as a major revolution in the energy field and possibly in the economy of the world, the United States included, then our concern with other sources of energy might be limited. But the fact is that nuclear energy is just another form of fuel. It may—and I think it will—come to have a very important part in our energy economy. The advantages we hope to realize in atomic power derive from the convenience and economy of highly concentrated fuel and, perhaps most important, its promise of continued abundance of energy.

But, in my opinion, it will require a long period of technological development to establish atomic power as an economically competitive source of energy. Its significance in our energy supply will, I believe, build up only gradually—a process which has been historically the case with our other energy resources.

In this connection it is worth while to observe the changing energy picture of the past century. Total energy use has constantly been on the increase, while relative positions of different sources of energy have all been subject to gradual shifting.

In 1850 the primary source of energy in the United States was fuel wood (tables X and XI, see p. 69). It was not long until 1890, 40 years later, that coal surpassed wood in the proportion of our total energy supply. It was not until 1950, nearly a hundred years after the first oil well was drilled, that petroleum equaled coal in the proportion of our total energy supply. In the case of gas it has taken 70 years or more for it to reach the point where it challenges coal's position. If we look at figures for the world during the period 1937–57 (excluding the United States), we find a similar transition taking place, also gradually, in favor of liquid fuel (table XII, see p. 70).

In the past two decades the United States has maintained its proportion of total world energy production at the fairly constant level of around 40 percent (table XIII, see p. 70).

Table XIV gives data on electric energy production alone for the United States since 1925 and also shows such production as a percentage of world production. For more than three decades the United States, with the exception of the period of the great depression of the 1930's, has maintained its proportion of the world's total supply at around 40 percent. These figures are remarkable when we consider the relatively low levels of energy consumption in the rest of the world and the rapid increase taking place in some parts of the world since the end of World War II.

The average compound rate of growth in electric energy consumption in the United States has been 7 percent a year (chart I, see p. 71). It is interesting that a trend line of 7.2 percent growth per year, or a doubling every 10 years, is a good representation of the growth of electric energy in the world as a whole and in a wide variety of countries ranging from the most highly industrialized to the least developed—from France, Switzerland, or Italy to Guatemala, Togoland, or the Belgian Congo (charts II and III, see pp. 73. 74).

This similarity in the rate of growth among these highly diverse economies traces back to my previous statements about the need for capital equipment to utilize the energy. The growth in production of electric energy is limited by the rate at which an economy can accumulate capital out of its national income over a long period of years. Although for relatively brief periods a particular economy can force extremely high rates of capital accumulation, over the longer run this rate is limited by growing demands in other sectors of the economy. I think, judging from the data available to us, that the U.S.S.R. will in the long run have the asme experience that we have had. In the U.S.S.R. production of electric energy doubled every 3 years between 1925 and 1938; Russia in 1925 started with an extremely low level of less than 3 billion kilowatt-hours, as compared with the 84 billion kilowatt-hours we were then producing. In the next interval for which we have data, 1950–58, this rate of growth dropped to only 12.5 percent, or about one-half the rate in the earlier period (chart IV, see p. 75); this rate is likely to fall further toward the 7 percent level and, eventually, even below that.

Interestingly, over the weekend I have had an opportunity to study a recent paper by the Soviet Minister for Electric Power Stations, Mr. Novikov. The projection that he makes for the 7-year period, 1959–65, shows a rate of growth of 10½ percent. You see, the percentage is continuing to go down.

With this background, I would like to turn now to a consideration of the energy requirements of this country in 1975 and those to be expected in the year 2000. I have selected these dates because we need to look as far ahead as we can in making decisions today; at the same time, if we stretch our projections too far, they will be so conjectural as to be meaningless. By attempting projections between now and the end of this century, we shall encompass a period within which the role of atomic power is likely to be established and important decisions with respect to other sources of energy will have to be made. The future with respect to supplying constantly increasing energy requirements is bright, but we will not come into that bright future unless we visualize the requirements and act wisely in respect to them.

I have no doubt there can be substantial differences of opinion about both my projections and their underlying assumptions. Of course, the year 2000 in particular is sufficiently far in the future for a great many unforeseen and unforeseeable eventualities to upset drastically any set of assumptions anyone might care to make. There can be differences in assumptions about technological change. It is possible to imagine changing technology about which we now know little or nothing. For example, it is possible to assume—although I am not prepared to make the assumption—that the gasoline-driven motorcar will be replaced by a battery-driven vehicle receiving its charge from nuclear-generated electricity. Changes of this kind could affect future prospects substantially.

Nevertheless, the projections which I have made represent my best judgment in the light of present technology and knowledge. I might add that my dates, 1975 and 2000, are meant to be representative of an approximate period of years rather than specific calendar years in which my projections are scheduled to fall. In these projections, to facilitate comparisons, I have converted all forms of energy to a common unit—tons of bituminous coal equivalent.

I have assumed for 1975 a population of 240 million, which is the average of the two highest Census Bureau projections for that year. I have then assumed a substantial slowdown in the rate of population growth so that by the year 2000 population will have grown an additional 60 to 300 million. I have projected the gross national product at a long-term growth rate of 3.5 percent to 1975, or 850 billion 1957 dollars by that year.

Again, I have assumed a slowing down in the rate of growth for the succeeding 25 years to an average of 2.25 percent per annum to a level of $1,500 billion by the year 2000. I would like to point out I have used that only as background. I have not used gross national product as the base for making projections. The Federal Reserve Board index of industrial production has been projected roughly proportional to the gross national product, so that index is projected at 245 in 1975 and 400 in 2000.

Table XVIII (see p. 79) affords a breakdown of my projections. I start with the projection of 2,000 billion kilowatt-hours as the country's electric requirements in 1975. Assuming an average efficiency of 9,000 B.t.u. per kilowatt hour, this represents a fuel requirement equivalent to 700 million tons of coal, compared with less than 300 million tons in 1957. Of this total 1975 generation, I have estimated that 150 billion kilowatt hours, or 7.5 percent, will be generated by nuclear power. If nuclear energy had no more place in our energy picture than to supply fuel for 7.5 percent of 1975 electric power, or 2 percent of the country's total energy needed in 1975, there would be little justification for the expensive atomic power program in which we are embarked. However, as the country's need for energy expands subsequent to 1975, atomic power should be able on an economic basis to assume much of the burden of providing fuel for electric generation that other sources of energy will then be unable to carry effectively.

For the year 2000 I have projected total generation of 6,000 billion kilowatt hours, or nearly 10 times the 1957 figure. Again I want to emphasize that these projections have been made not for precision but to examine on the basis of what appears to be a reasonable order of magnitude this longer run picture of our energy requirements.

Nearly 40 percent of this total electric energy in the year 2000, according to my projection, will still be generated by coal, a small amount by fuel oil and gas, a somewhat larger but still relatively small amount by hydroelectricity, and the largest percentage by nuclear energy.

I would like at this point to once again emphasize that I do not say today, and I don't believe anybody can say, that the large percentage shown in table XVIII to be carried by nuclear energy will actually take place by the year 2000.

But this, in my judgment, is a highly optimistic projection of a possible development of atomic energy. I do not know how probable it is going to be.

Compared with my estimate of 475 million tons of coal and 50 million tons of coal equivalent of nuclear power for 1975, for the year 2000 I estimate coal burned for electric power generation at 600 million tons, but nuclear power at the equivalent of more than 850 million tons.

Despite this optimistic projection of electric energy use and the assumption that nuclear power will account for over 75 percent of the increase in electric energy generation between 1975 and 2000, the part of our total energy requirements to be satisfied by nuclear energy, according to my estimates, is only slightly over 20 percent, that is, 850 million tons of coal equivalent out of a total requirement of 4 billion tons. This would still leave almost 80 percent of our total energy requirements to be supplied by conventional sources, and of this 80 percent approximately 20 percent will also go to generate electric power; the remaining 60 percent will be available for all other energy work.

It is clear, then, that our total energy requirements in the year 2000 and in the intervening period will necessarily require very large amounts of fossil fuel. I believe there is grave danger that so great an emphasis will be placed on atomic power development that will tend to forget the essentiality of fostering the continued development of an adequate supply of coal, oil, and gas for the long period during which atomic energy will only gradually assume an increasing part of total energy burden. If these projections have any validity—and they would have, even if we allow fairly wide latitude for error—they indicate that we must not forget the continuing importance of our fossil fuels and that we must make certain in our policy considerations that they will be capable of fulfilling their important role of providing the far larger share of our total energy needs that nuclear power, even under the most favorable conditions, will not be able to satisfy, at least for the remainder of this century.

PART 3. TECHNOLOGICAL DEVELOPMENTS IN ELECTRIC SUPPLY; THEIR EFFECT ON REDUCTION OF COST AND EXTENSION OF USE OF ELECTRICITY; FUTURE TECHNOLOGICAL DEVELOPMENTS

The utility industry has been characterized throughout its history by rapid growth and technological advances. Particularly has this been so in the last quarter-century, when rapidly growing use of electric energy and substantial technological advances have made possible a decline in the average price per kilowatt-hour in the face of major increases in many other prices.

Chart V (p. 80) shows how during the last quarter-century electric utility generation expanded by well over 700 percent, or at a rate almost 2½ times as fast as the increase in the real gross national product after eliminating changes in the price level. The expanding use of electric energy in every aspect of American life has contributed to, and in turn has been made possible by, the rising standards of living and the increased productivity this country has enjoyed in this period.

In 1934 the electric utility industry had only 24.7 million customers; by the end of 1958 the total had increased almost 2½ times, to over 56 million. While this was partly the result of an expanding population, it was in large measure attributable to the expansion in electric service to a larger portion of the population, so that well over 95 percent of the total residences in the United States, or all but the most remotely located, now have central-station electric service available, compared with only 65 percent in 1934. Contributing to this result was the substantial completion of the program of rural electrification. At the end of 1934 almost 744,000 farms, or slightly less than 11 percent of the total number of farms in the United States, were served by the utility industry. By 1958, however, the extent of rural service was almost equal to that found in urban areas, with almost 95 percent of the total farms receiving utility service.

The 20.4 million residential customers in 1934 used an average of only 629 kilowatt-hours per customer; in 1958, the more than 46 million residential customers consumed 3,385 kilowatt-hours per customer. In the same period, average price per kilowatt-hour had fallen from 5.33 to 2.52 cents, despite a more than doubling in the consumer price level (chart VI, see p. 81).

Similar growth took place in the commercial and industrial consumption of electric energy. Electricity used per production worker man-hour rose from 4.07 killowatt-hours in 1934 to more than 9 kilowatt-hours in 1958. (These data exclude energy used by the aluminum industry and the Atomic Energy Commission because the utilization there is so high it would cause a misleading distortion of the data, which is impressive enough even without aluminum and AEC loads.) The effect on the average use for ultimate consumer goes from somewhat under 3,000 kilowatt-hours per year in 1934 to over 10,200 kilowatt-hours per year in 1958. And the decline in average price (revenue) in the same period from almost 2.6 cents per kilowatt-hour to 1.7 cents (a reduction in cost of more than 33 percent), as shown in chart VII (see p. 82), is particularly noteworthy when compared with the change in indexes of consumer's price, wholesale price, and electric utility construction costs from 57 to 123, 48.7 to 120, and 54 to approximately 170, respectively (chart VIII, see p. 82). In the total, electric utility generation grew in these 25 years from a little over 87 billion to 641 billion kilowatt-hours, and the generating capacity of the industry expanded from 34 million to 140 million kilowatts (chart IX, see p. 83.)

This growth in the past quarter century has also involved a change in the character of a considerable part of the industry from relatively small, more or less isolated systems into large, integrated systems, many of these in turn being interconnected in larger pools, with the advantages of mass production and transmission of electric power at costs lower than could have been achieved by the smaller systems. This phase of the industry's development has been made possible in large part by a number of important technological achievements, and the large systems themselves have in turn made possible the incorporation of cost-saving technological developments which would otherwise not have been made. For example, the savings in construction cost per kilowatt of capacity by building larger units would not have been possible without the large systems able to absorb them, and the savings in fuel costs now being achieved through the use of larger, more efficient units and the transmission of large blocks of power from plants built close to a source of fuel and condensing water would not have been possible without the need for large quantities of power in single systems.

Important forward strides in technology have taken place in every phase of the industry's operations.

The expansion of electric utility capacity from 34 million kilowatts in 1934 to the present 140 million kilowatts was much more than a simple multiplication in kind. Units of recent installation can hardly be classified as of the same species as those of 25 years ago; the size of units, the steam pressures and temperatures, and the efficiencies were all almost undreamed of, even considered impossible, a quarter century ago.

The developments in steam generation are reflected in the comparisons of thermal efficiency which are shown in chart X (see p. 85). In 1934, the average heat rate of units installed was 16,500 B.t.u. per kilowatt-hour, and in 1958 the average was 9,900. The average for the industry in this same period declined over 38 percent, from 17,950 to 11,090, and for one whole system, the American Electric Power System, the average system heat rate in 1958 was reduced below 10,000 B.t.u. per kilowatt-hour. This was only 8 years after the Philip Sporn plant was the first to achieve an average plant heat rate that low.

Along with improvements in thermal efficiency, the great increase in unit size has been of major importance. The typical large turbogenerator in 1934 was 40,000 to 50,000 kilowatts—today we have 325,000-kilowatt units in operation and several much larger ones are now on order, including one of 600,000 kilowatts.

These larger sizes have resulted in construction cost savings and operating manpower savings which have helped to offset part of the higher construction and labor prices, thus holding down price per kilowatt-hour.

Enumeration of the phases of the business in which, as in steam generation, great progress has been made is impressive. There have been significant advances in the art of hydroelectric dam design and construction, advances in transformers in keeping with generation and dramatic progress in transmission at high voltage (American Electric Power System's new 345-kilovolt backbone transmission is illustrative). In the field of system control and protection an example is the successful ultra-high-speed reclosing of transmission lines by which a faulted line is opened at both ends simultaneously to clear the fault and reclosed for normal operations all in a fraction of a second so that the net effect in service is as if there never had been any interruption. The immense growth of systems and pools has required reliable communications at all times, a requirement that is being met most effectively by microwave communication which provides high-quality voice transmission and a large number of channels. Application of digital computers to power system planning problems, to certain operating problems, and to commercial and accounting phases of the utility industry has made rapid strides. In distribution, as in transmission, great progress has been made in the technology and in its application. The pervasive utilization of electric power in itself has suggested new concepts of utilization—the all-electric home for example.

In the paper which I am submitting for the record, all the foregoing matters are treated in detail. I would like to use my remaining time to consider what seem to me likely future developments in the technology of electric power service.

I have already stated my belief that fossil fuel steam generation will provide the fundamental base of the American power systems for some time to come and that nuclear power will not provide a substantial assist to coal in this regard for another 20 years. I have also expressed my belief that our fossil fuel technology must not and will not be neglected.

We can look for developments in new steam cycles, such as the combination steam-and-gas turbine cycle, and we can look for developments in higher temperatures and higher pressures of steam even beyond those of the most advanced supercritical temperature and pressure units in operation or under construction today. There are possibilities of further advances in efficiency by the exploitation of higher pressures, perhaps up to 15,000 pounds per square inch, but such higher pressures will have to be accompanied by higher temperatures, which in turn involve us in metallurgical difficulties.

I am confident that progress will be made in developing the materials that can be used at such pressures and temperatures, and the work now being done in the field of nuclear generation will probably contribute to this goal. I would also expect that units even larger than the 600,000-kilowatt size now projected are likely to be built. I have every confidence that over the next several decades nuclear generation will make substantial advances and achieve a competitive position with more conventional generation in many parts of the country. But the effort to make nuclear generation competitive with conventional fuels is confronted with a moving target of increasing efficiency in conventional generation.

There are other developments in energy generation in prospect that may be even more exciting than nuclear energy. Nuclear fission provides a new source of fuel, but it is essentially a substitution of one fuel for another in a generating process that remains substantially the same. Nuclear energy would continue the reign of the steam engine, which began with Watt almost 200 years ago.

In the last 12 months three avenues in energy conversion have developed that may change this—but I must quickly add that I am now looking at long-term prospects approaching the year 2000. There are developments in thermionic generation, in thermoelectric generation, and in the application of the magneto-hydrodynamic principle to the generation of electric energy. All three involve direct conversion of heat energy into electric energy, with prospects of greater thermal efficiencies and elimination of important moving parts as compared with conventional or nuclear-fuel power generation.

Perhaps the most promising is the last of these three, which involves the passing of a high-velocity gas through a strong magnetic field. To obtain a practical evaluation of the potentialities of this concept a 3-month study has recently been carried out jointly by American Electric Power Service Corp. and the Avco-Everett Research Laboratory. There is indication that such a process may achieve a heat rate as low as 6,200 B.t.u. per kilowatt-hour (or 25 percent better than the most efficient plants now projected) and an even greater potential with experience.

I have been speaking of the most preliminary kind of study, and a very great deal more work is required before this concept can be tested in any meaningful way. For this reason a small group of 10 private electric utilities, operating in the Middle West, have reached substantial agreement to sponsor the next phase of this research in a cooperative arrangement with the Avco-Everett Research Laboratory, and the new work is expected to commence soon. I should note that the magnetohydrodynamic generator principle is not confined to any particular kind of fuel; thus, an atomic reactor could be the source of the high-temperature gas.

Further advances can be expected in every other phase of the electric industry. In transmission it seems almost certain that the presently successful 345–360 kilovolt lines will be followed by voltages of 500,000–650,000 volts and higher. Work to this end is now going on. Similarly, in the field of distribution and electric energy utilization equipment I anticipate very substantial developments.

Throughout my testimony I have assumed constant increase in use of electric power leading to immense quantities for the year 1975, over threefold that of 1958 and for the year 2000, almost tenfold that of 1958. But these results cannot be expected to develop automatically in the natural course of events. A great deal of effort in research, development, and in utilization of new concepts and discoveries will be required on the part of many technicians, engineers, and technologists associated with the industry. Particularly in utilization, much remains to be done to develop further those devices which show promise of contributing importantly to our national productivity, welfare, and well-being.

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Although the industry in the past quarter century has made very substantial technological strides which have given the country perhaps the finest series of power systems for making available to its economy an abundant and highly economical supply of electric energy, many technological challenges loom up for the quarter century ahead and for the period beyond that.

Representative PATMAN. Thank you very much, sir. You have provided us with a very interesting statement. Your longer paper will be inserted at this point in the record along with all of your tables and charts.

(The material referred to follows:)

THE ROLE OF ENERGY AND OF ELECTRIC ENERGY IN THE UNITED STATES

PART 1: THE BASIC ROLE OF ENERGY AND OF ELECTRIC ENERGY IN THE UNITED STATES [1]

Part 1 of this testimony is primarily concerned with the role of energy in the United States. In the course of discussion, however, it will become necessary to make occasional comparisons with conditions in other economies.

Before we can visualize our energy resources picture it is important to measure the part which fuel and power play in an economic system. Although important, they do not play the decisive role frequently assumed for them. This part of my testimony will, therefore, concentrate on trying to identify the place where fuel and power do their work and will then try to measure their place in the process. Once that has been done it will become possible to evaluate better in the other parts of my testimony the prospective role of energy in this country's economic growth.

Since I am concerned primarily with the economic growth of electric power I start with the utilization of energy—that is, fuel—in the form of electric power. Generally, the cost of fuel in the United States is not the largest item in the cost of electric generation, nor the determinant of the use of electric energy.

Table I shows the total cost, including capital charges, of power at the generating site under various assumptions of fuel cost, which include approximately the full range of fuel costs in the United States, from the lowest to the highest. In a modern powerplant, fuel cost represents at most only 55 percent of the total cost per kilowatt-hour on the plant bus bars, and this high percentage occurs only in the unusual case of 8,500 hours of operation per year—almost 100 percent plant factor—and a fuel cost of 40 cents per million B.t.u.—in coal equivalents almost $10.50 per ton. At the more usual plant factor of 50 percent, or 4,380 hours' operation annually, and with the same expensive fuel of 40 cents per million B.t.u., fuel cost represents less than 40 percent of the total cost of power at the plant; this percentage diminishes sharply when transmission and distribution to the ultimate consumer are added.

[1] In preparation of this pt. 1 I have drawn on a paper I prepared for the First International Conference on the "Peaceful Use of the Atom," Geneva, 1955.

TABLE I.—*Electric power production costs in a modern powerplant* [1] *under various fuel cost assumptions and plant factors*

Hours in operation	Fuel cost per million B.t.u. (mills)				Other production cost (mills)	Capital charges per kilowatt-hour (mills)	Total cost per kilowatt-hour (mills)				Fuel cost as percent of total cost			
	40 cents	30 cents	20 cents	10 cents			40 cents	30 cents	20 cents	10 cents	40 cents	30 cents	20 cents	10 cents
8,500	3.4	2.55	1.7	0.85	0.4	2.39	6.19	5.34	4.49	3.64	55	48	38	23
7,500	3.4	2.55	1.7	.85	.4	2.71	6.51	5.66	4.81	3.96	52	45	35	21
6,000	3.4	2.55	1.7	.85	.5	3.38	7.28	6.43	5.58	4.73	47	40	30	18
5,000	3.4	2.55	1.7	.85	.5	4.06	7.96	7.11	6.26	5.41	43	36	27	16
4,380	3.4	2.55	1.7	.85	.6	4.63	8.63	7.78	6.93	6.08	39	33	25	14
3,500	3.4	2.55	1.7	.85	.7	5.80	9.90	9.05	8.20	7.35	34	28	21	12

[1] Assumed: Plant cost $140 per kilowatt, annual capital charges 14.5 percent or $20.30 per kilowatt, and heat rate 8,500 B.t.u. per kilowatt-hour.

Capital costs, maintenance, and other operating costs apart from fuel play a major part even in electric energy at the bus bar. In the cost of power, then, fuel is simply one element among a number of important items.

Now when we look for the influence of this fuel cost on use of power, on the willingness and ability of consumers to buy power, it is difficult to discover any substantial effect. Allow me to put to one side for the moment that special group of industries which use power more or less as a raw material. They are important and I shall deal with them presently, but the economic system is rare indeed—if it exists at all—where such industries make the difference between a high or a low standard of living.

Speaking generally, there is little regional correlation between fuel costs per kilowatt-hour and kilowatt-hour sales per capita. This is shown in table II. Thus, in the east north central region of the United States, fuel cost is only slightly below the national average, while sales of power per capita are considerably above the national average. In the West North Central States, with fuel cost slightly below the national average, sales per capita are considerably below the national average. In the west south central region, although fuel costs are less than one-half the national average, the per capita sales are also well below the national averge.

Viewed in another way, we might expect to find that the ratio of percent of kilowatt-hour sales to percent of population would decline as fuel costs rose. As appears in table II, this is not the case. Comparison of the percentage of population and the percentage of kilowatt-hour sales indicates little difference in the ratio of one to the other between the regions with the highest and the regions with the lowest fuel costs. Where wide variations appear, special circumstances account for them, such as Atomic Energy Commission loads in Tennessee and Kentucky and concentration of electrochemical or electrometallurgical industries.

TABLE II.—*Fuel cost for electric power generation and kilowatt-hour sales per capita by the total electric utility industry in the United States by region,*[1] *1957*

Region	Average total fuel cost per million B.t.u. (cents)	Kilowatt-hour sales per capita	Percent kilowatt-hour sales	Percent population	Ratio percent kilowatt-hour sales to percent population	Percent total kilowatt-hours generated by hydro[2]
United States	27.1	3,275	100.0	100.0	1.000	20.6
New England	43.1	2,227	3.9	5.8	.672	16.7
Middle Atlantic	33.1	2,744	16.0	19.1	.838	7.1
East north central	25.7	3,564	22.4	20.6	1.087	2.2
West north central	25.1	2,189	6.0	9.0	.667	14.9
South Atlantic	31.0	2,658	11.8	14.5	.814	15.0
East south central	19.6	[3] 6,684	14.2	7.0	2.029	24.5
West south central	12.7	2,682	7.8	9.5	.821	7.2
Mountain	22.4	3,566	4.1	3.7	1.108	56.8
Pacific	32.9	4,185	13.8	10.8	1.278	65.2

[1] Regions include the following States: New England: Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut; Middle Atlantic: New York, New Jersey, Pennsylvania; east north central: Ohio, Indiana, Illinois, Michigan, Wisconsin; west north central: Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, Kansas; south Atlantic: Delaware, Maryland, District of Columbia, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida; east south central: Kentucky, Tennessee, Alabama, Mississippi; west south central: Arkansas, Louisiana, Oklahoma, Texas; mountain: Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada; Pacific: Washington, Oregon, California.

[2] Data on hydroelectric generation indicate that, with the possible exception of the Pacific and mountain regions, the extent of availability of hydroelectric generation has had little effect on the relationships between fuel costs and kilowatt-hour sales per capita. In the Pacific and mountain regions hydro has undoubtedly affected kilowatt-hour per capita upward.

[3] Atomic Energy Commission accounts for over 46 percent of total kilowatt-hour sales in this region Kilowatt-hour sales per capita exclusive of AEC is 3,583.

The use of electric energy is determined by a complex of economic and noneconomic factors. Only one of these is cost of electric energy Except for the special industries using electric energy as a raw material, the cost of fuel for the generation of electric energy is a minor factor in determining the quantities of energy used. Much more important in determining the establishment and expansion of electric-energy-consuming industries are markets, labor supplies, transportation costs, location of raw materials for processing, and so on. Rarely is it true to say that the cost of electric energy determines the characteristic of an economy.

There is another measure of the true influence of the cost and availability of an indigenous supply of primary energy on economic well-being. The conclusion is sometimes drawn that the availability of energy results in high income, but the cause-and-effect relationships are not so simple. High income results from the application to production of large quantities of capital equipment which require energy. Income and energy consumption are thus interrelated via the intermediary of capital and the numerous economic and noneconomic forces which determine capital development and the use of capital facilities.

Table III shows that although high per capita income is accompanied by high energy consumption, it is not necessarily accompanied by the production of large quantities of energy within national boundaries. Where other favorable factors are present, energy resources can be, and are, imported. A large part of the world's fuel reserves is located in the less developed areas, which export the major part of their production to industrialized countries. The low levels of energy consumption in these countries is a result of absence of demand rather than of supply. This deficiency in turn results from other factors, political, social, and economic, which limit the particular society's ability to exploit its resources.

TABLE III.—*Per capita income and energy production and consumption in selected countries, 1956*

[Metric tons of coal equipment]

Country	Per capita income (U.S. dollar equivalent)	Energy production per capita (metric tons coal equivalent)	Energy consumption per capita (metric tons coal equivalent)
United States	2,078	8.28	8.58
Canada	1,493	5.77	8.25
Switzerland	1,195	1.75	3.18
New Zealand	1,135	1.97	2.81
Sweden	1,184	2.01	4.59
Australia	1,111	2.63	3.85
United Kingdom	904	4.42	5.03
Norway	881	4.19	5.66
Belgium	877	3.31	4.34
Denmark	823	.10	2.62
Venezuela	664	29.41	2.18
Mexico	220	.84	.75
Brazil	227	.18	.39
Iran	175	1.83	.12
Iraq	175	8.41	.48
Kuwait	80	359.27	1.54
Saudi Arabia	80	10.38	.18

Source: United Nations except in the case of income for Iran, Kuwait, Saudi Arabia; these estimated on the basis of United Nations estimate for 1952.

The same conditions with respect to the point just made obtain among the States of the United States. Table IV provides data on the rank of 48 States in per capita income, from the highest to the lowest, and energy production in each. (Lack of adequate current data explains the omission of Alaska and Hawaii from the list.)

TABLE IV.—*Rank of States (continental United States) per capita income payments to individuals and production of energy, 1957*

States	Per capita income (dollars)	Rank per capita income	Rank total energy production	Percent of total U.S. primary energy production	Total electric utility industry sales per capita (kilowatt-hours)
Continental United States	2,027			100.0	2,944
Connecticut	2,821	1	45	(1)	2,750
Delaware	2,740	2	48	0	2,705
New York	2,578	3	28	.2	2,500
California	2,523	4	5	6.5	3,071
New Jersey	2,504	5	46	(1)	2,523
Illinois	2,447	6	8	4.1	2,899
Nevada	2,423	7	36	.1	6,464
Massachusetts	2,335	8	43	(1)	2,049
Ohio	2,255	9	11	2.5	3,527
Maryland	2,156	10	32	.1	2,509
Michigan	2,141	11	26	.2	2,962
Washington	2,128	12	18	.8	7,870
Pennsylvania	2,112	13	4	7.3	3,207
Wyoming	2,038	14	12	1.9	2,722
Indiana	2,010	15	15	1.2	3,046
Colorado	1,996	16	14	1.3	2,112
Rhode Island	1,990	17	47	(1)	1,846
Missouri	1,940	18	27	.2	2,332
Wisconsin	1,920	19	38	(1)	2,688
Oregon	1,914	20	24	.4	6,075
Montana	1,896	21	20	.6	6,634
New Hampshire	1,862	22	39	(1)	2,360
Minnesota	1,850	23	41	(1)	2,095
Florida	1,836	24	44	(1)	2,592
Nebraska	1,818	25	25	.3	2,173
Iowa	1,806	26	31	.1	2,151
Texas	1,791	27	1	28.4	2,889
Kansas	1,787	28	9	3.3	2,534
Arizona	1,750	29	33	.1	3,657
Utah	1,694	30	22	.5	2,447
New Mexico	1,686	31	10	3.2	2,039
Vermont	1,665	32	42	(1)	1,891
Maine	1,663	33	35	.1	2,296
Virginia	1,660	34	13	1.9	2,339
Idaho	1,630	35	30	.1	6,691
Oklahoma	1,619	36	7	5.0	2,173
Louisiana	1,566	37	3	9.9	2,361
West Virginia	1,554	38	2	10.4	3,823
South Dakota	1,531	39	40	(1)	1,536
North Dakota	1,435	40	23	.4	1,494
Georgia	1,431	41	37	(1)	2,474
Tennessee	1,383	42	19	.8	5,189
Kentucky	1,372	43	6	5.2	2,800
Alabama	1,324	44	16	1.1	3,848
North Carolina	1,317	45	29	.1	2,420
South Carolina	1,180	46	34	.1	2,980
Arkansas	1,151	47	21	.6	2,825
Mississippi	958	48	17	1.0	1,744

1 Less than ½ of 1 percent.

Source: U.S. Department of Commerce, Office of Business Economics, U.S. Department of the Interior, Bureau of Mines, and Edison Electric Institute.

By ordering the States according to their rank in per capita income, the major fuel-producing States are listed toward the bottom of the table. Only California and Illinois are in the top 10 in both per capita income and energy production, and their rank in per capita income is not determined in any major degree by their energy production. The leading fuel-producing States rank low in per capita income, and they export their fuel to supply the energy requirements of the high-income States. Fuel costs favor those States which rank at the lower end of the per capita income scale. Connecticut and Delaware, the two leading States in per capita income, produce almost no energy.

Neither the absence of energy nor the presence of high-cost energy is a necessary cause of low income; nor are they a bar to high income. On the other hand, although the availability of abundant low-cost energy supplies may be a factor in promoting economic growth, such growth is not a necessary result. The availability of energy resources in their natural condition in the ground, or even the actual production of energy, is not enough. Energy consumption is the significant factor, and consumption need not be related to production in any particular area or region.

In a modern industrial society, electric energy use is pervasive. In an interindustry relationships study for 1947 by the U.S. Bureau of Labor Statistics, the country's economy was classified in 190 component industries; these included manufacturing, mining, agriculture, commerce, and services. All but 3 of these 190 industries consumed significant quantities of electric power; the only exceptions were cotton farming, oil bearing crops and fisheries, and hunting and trapping. Today more than 98 percent of the homes and farms in the United States are wired for electricity, and their consumption of electric energy in a great variety of common appliances is growing at a rapid rate. The pervasiveness of electric energy in the United States is a measure of the growing productivity of the economy of this country. It is also a measure of the increasing conveniences and aids for comfort and ease of living in the home.

But electric energy, as I have already emphasized, is only one among many factors important in the production of material wealth. Table V gives 1954 cost and electric energy consumption data for the 20 manufacturing groups as classified in the U.S. census of manufacturing. Table VI gives similar figures for a group of special industries within the larger manufacturing groups which are especially heavy users of electric energy.

Table V shows that electric energy costs are less than 2 percent—a minor percentage—of the total value added by all manufacturing. If we were to compare this cost with the value of products shipped, the figure would be reduced well below 1 percent. As appears from table VI, it is only in those industries where electric energy tends to enter into production much as a raw material that cost of power is significant.

TABLE V.—*Cost of purchased electric energy as percent of value added by manufacture in the United States, 1954*

Industry	Value added [1] by manufacture (thousands)	Cost of purchased electric energy (thousands)	Cost of purchased electric energy as percent of value added
All industries, total	$88,675,161	$1,725,350	1.95
Food and kindred products	11,827,942	168,645	1.43
Tobacco manufactures	732,961	3,498	.48
Textile mill products	4,243,034	114,758	2.70
Apparel and related products	5,165,547	23,538	.46
Lumber and products (excluding furniture)	2,444,171	41,505	1.70
Furniture and fixtures	1,855,683	18,830	1.01
Paper and allied products	2,134,501	91,452	4.28
Printing and publishing	6,392,914	36,150	.57
Chemicals and allied products	7,266,052	286,015	3.94
Petroleum and coal products	1,662,347	56,052	3.37
Rubber products	1,608,472	32,745	2.04
Leather and leather products	1,478,364	11,859	.80
Stone, clay and glass products	3,058,187	95,116	3.11
Primary metal industries	6,610,866	305,346	4.62
Fabricated metal products	7,538,590	86,214	1.14
Machinery (excluding electrical)	11,463,818	107,948	.94
Electrical machinery	6,686,440	63,259	.95
Transportation equipment	12,976,940	123,500	.95
Instruments and related products	1,558,209	11,404	.73
Miscellaneous manufactures	4,260,844	47,516	1.12

[1] Value added adjusted by ratio of purchased electric energy to total electric energy consumed.

Source: 1954 Census of Manufactures.

TABLE VI.—*Cost of purchased electric energy as percent of value added by manufacture for selected industries in the United States, 1954*

Industry	Value added [1] by manufacture (thousands)	Cost of purchased electric energy (thousands)	Cost of purchased electric energy as percent of value added
Pulp, paper, paper board	$987,600	$70,339	7.12
Industrial inorganic chemicals	1,167,076	176,301	15.10
Alkalies and chlorine	135,163	18,112	13.40
Cement, hydraulic	334,377	30,934	9.25
Electrometallurgical products (steel)	72,233	15,503	21.46
Primary nonferrous metals	401,453	65,478	16.31
Copper	105,925	3,347	3.16
Lead	17,389	877	5.04
Zinc	67,272	8,164	12.14
Aluminum	169,841	46,719	27.51
Other nonferrous	75,117	6,371	8.48

[1] Value added adjusted by ratio of purchased electric energy to total electric energy consumed.

Source: 1954 Census of Manufactures.

Energy is essential to operate the capital equipment which, when applied to production processes, increases productivity. The need for energy results from the marshaling and use of capital equipment in production. The availability of capital, therefore, in the form of tools, machinery, and equipment, is a fundamental requirement to raising productivity and to increasing the consumption of energy. An existing or potential supply of low-cost energy may encourage the use of energy-consuming capital equipment. It may catalyze other forces necessary to bring about industrialization, but this is not an inevitable consequence. A flourishing industrial society requires many highly developed human and material resources, of which energy is only one.

The only flat statement that can be made is that energy, particularly electric energy, is critically important if absent. But I think I have shown that, if other factors are favorable, energy can be made available with relative ease—at least under present conditions in the world's resources.

Among the numerous factors that determine the extent to which machinery will be applied to production, availability of capital is crucial. Table VII shows that the cost of energy-consuming equipment far exceeds the cost of electric energy required for operation and the capital cost of the electric-energy-producing facilities. This is true equally of an electric shaver that has an annual power consumption of 1 kilowatt-hour and of a gaseous diffusion plant having an annual consumption in excess of 17 billion kilowatt-hours.

TABLE VII.—*Cost of electric power consuming equipment, kilowatt-hour consumption and cost, and cost of electric power facilities in the United States*

Equipment	Cost of equipment (dollars)	Estimated annual electric power consumption (kilowatt-hours)	Estimated annual electric power cost (dollars)	Estimated electric power facilities (dollars)
Electric shaver	25–30	1	0.028	0.125
Refrigerator	400–450	600	15.18	75
200-ton gantry crane	375,000	40,000	400	1,800
100-ton overhead crane (steel mill)	263,000	20,000	200	900
Turret lathe, 12-inch	32,000	30,000	450	1,500
Plant and equipment per ton of annual pig aluminum including alumina facilities	1,000	16,500	72	360
Gaseous diffusion plant	745,000,000	17,040,000,000	68,739,000	377,000,000

Source: Various manufacturers, and U.S. Atomic Energy Commission.

When we observe utilization of electric power in the home and on the farm the same general pattern appears. Residential consumption of electricity in the United States has risen dramatically in the past quarter century. The increase is shown in table VIII. Average consumption has gone up by a factor of over six. Meanwhile in this interval, average residential cost of electric energy has been more than cut in half. Reduction in cost combined with the advantages of electricity over alternatives have certainly contributed to increased utilization. But I think a much more signifiicant factor in the increased utilization is the rise in income. As table VIII shows, disposable income per capita over this period has increased threefold. The rise in income is largely the result of growth in productivity, which in turn has resulted from the application of increasing amounts of capital per worker in production.

TABLE VIII.—*Residential kilowatt-hour consumption, cost per kilowatt-hour; average fuel cost per kilowatt-hour, consumers price index; and per capita disposable income in the United States, 1930–58*

Year	Average residential kilowatt-hour consumption	Residential cost of electric energy (cents)	Average fuel cost per kilowatt-hour (cents)	Consumers price index 1947–49=100	Disposable personal income per capita (dollars)
1930	547	6.03	(1)	71.4	604
1931	583	5.78	(1)	65.0	514
1932	601	5.60	0.24	58.4	389
1933	600	5.52	(1)	55.3	364
1934	629	5.33	(1)	57.2	411
1935	677	5.01	(1)	58.7	458
1936	735	4.67	(1)	59.3	517
1937	805	4.30	.23	61.4	551
1938	853	4.14	.22	60.3	505
1939	897	4.00	.21	59.4	538
1940	952	3.84	.23	59.9	576
1941	986	3.73	.23	62.9	697
1942	1,022	3.67	.25	69.7	871
1943	1,070	3.60	.27	74.0	977
1944	1,151	3.51	.28	75.2	1,060
1945	1,229	3.41	.29	76.9	1,075
1946	1,329	3.22	.32	83.4	1,126
1947	1,438	3.09	.37	95.5	1,173
1948	1,563	3.01	.42	102.8	1,279
1949	1,684	2.95	.38	101.8	1,261
1950	1,830	2.88	.35	102.8	1,359
1951	2,004	2.81	.34	111.0	1,465
1952	2,169	2.77	.33	113.5	1,509
1953	2,346	2.74	.33	114.4	1,567
1954	2,549	2.69	.30	114.8	1,588
1955	2,751	2.64	.28	114.5	1,661
1956	2,969	2.60	.29	116.2	1,727
1957	3,174	2.56	.31	120.2	1,782
1958	3,366	2.57	(1)	123.5	1,818

1 Data unavailable.

Sources: Edison Electric Institute, Department of Commerce, and Bureau of Labor Statistics.

It is the growth and wide distribution of disposable income that has made it possible for the consumer to purchase the great number of electric appliances which are now available to him in the United States and which account for his large use of power in the home. Because even in the home the availability of capital or income from which capital can be accumulated is an important determinant. I do not mean to minimize the role which low-cost electric power has played in the rapid growth of residential consumption of electric energy, but I do want to show that that role has not been decisive. When a refrigerator, for example, costs $400 to $450 in capital outlay and the power to operate it only about $15 a year, it should be apparent that what primarily determines whether a family obtains the appliance and consumes the power necessary for its operation is the cost of the appliance and not the cost of the power to run it. If the power cost $25 a year, as it would 25 years ago, that amount would still be small in comparison to the cost of the refrigerator.

On the farm the situation is somewhat different from the urban home. Electricity has made farm life attractive where formerly it was drudgery. It has meant that the farmer can have light, electric pumps to bring him water, and all manner of conveniences formerly associated only with urban life. The effect of electric power is incalculable in raising the level of comfort and in ending the isolation of farm life. But however important electric power is in this respect, it is not of major significance in accounting for the increased productivity which is the outstanding fact of recent agricultural history in the United States (table IX). Electric energy consumed on the farms of the United States and the electric energy consumption per capita on farms have increased more than twelvefold and seventeenfold, respectively, in the past quarter century (table IX). In this period many uses of electricity have developed on the farm, leading to greater or more efficient production of food and livestock. But the principal contribution to the increased productivity is from other sources. The fact that farm productivity has increased sharply, while farm population has been declining, is due primarily to the increase in the use of mobile farm machinery and tractors, which consume liquid fuels. Electric energy used per capita on the farm is only moderately above that of the average residential user in the United States. Thus, while the availability of electric energy and electric-energy-consuming devices on the farm has made possible the rise in living comforts and in the availability of information and entertainment to the previously isolated farm areas comparable to urban levels, the major source of agricultural wealth must be sought in other causes.

TABLE IX.—*Population, productivity, machinery, and electric power consumption on farms in the United States, 1930–56*

Year	Farm population	Farm output per man-hour [1] (1947–49=100)	Value of machines	Tractors on farms	Electric energy consumed on farms	Farm electric energy consumption per capita	Nonfarm electric consumption per capita
	Thousands		*Millions*	*Thousands*	*Million kilowatt-hours*	*Kilowatt-hours*	*Kilowatt-hours*
1930	30,529	54	$3,302	920	1,789	59	116
1931	30,845	----------	----------	997	1,878	61	122
1932	31,388	----------	----------	1,022	1,579	50	123
1933	32,393	----------	----------	1,019	1,633	50	122
1934	32,305	----------	----------	1,016	1,857	58	130
1935	32,161	59	2,153	1,048	1,693	53	142
1936	31,737	----------	----------	1,125	2,138	67	156
1937	31,266	----------	----------	1,230	2,389	76	174
1938	30,980	----------	----------	1,370	2,528	82	186
1939	30,840	----------	----------	1,445	3,320	108	196
1940	30,547	70	3,060	1,545	3,355	110	216
1941	30,273	----------	----------	1,675	3,614	119	232
1942	29,234	----------	----------	1,885	4,285	147	244
1943	26,681	----------	----------	2,100	4,819	181	249
1944	25,495	----------	----------	2,215	5,135	201	275
1945	25,295	86	6,291	2,354	5,908	234	279
1946	26,483	91	----------	2,560	7,278	275	315
1947	27,124	92	----------	2,735	8,974	331	350
1948	25,903	104	----------	2,980	11,393	440	382
1949	25,954	104	----------	3,315	13,841	533	421
1950	25,058	112	11,216	3,615	12,309	491	492
1951	24,160	113	----------	3,940	15,978	661	534
1952	24,283	120	----------	4,170	17,479	720	586
1953	22,679	123	11,383	4,100	19,468	858	637
1954	21,890	127	15,919	4,243	20,836	952	696
1955	22,158	132	15,981	4,345	20,828	940	772
1956	21,537	136	16,528	4,515	22,068	1,025	837

[1] Index of farm output (production available for human use) divided by index of man-hour requirements.

Source: Statistical Abstract of the United States, Department of Commerce, and Edison Electric Institute.

To sum up then, the role of energy and electric energy becomes significant only when a host of complex economic, social, and political forces have created the environment in which it is possible to harness inanimate energy resources.

PART 2: THE HISTORY OF DEVELOPMENT OF ENERGY USE IN THE UNITED STATES IN RECENT YEARS AND PROJECTIONS TO 1975 AND 2000

If we could view the development of electric energy generation by nuclear fission as a major revolution in the energy field and possibly in the economy of the world, including the United States, we might disregard other sources of energy in our concern about future requirements. But nuclear energy is in fact just another form of fuel. As such, it offers a potentially attractive alternative source of energy to supplement the world supply of falling water and the fossil fuels—coal, oil, and gas. Its attractiveness lies in its high degree of concentration, making for cheaper transport; it is potentially more abundant than all the other fuel resources, and it may some day be cheaper than the other sources. Its great importance in energy supply, however, is going to develop as a slow and gradual affair. Such gradualness has also characterized other displacements of energy sources that have occurred in the history of the United States and other technologically advanced energy-using countries.

It is illuminating in this connection to observe developments of the last century. In 1850 in the United States, bituminous and anthracite coal occupied a relatively minor position in an already heavy energy-using country. Although coal was known and in use prior to the Revolutionary War, approximately 90 percent of the total sources of energy, except that supplied by human or animal power, was still supplied by wood. The period of the Civil War and immediately following was primarily a fuel wood energy economy.

With the years, wood gradually lost its position, as appears in table X showing the consumption of energy in the United States by sources, all expressed in millions of tons of coal equivalent.

TABLE X.—*U.S. energy consumption by source*

[Million tons coal equivalent]

Year	Bituminous coal	Anthracite coal	Total coal	Crude petroleum	Natural gas	Hydroelectricity	Fuel wood	Total
1850	4.2	4.2	8.4	----------	----------	----------	81.6	90.0
1860	9.3	10.5	19.8	----------	----------	----------	100.8	120.6
1870	20.8	19.2	40.0	0.9	----------	----------	110.4	151.3
1880	51.0	27.4	78.4	5.8	0.3	----------	108.8	193.3
1890	110.8	44.2	155.0	10.1	10.3	0.4	96.0	271.8
1900	207.4	53.8	261.3	14.0	9.7	9.5	76.9	371.4
1910	407.3	78.6	485.9	45.6	20.9	20.6	67.4	640.4
1920	508.6	83.2	591.8	100.5	33.2	29.6	61.5	816.6
1930	455.0	65.6	520.6	215.7	84.4	30.0	55.6	906.3
1940	430.9	47.5	478.4	285.8	113.3	35.0	55.6	968.1
1945	559.6	50.0	609.6	367.1	170.4	56.7	45.9	1,249.7
1947	545.9	46.7	592.6	412.3	193.9	55.7	[1] 41.0	1,295.5
1950	454.2	38.7	492.9	485.0	264.6	61.1	37.0	1,340.6
1957	413.7	20.2	433.9	661.4	445.0	59.8	[1] 27.0	1,627.1

[1] Estimate.

Source: "America's Needs and Resources," Dewhurst and Associates, Bureau of Mines.

Coal appeared on the scene in significant amounts along about 1870 and began to pick up the burden of energy supply gradually until by the year 1910—40 years later—it was carrying over 75 percent of the energy burden of the country (table XI). From then on coal itself began to lose its relative position, and petroleum and natural gas began to account for an increasing share of the total energy supply—more than two-thirds by the year 1957.

TABLE XI.—*U.S. energy consumption by source*

[Percent [1]]

Year	Bituminous coal	Anthracite coal	Total coal	Crude petroleum	Natural gas	Hydro electricity	Fuel wood
1850	4.7	4.7	9.4	----------	----------	----------	90.6
1860	7.7	8.7	16.4	----------	----------	----------	83.6
1870	13.7	12.7	26.4	0.6	----------	----------	73.0
1880	26.4	14.2	40.6	3.0	0.2	----------	56.2
1890	40.8	16.3	57.1	3.7	3.8	0.1	35.3
1900	55.8	14.5	70.3	3.8	2.6	2.6	20.7
1910	63.6	12.3	75.9	7.1	3.3	3.2	10.5
1920	62.3	10.2	72.5	12.3	4.1	3.6	7.5
1930	50.2	7.2	57.4	23.8	9.3	3.3	6.1
1940	44.5	4.9	49.4	29.5	11.7	3.6	5.7
1945	44.8	4.0	48.8	29.4	13.6	4.5	3.7
1947	42.1	3.6	45.7	31.8	15.0	4.3	3.2
1950	33.8	2.9	36.7	36.2	19.7	4.6	2.8
1957	25.4	1.2	26.6	40.6	27.3	3.7	1.7

[1] May not add to 100 percent because of rounding.

Two other points are worth noting from tables X and XI: the rapid upsurge in the position of natural gas since World War II, and the relatively small position that hydroenergy occupied in our energy economy even at the point when it had its peak effect, along about 1945, namely 4.5 percent.

Finally, it is important to observe that with an expansion in energy use, in a little over a century, from 90 million tons of coal equivalent a year to over 1,600 million—an expansion of close to 1,700 percent—energy was always available, although in different forms, and the changes were evolutionary rather than revolutionary, with adequate energy always available to meet requirements. The jump in natural gas use after World War II and a similar jump in use of petroleum after World War I were each preceded by decades of development.

Table XII is interesting, showing the change that occurred worldwide (exclusive of the United States) in the sources of energy from 1937 to 1957. With an increase in these two decades of more than 100 percent in energy use, coal and lignite dropped from a position of close to 80 percent to something slightly under 57 percent; petroleum increased from a position of slightly over 12 percent to a position of almost 30 percent; natural gas from a position below 1 percent to more than 3 percent. Hydroelectricity for the world as a whole increased from a position of a little under 8 percent to almost 11 percent. Thus hydro has played a greater role in the world energy picture than it plays in the energy picture of the United States. This is understandable because of the unusually rich hydroresources that exist in other parts of the world and the relatively lesser fossil fuel resources, whether gas, oil, or coal, that exist in these same parts of the world.

TABLE XII.—*Total world*[1] *energy production excluding the United States by source for selected years*

[Thousand metric tons of coal equivalent]

Year	Coal and lignite		Crude petroleum		Natural gas		Hydroelectricity		Total energy, Amount
	Amount	Percent of total	Amount	Percent of total	Amount	Percent of total	Amount	Percent of total	
1937	897,826	79.37	138,625	12.26	7,689	0.68	87,001	7.69	1,131,141
1950	1,014,229	66.12	333,050	21.71	25,023	1.63	161,641	10.54	1,153,943
1955	1,233,750	59.02	568,173	27.18	49,599	2.37	238,885	11.43	2,090,407
1956	1,285,328	58.16	631,933	28.60	58,379	2.64	234,245	10.60	2,209,885
1957	1,332,475	56.81	689,871	29.41	73,089	3.12	249,961	10.66	2,345,396

[1] Excludes mainland China.

Source: United Nations.

Table XIII shows the total energy production for the world and for the United States during the past two decades. Despite the impressive industrial awakening that occurred in those two decades all over the world, and the growing use of energy in many parts of the world at a rate greater than in the United States, on the whole the United States has maintained its position in production vis-a-vis the rest of the world. (In the case of the United States, production is essentially utilization.) Thus the U.S. figure of 41.45 percent of the total energy production in 1937 climbed above 43 percent by 1950 and stayed at an average of 38 percent in the years 1956 and 1957.

TABLE XIII.—*Total world*[1] *and U.S. energy production for selected years*

[Thousand metric tons of coal equivalent]

Year	World	United States	United States as percent of world total
1937	1,932,079	800,938	41.45
1950	2,694,202	1,160,259	43.07
1955	3,394,194	1,303,787	38.41
1956	3,601,808	1,391,923	38.65
1957	3,755,671	1,410,275	37.55

[1] Excludes mainland China.

Source: United Nations.

Table XIV shows similar trends for electric energy. Over a period of more than 30 years the United States has maintained its position of producing, on the average, 40 percent of the world's electric energy. Considering the fact that its population during most of this time has been of the order of 5 percent of the world's, this is a unique record. It attests, I believe, to the vitality of the electric energy utilization and electric energy production technologies. Electric utilization technology is important since it is sometimes overlooked that electric energy cannot be produced and stored; electric energy can only be developed and used if the utilization equipment and technology for its use have first come into being.

TABLE XIV.—*Total world and U.S. electric energy production, 1925–58*

[Million kilowatt-hours]

Year	World	United States	United States as percent of world	Year	World	United States	United States as percent of world
1925	180,000	84,666	47.04	1942	585,000	233,146	39.85
1926	208,000	94,222	45.30	1943	620,000	267,540	43.15
1927	230,000	101,390	44.08	1944	660,000	279,525	42.35
1928	265,000	108,069	40.78	1945	580,000	271,255	46.77
1929	305,000	116,747	38.28	1946	620,000	269,609	43.49
1930	310,000	114,637	36.98	1947	700,000	307,400	43.91
1931	300,000	109,373	36.46	1948	797,000	336,808	42.26
1932	280,000	99,359	35.49	1949	810,000	345,066	42.60
1933	310,000	102,655	33.11	1950	965,000	388,674	40.28
1934	330,000	110,404	33.46	1951	1,065,300	433,358	40.68
1935	375,000	118,935	31.72	1952	1,151,300	463,055	40.22
1936	380,000	136,006	35.79	1953	1,257,500	514,169	40.89
1937	445,800	146,476	32.86	1954	1,360,400	544,645	40.04
1938	459,000	141,955	30.93	1955	1,535,600	629,010	40.96
1939	460,000	161,308	35.07	1956	1,677,900	684,804	40.81
1940	505,000	179,907	35.63	1957	1,781,300	716,356	40.22
1941	550,000	208,306	37.87	1958	1,871,131	724,013	38.69

Source: United Nations, Federal Power Commission, and Edison Electric Institute.

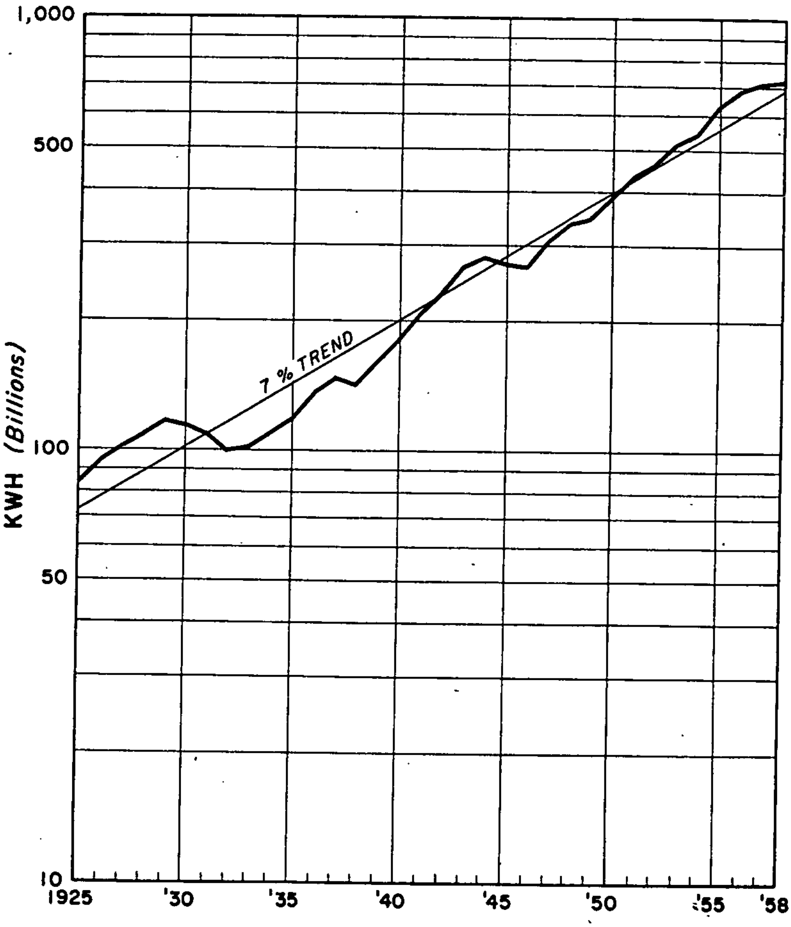
I make this observation because recently in a comparison of labor productivity in the U.S.S.R. and the chief capitalistic countries the statement is made that "the chief reason for the Soviet lag in labor productivity behind America is the lower power consumption per worker and consequently the lower technical equipment per worker." (See A. Kats, in the Socialist Labor Monthly of the U.S.S.R., Council of Ministers' Committee on Problems of Labor and Wages, issue 1, January 1959, pp. 42–55.) I believe, contrary to Mr. Kats, that the reason for the lag is the lower technical equipment per worker and the consequent lower electric energy use per worker. This is a fundamental difference: the technical equipment must be available in order to use the electric energy. Of course, the electric energy must also be available when the technical equipment is ready to receive energy. But the relative costs of equipment versus energy are so much greater for the equipment, as I pointed out in part 1, that it is important to underscore this point.

Another important factor in the history of the growth, production, and utilization of electric energy in the United States is shown in chart I. Here electric energy production over the 33-year period 1925–58 is plotted on semilogarithmic paper. The average compound rate of growth in the United States, charted in the graph, has been at the rate of 7 percent.

CHART I

GROWTH IN PRODUCTION OF ELECTRIC ENERGY IN THE UNITED STATES

1925 – 1958

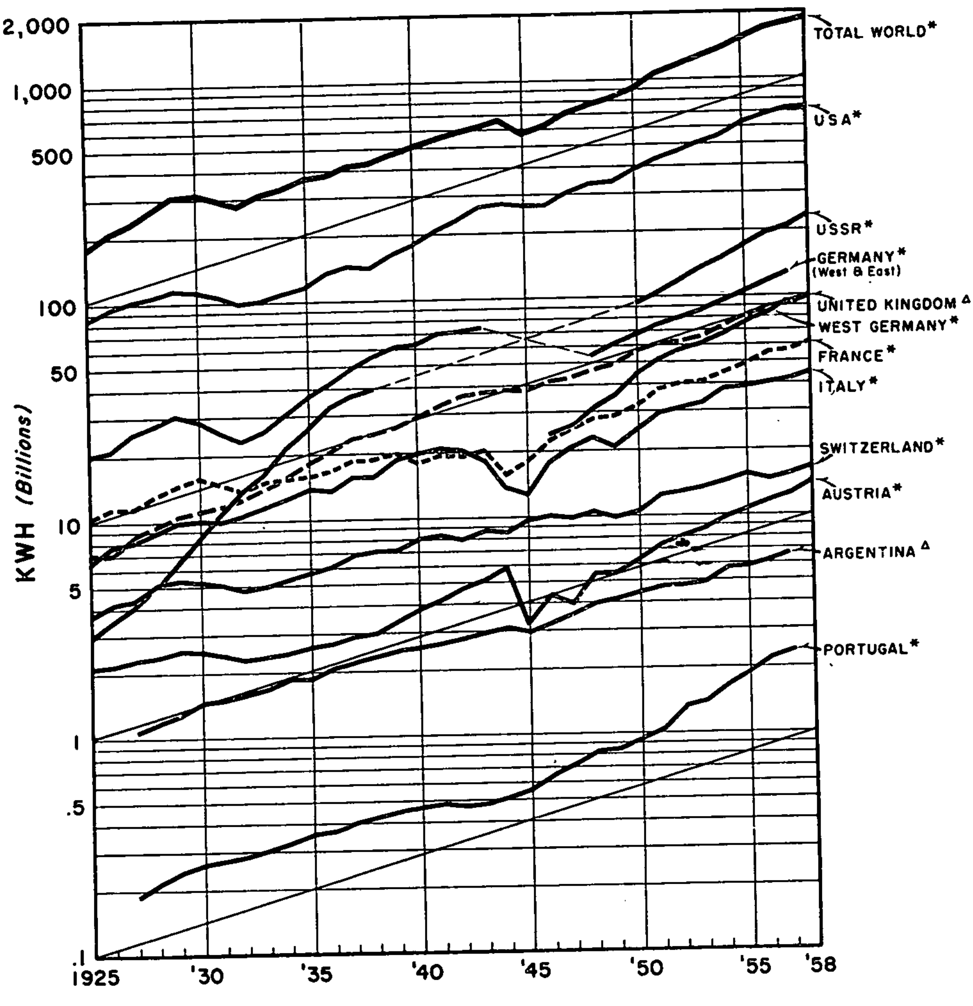


Charts II and III show growth in production of electric energy in various countries of the world, over the period 1925–58 in the case of chart II and 1932–58 in chart III. On each of these two charts a set of parallel trend lines has been drawn, all of them representing an average rate of doubling every 10 years (7.2 percent compound).

CHART II

GROWTH IN PRODUCTION OF ELECTRIC ENERGY IN VARIOUS COUNTRIES & THE WORLD

1925 - 1958



* Total Production Including Industrial

Δ Production Primarily for Public Use

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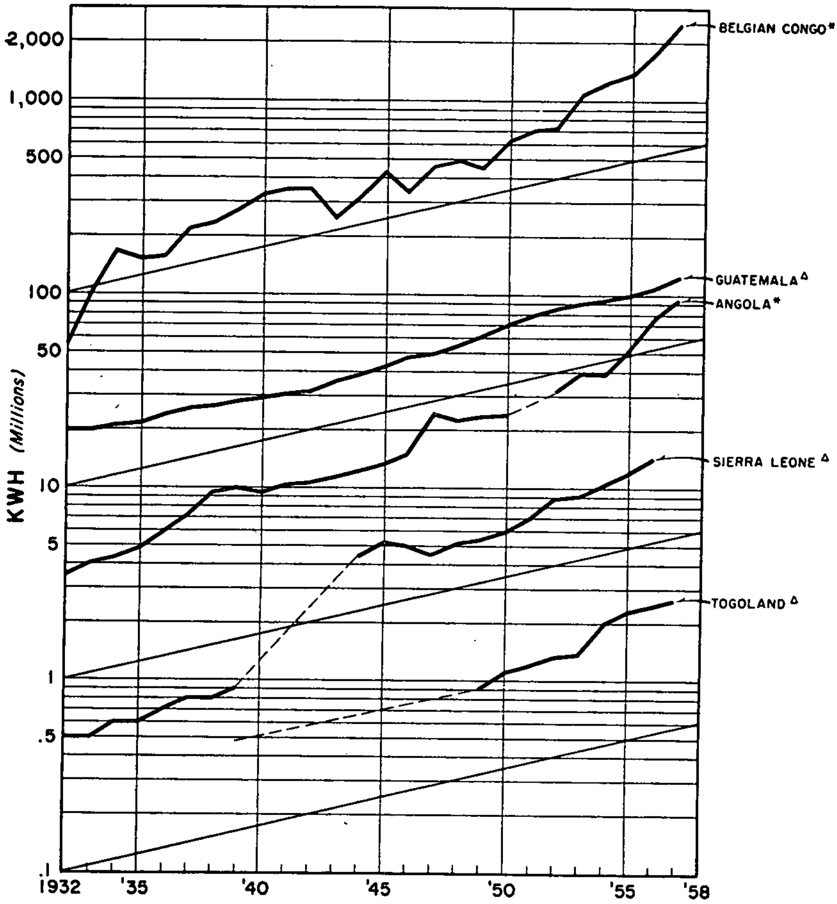
CHART III

GROWTH IN PRODUCTION OF ELECTRIC ENERGY IN VARIOUS COUNTRIES

1932 – 1958



* Total Production Including Industrials

△ Production Primarily for Public Use

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While there are some exceptions, it will be seen from a study of charts II and III how closely throughout the world, by and large, the curve of 7.2 percent rate of growth matches over a long enough period the actual growth. Analysis of chart I has shown this to be the case in the United States and can be seen for the world in chart II, which is of course heavily influenced by the 40 percent position of the United States. Notice that such a trend line holds not only for an industrial country like Switzerland or France (chart II) but even for such relatively underdeveloped countries as Togoland or Guatemala (chart III).

There is good reason for this similarity in trends, which traces back to the point that electric energy does not come into being except as utilization equipment and the technology of use are present. It is necessary constantly to keep in mind that electric energy has got to be used in order to be created. And the rate of growth in use of electric energy is vitally tied to the particular state of any economy and the rate at which an economy can expand annually.

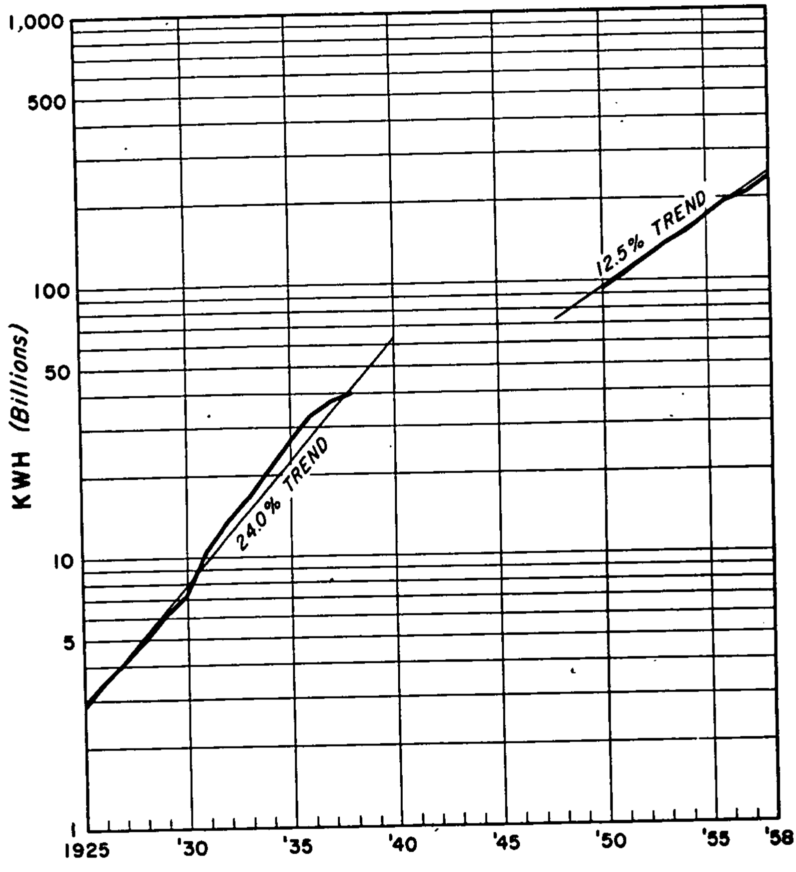
The observations I have made do not mean that each year's expansion of electric use will be limited to 7 percent. On the contrary, there can be periods, sometimes as long as 5 or 10 years, when the rates of expansion can be much higher. But essentially, and this is another way of stating the same underlying reason, the growth in production of electric energy, which as I have pointed out involves the development of technology and the accumulation of energy-using capital equipment, is limited by the rate at which any economy can accumulate capital out of its national income over a long span of years. Although for relatively brief periods a particular economy can force extremely high rates of capital accumulation, over the long term this rate is limited by growing demands in other sectors of the economy.

These considerations have an important application to the analysis of the growth in production of electric energy in the U.S.S.R. (chart IV). Chart IV shows production of electric energy in that country for the only periods for which we have data, 1925–38 and 1950–58. In 1925 the United States produced about 84 billion kilowatt-hours; Russia produced less than 3 billion.

CHART IV

GROWTH IN PRODUCTION OF ELECTRIC ENERGY IN THE U.S.S.R.

1925-1938 1950-1958*



* No Figures Available 1939-1945

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But the rate of growth in Russia, starting at such a low level and doubling every 3 years, was much greater than the rate in the United States. In the latter period, beginning in 1950, Russian production of 91 billion kilowatt-hours increased to 233 billion in 1958. This is a rate of growth of 12.5 percent. Expansion experienced in this 8-year period has been at a rate only half that experienced in the interval 1925–38. This is a slowdown in the rate of no small proportions, and the rate is slowing down even further. In a paper that appeared in the May 1959 issue of the Soviet publication Teploenergetika, I. T. Novikov, Minister for Electric Power Stations, projected Soviet electric power expansion at 2.1 to 2.2 times the 1958 level. Although Soviet projections in the economic sphere tend to be somewhat optimistic, this 7-year projection represents an average annual growth rate of about 10.5 percent, compared with the 12.5-percent rate of the previous 8 years.

The production of 233 billion kilowatt-hours in 1958 represents an enormous expansion in a period of only 8 years. Still it is not as high as would have been produced had Russia started in 1925, say, with an annual production of 25 billion kilowatt-hours (only one-third of what the United States had in 1925) and if Russia had maintained thereafter a compound rate of growth of only 7.2 percent.

This leads to the further thought that given a long enough period of time it is likely that the rate of growth will slow down and will trend more and more toward a figure of somewhere around 7.2 percent long-term growth; but even that rate will eventually slow down.

With this background I would like to turn now to a discussion of the energy requirements of this country in the year 1975 and in the year 2000 I have made these projections for two reasons: The first is that there are altogether too many energy projections and too much time and effort being devoted to study of the supposed energy requirements of the country in the distant future, say the year 2100 or 3000, and not enough to study of the period immediately ahead, say the next 20 to 25 years. Bright as I believe the future of this country is, we will never come into that future if we cannot pass through the next 5, 10, 15 and 25 years successfully—politically, economically, ideologically, and all three are vitaly interreated. The second reason has to do with the future of atomic energy. I believe there is a bright future for atomic energy. But there are still ahead in this field a great many technological and engineering economic problems of the most difficult kind. I take an optimistic view of these problems and am confident of their ultimate solution. It is my judgment that a sound picture of the future of atomic power cannot be drawn, nor policy with regard to atomic power established, unless such projections are made.

Before I present to the committee my projections for 1975 and 2000, I want to indicate the assumptions underlying them. I have no doubt there can be substantial difference of opinion about both my projections and the premises on which they rest. The year 2000 is sufficiently far in the future for a great many unforeseen and unforeseeable contingencies to upset drastically any set of assumptions one might care to make. There can be differences in assumptions about technological change. It is possible to imagine changing technology about which we know either very little or not enough.

For example, one might assume—although I am not prepared to make the assumption—that the gasoline-driven motor vehicle will be replaced by a battery-driven motor vehicle which will receive its charge from nuclear-generated electricity. Or one might assume that the hydrogen-oxygen fuel cell will move along at a great enough technological pace so as to become a significant item in transportation, both apssenger and commercial, by motorcar and truck. But the fuel in this case would be hydrogen produced by electrolysis of water, utilizing either conventional or nuclear energy. Numerous other processes which require oil or coal or gas—for example, the home heating market—may possibly become almost entirely electric, so that nuclear-generated energy could substitute for the oil, gas, and coal that would otherwise be used for space heating. Such developments could certainly affect future prospects substantially

Nevertheless, the projections which I have made represent my best judgment in the light of present technology and knowledge. I have used the years 1975 and 2000 as convenient marks to designate the period around those dates rather than specific years.

In my projections, to facilitate comparisons I have converted all forms of energy to a common unit, tons of bituminous coal equivalent.

I have assumed for 1975 a population of 240-million, which is the average of the two highest Census Bureau projections for that year. I have then assumed a substantial slowdown in the rate of population growth so that by the year 2000 population will have grown to 300 million. I have projected the gross national product at a long-term growth rate of 3.5 percent to 1975, or 850 billion 1957 dollars by that year. Again I have assumed a slowing down in the rate of growth for the succeeding 25 years to an average of 2.25 percent per annum to a level of $1,500 billion by the year 2000. The Federal Reserve Board index of industrial production has been projected roughly proportional to the gross national product so that index is projected at 245 in 1975 and 300 in 2000.

I start with a projection of 2,000 billion kilowatt-hours as this country's electric requirements in 1975—or three times those of 1957 (table XV). This represents a fuel requirement equivalent to 700 million tons of coal in 1975, as compared with less than 300 million tons of coal equivalent in 1957. I repeat the caution that such a projection of 2,000 billion kilowatt-hours as the country's requirement for that year is one that cannot be made with precision. I think it is a reasonable projection of the probable order of magnitude. There have been some slightly more optimistic and other considerably less optimistic projections. In the trebling of electric energy generation between 1957 and 1975 to reach the total of 2 trillion killowatt-hours, I have estimated that 150 billion kilowatt-hours, or 7.5 percent, will be generated by nuclear power (tables XV and XVI).

TABLE XV.—*Total electric utility generation by fuel source*

[Billion kilowatt-hours]

Year	Total Billion kilowatt-hours	Coal		Fuel oil		Gas		Hydro		Nuclear	
		Billion kilowatt-hours	Percent total	Billion kilowatt-hours	Percent total	Billion kilowatt-hours	Percent total	Billion kilowatt-hours	Percent total	Billion kilowatt-hours	Percen total
1920	39.4	22	55.8	1.2	3.1	0.4	1.0	15.8	40.1	--------	--------
1947	255.0	137	53.7	17.0	6.7	23.0	9.0	78.0	30.6	--------	--------
1957	631.0	347	55.0	40.0	6.3	114.0	18.1	130.0	20.6	--------	--------
1975	2,000.0	1,310	65.5	90.0	4.5	200.0	10.0	250.0	12.5	150	7.5
2000	6,000.0	2,250	37.5	50.0	.8	150.0	2.5	350.0	5.8	3,200	53.4

TABLE XVI.—*Fuel consumption for electric utility generation*

[Million tons bituminous coal equivalent]

Year	Total fuel (million tons)	Coal		Fuel oil		Gas		Hydro		Nuclear	
		Million tons	Percent of total	Million tons	Percent of total	Million tons	Percent of total	Million tons	Percent of total	Million tons	Percent of total
1920	76.9	42.9	55.8	2.4	3.1	0.8	1.0	30.8	40.1	--------	--------
1947	167.0	90.0	53.9	11.0	6.6	15.0	9.0	51.0	30.5	--------	--------
1957	293.0	161.0	54.9	19.0	6.5	53.0	18.1	60.0	20.5	--------	--------
1975	700.0	475.0	67.9	30.0	4.3	65.0	9.3	80.0	11.4	50	7.1
2000	1,600.0	600.0	37.5	13.0	.8	40.0	2.5	92.0	5.8	855	53.4

If nuclear power had no more place in our energy picture than to provide 7.5 percent of the total electric energy requirements, or less than 2 percent of our total energy requirements in 1975—which total energy requirements I estimate at over 2,700 million tons of coal equivalent (table XVII)—there would be little justification for all the activity and all the national effort that is being given to this atomic program. The justification for what we are doing is the belief—which in my judgment is sound—that as the country's future need for energy expends, atomic power will be able, on an economic basis, to assume the burden that the other sources of energy will be then unable to carry effectively.

TABLE XVII.—*Energy consumption in the United States for selected years*

[Million tons of bituminous coal equivalent]

Year	Total energy (million tons)	Total coal (bituminous, anthracite, and lignite)		Petroleum, includes net imports		Natural gas		Hydro		Nuclear power	
		Million tons	Percent of total	Million tons	Percent of total	Million tons	Percent of total	Million tons	Percent of total	Million tons	Percent of total
1920	755	592	78.4	101	13.3	33	4.4	29	3.9		
1947	1,255	593	47.2	412	32.9	194	15.5	56	4.4		
1957	1,600	434	27.1	661	41.3	445	27.8	60	3.8		
1975	2,750	900	32.7	1,055	38.4	665	24.2	80	2.9	50	1.8
2000	4,000	1,200	30.0	1,238	31.0	615	15.4	92	2.3	855	21.3

For some appreciation of what this may involve, I have made the projection beyond 1975. Obviously, the fallibility I stressed in projections as far ahead as 1975 applies with much greater force to a projection 40 years or more ahead. In the case of electric energy—optimistic as I am about its increasingly effective utilization—I feel that there are factors of saturation that we are only dimly aware of at the present time which may arrest the present rate of growth. Nevertheless, I have estimated for the year 2000 a total generation of 6,000 billion kilowatt-hour. This is nearly 10 times the electric energy generation of 1957. It may eventually prove to be in error by a substantial margin, more likely on the high than the low side. I have made this projection, however, not for precision but to examine, on the basis of an order of magnitude that can reasonably be anticipated, the fundamental purpose for our atomic program.

Assuming these projected requirements, I estimate that in the year 2000 nearly 40 percent of this total will still be generated by coal, a small amount by fuel oil and by gas, some 350 billion kilowatt-hours by hydro (this is not quite three times the amount we generated hydraulically in 1957), and the largest percentage, not quite 55 percent, by nuclear fuel.

For 1975, I estimate a possible consumption of 475 million tons of coal and 50 million tons of coal equivalent of nuclear power of electric energy generation. For the year 2000, I estimate a relatively small increase over 1975 in the coal portion, to 600 million tons, but for nuclear power more than a seventeenfold increase to the equivalent of more than 850 million tons (table XVI).

More significant is total energy consumption for all purposes in the United States. An interesting thing to point out here is that while electric energy kilowatt-hours increased almost fifteenfold between 1920 and 1957—from 39 billion to 631 billion kilowatt-hours—and the total energy consumed for electric generation increased only fourfold—from 77 million to 293 million tons of coal equivalent—the total energy used in the United States little more than doubled—from 755 million to 1,600 million tons of coal equivalent (table XVII). Parenthetically, energy consumed for electric generation increased in this relatively low proportion, as compared with kilowatt-hours produced, because of increased generating efficiencies in that interval. The best projection that I feel can be made for 1975 is an increase in total energy from 1,600 million tons of coal equivalent in 1957 to a figure that would be about 70 percent greater, 2,750 million tons; and I estimate the total energy requirement in the year 2000 as equivalent to 4 billion tons of coal. This is an increase of close to 50 percent in the 25-year interval, 1975–2000.

Yet despite the optimistic projection of electric energy use and the assumption that nuclear power will account for over 75 percent of the increase in electric energy generation between 1975 and 2000, the part of the total energy requirements of all kinds that is likely to be satisfied by nuclear energy in that year is only slightly over 20 percent—that is, 850 million tons of coal equivalent out of 4 billion tons. This still leaves almost 80 percent of our total energy requirements to be supplied by conventional sources. Of the 80 percent, approximately 20 percent will still go to generate electric power; the remaining 60 percent for all other energy work (table XVIII).

TABLE XVIII.—*Breakdown of U.S. energy requirements in the year 1957 and possible figures for years 1975 and 2000*

[Million tons bituminous coal equivalent]

Year	1957	1975	2000	
	Million tons	Million tons	Million tons	Percent
Electric energy generation:				
Coal	161	475	600	15.0
Hydro	60	80	92	2.3
Gas	53	65	40	1.0
Oil	19	30	13	.3
Nuclear		50	855	21.4
Total electric energy generation	293	700	1,600	40.0
Coal (excluding electric energy)	273	425	600	15.0
Petroleum (excluding electric energy)	642	1,025	1,225	30.6
Natural gas (excluding electric energy)	392	600	575	14.4
Total energy requirements	1,600	2,750	4,000	100.0

Having in mind that the projections I have made are to be regarded only as an order of magnitude, it seems to me that one certain and inescapable conclusion can be drawn which is directly pertinent to the program we are attempting to develop at the present time.

It is clear that our total energy requirements in the year 2000 and in the intervening period will necessarily require very large amounts of fossil fuel. I believe there is grave danger—and I cannot overemphasize the vital importance of avoiding that danger—that so great an emphasis will be placed on atomic power development that we will tend to forget the essentiality of fostering the continued development of an adequate supply of coal, oil, and gas for the long period during which atomic energy will only gradually assume an increasing part of our total energy burden.

Even allowing for a very wide range of error in projections, the trends and tendencies they reveal—the need to provide until the year 2000 and beyond, increasing quantities of fossil fuels, especially coal and liquid fuel, and the likelihood that nuclear power will by then be able to supply a very large quantity, but still only a limited share, of our total energy requirements—remain unchanged. It is with an overall outlook for our total energy requirements such as this that we must consider our atomic program if we are to provide an adequate supply of total energy in its proper forms. In our concern for the long-term promise of nuclear energy we cannot permit ourselves to lose perspective. We cannot forget the continuing importance of our fossil fuels. We must be certain that they will be able and will continue to provide, for some time to come, the far larger share of our total energy needs that nuclear power will not be able to satisfy even under the most favorable conditions.

PART 3: TECHNOLOGICAL DEVELOPMENTS IN ELECTRIC POWER SUPPLY: THEIR EFFECT ON REDUCTION OF COST AND EXTENSION OF USE OF ELECTRIC ENERGY; FUTURE TECHNOLOGICAL DEVELOPMENTS [2]

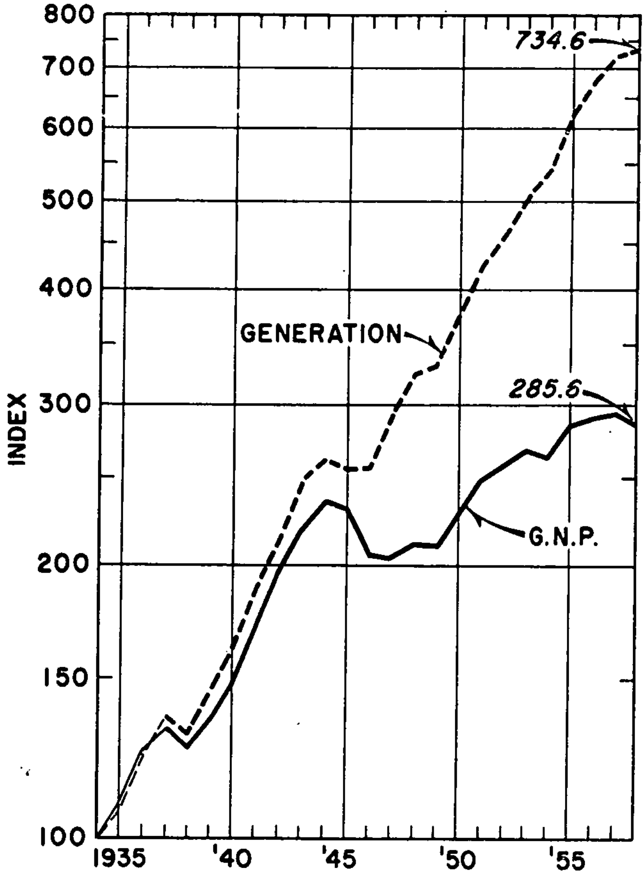
The growth and development of the art and business of electric power supply has always relied heavily on science and technology. This has been so since the beginning of the industry, in 1882, and never more so than in the last 25 years. During this last quarter century, tremendous strides have been made in the United States in meeting the demands for electric service and, at the same time, improving service through increasing the efficiency of operations. This growth and development have been made possible through major advances in the complex technologies involved in the production and delivery of power.

From 1934 to 1959, electric utility generation expanded by well over 700 percent, or at a rate almost 2½ times as fast as the increase in the real gross national product (GNP) after eliminating changes in the price level (chart V).

[2] In the preparation of pt. 3 I have drawn partly on a paper I prepared for the 75th anniversary (May 1959) issue of Electrical Engineering, the monthly journal of the American Institute of Electrical Engineers.

The expanding use of electric energy in every aspect of American life has contributed to, and in turn has been made possible by, the rising standards of living and the increased productivity enjoyed by the country in this period.

CHART V

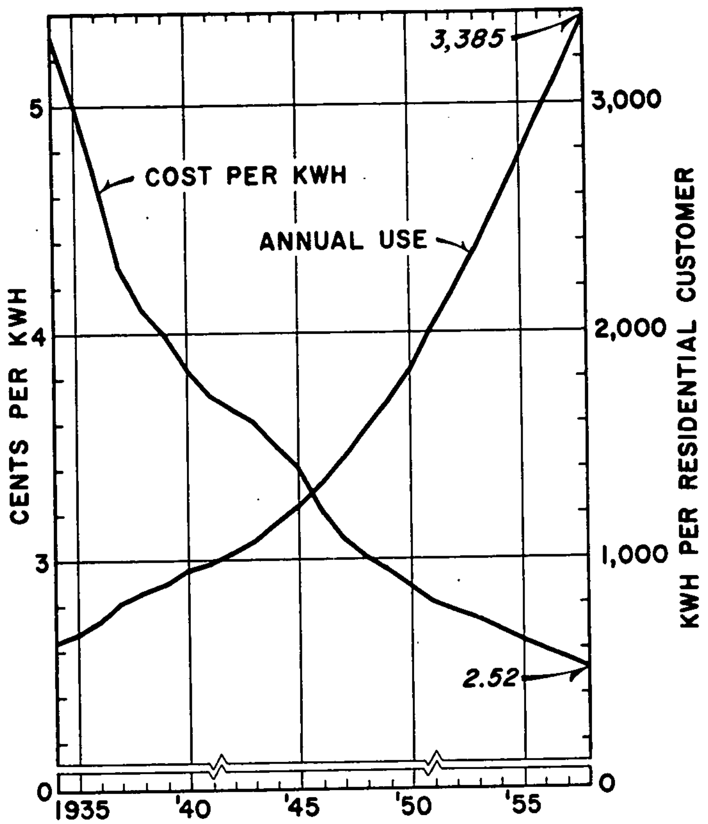


INDEXES OF TOTAL ELECTRIC UTILITY GENERATION AND GROSS NATIONAL PRODUCT IN CONSTANT 1958 DOLLARS, 1934 1958 (1934 = 100)

In 1934, the electric utility industry had only 24.7 million customers. By the end of 1958, the total had increased to over 56 million. This was partly the result of an expanding population, but it was in large measure attributable to the expansion in electric service to a larger portion of the population. Well over 95 percent of the total residences in the United States—all but the most remotely located—now have central station electric service available, compared with only 65 percent in 1934. Contributing to this result was the substantial completion of the program of rural electrification. At the end of 1934, almost 744,000 farms, or slightly less than 11 percent of the total number of farms in the United States, were served by the utility industry. By 1958 the extent of rural service was nearly equal to that found in urban areas, with just under 95 percent of the total farms receiving utility service.

The 20.4 million residential customers in 1934 used an average of only 629 kilowatt-hours per customer; in 1958, more than 46 million residential customers consumed 3,385 kilowatt-hours per customer. In the same period, average price per kilowatt-hour had fallen from 5.33 cents to 2.52 cents, despite a more than doubling in the consumer price level (chart VI).

CHART VI



RESIDENTIAL CONSUMERS' AVERAGE COST PER KWH AND AVERAGE ANNUAL KWH USE

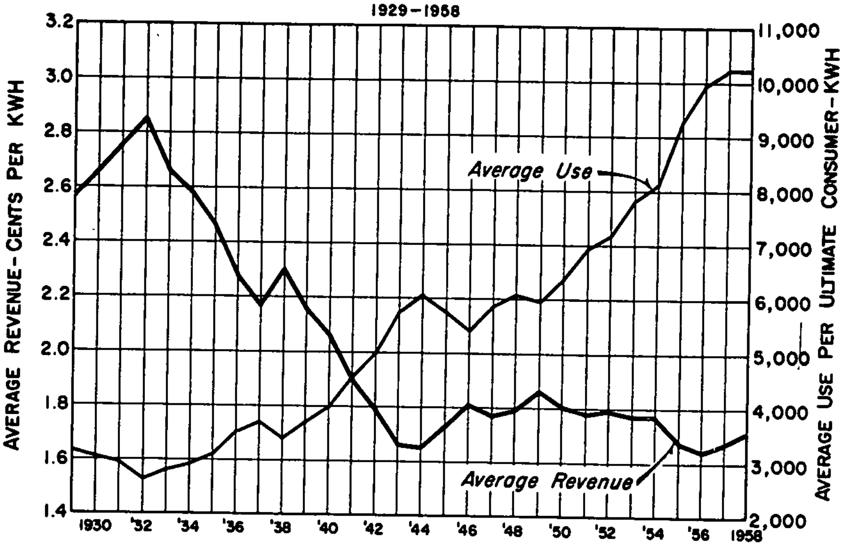
1934 - 1958

Similar growth took place in the commercial and industrial consumption of electric energy. Electricity used per production worker man-hour rose from 4.07 kilowatt-hours in 1934 to over 9 kilowatt-hours in 1958, excluding energy used by the aluminum industry and the Atomic Energy Commission. (The aluminum industry and AEC are excluded because they are such heavy users that their inclusion would give a misleading figure for the increase.) This has had its effect on the average use per ultimate consumer from somewhat under 3,000 kilowatt-hours per year in 1934 to over 10,200 kilowatt-hours per year in 1958. The decline in average price (revenue) in the same period, from almost 2.6 cents per kilowatt-hour to 1.7 cents (a reduction in cost of more than 33 percent), as shown in chart VII, is noteworthy when compared with the change in indexes of consumer prices, wholesale prices, and electric utility construction costs from 57 to 123, 48.7 to 120, and 54 to approximately 170, respectively (chart VIII). In the total, electric utility generation grew in these 25 years from a little over 87 billion kilowatt-hours to 641 billion, and the generating capacity of the industry expanded from 34 million kilowatts to 140 million (chart IX).

CHART VII

AVERAGE ELECTRIC ENERGY USE PER ULTIMATE CUSTOMER AND REVENUE PER KWH

1929–1958

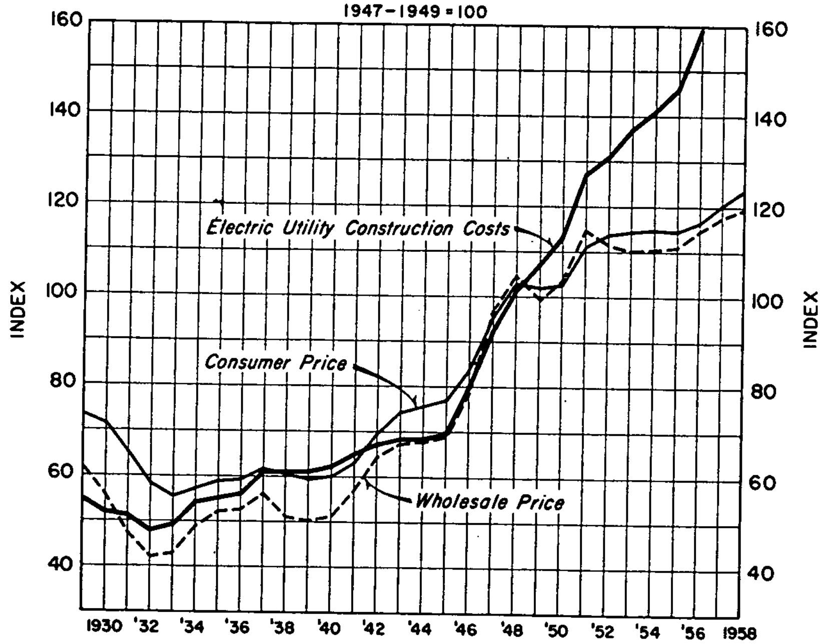


Source: E.E.I.

CHART VIII

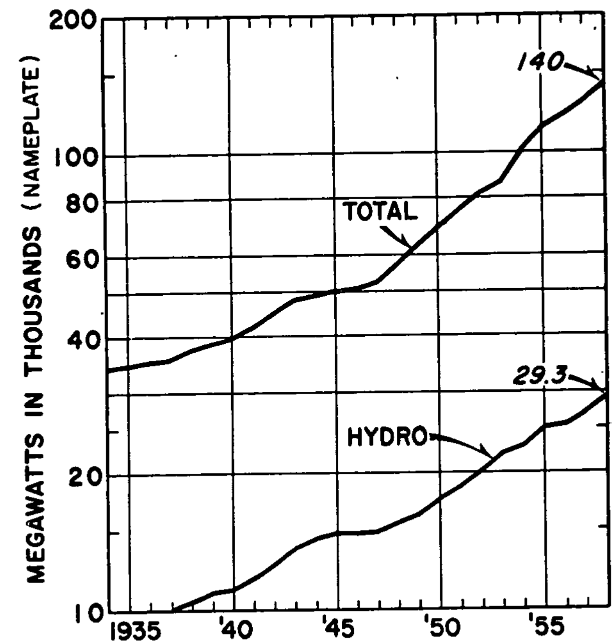
INDEXES OF CONSUMER AND WHOLESALE PRICES AND ELECTRIC UTILITY CONSTRUCTION COSTS

1947–1949 = 100



Source: Dept. of Labor, National Industrial Conference Board

CHART IX



TOTAL ELECTRIC UTILITY GENERATING CAPACITY
1934 - 1958

This growth in the past 25 years has also involved a change in the character of a considerable part of the industry from relatively small, more or less isolated systems into large, integrated systems, many of these in turn being interconnected in larger pools, with the advantages of mass production and transmission of electric power at costs lower than could have been achieved by smaller systems. This phase of the industry's development has been made possible in large part by important technological achievements, and the large systems themselves have made possible the incorporation of cost-saving technological developments which would otherwise not have been made. For example, the savings in construction cost per killowatt of capacity by building larger units would not have been possible without the large systems able to absorb them; the savings in fuel costs now being achieved through the use of larger, more efficient units and the transmission of large blocks of power from plants built close to fuel sources and condensing water would not have been possible without the need for large quantities of power in single systems.

Important forward strides in technology have taken place, as will be seen in the following discussion, in every phase of the industry's operations.

Steam-electric generation

The expansion of electric utility capacity from 34-million kilowatts to 140 million was more than a simple multiplication in kind. As a consequence, the generating plant, particularly the steam-electric plant, being installed on the utility systems of the United States today can hardly be classified as of the same species as those installed in 1934. The size of units, the steam pressures, the temperatures, and efficiencies were all almost undreamed of, even considered impossible, in 1934. The growth of unit sizes in this period has been most notable. In 1934 the typical large turbine-generator unit delivered for power system installation was 40,000 to 50,000 kilowatts. In 1937, a 40,000- kilowatt unit was the largest single-shaft, 3,600-revolutions-per-minute machine installed up to that time. Today, a tendem-compound, single-shaft, 3,600-revolutions-per-minute unit of 250,000 kilowatts is operating, and one of 325,000 kilowatts is on order. At the same time, cross-compound units have progressed from the 3,600/1,800-revolutions-per-minute combinations of 90,000 kilowatts that were typical in 1939 to the 325,000-kilowatt units now in operation and to the 3,600/3,600-revolutions-per-minute 450,000-kilowatt units now under construction and to several 500,000-kilowatt units and one 600,000-kilowatt unit also now on order.

While these advances have been the result of many technical improvements, perhaps the most significant as far as generators are concerned are the advances in methods of cooling. In this development, the most important single step has been the use of hydrogen as the coolant, first at 0.5 p.s.i. ((pounds per square inch), and later increased to 15, 30, and, finally, to 45 p.s.i. The more recent development of inner cooling of conductors, both stator and rotor windings, has made possible the latest increases in unit sizes to what were considered impossible figures only a few years ago. On the turbine, the development of longer last-stage buckets, along with multiflow exhausts, has made possible the handling of the large volumes of steam required in units ranging in size from 325,000 to 500,000 kilowatts; even greater length buckets are now under development.

Along with, and contributing to, the increased unit size have been the major advances in turbine and boiler technology in steam temperatures, pressures, reheat, and size and design of boilers. Steam temperatures of 900° F. were first achieved in 1936, and in two steps this was advanced first to 925° F. in 1937 and to 940° F. in 1940. Further development was of necessity suspended during World War II, but in 1947 a major step was taken in the Atlantic City No. 7 unit, which advanced temperatures to 1,000° F. This was quickly followed by 1,050° F., at Sewaren in 1948; 1,100° F., at Kearny in 1953; 1,150° F. for Philo No. 6 in 1957; and finally, the maximum to the present time, 1,200° F. for Eddystone No. 1, now under construction. The economic validity of the very high temperatures of the last two steps remains to be established. But the 300° F. increase represents a remarkable technical advance in steam temperatures in the past 25 years—one which has left its mark on heat energy conversion technology.

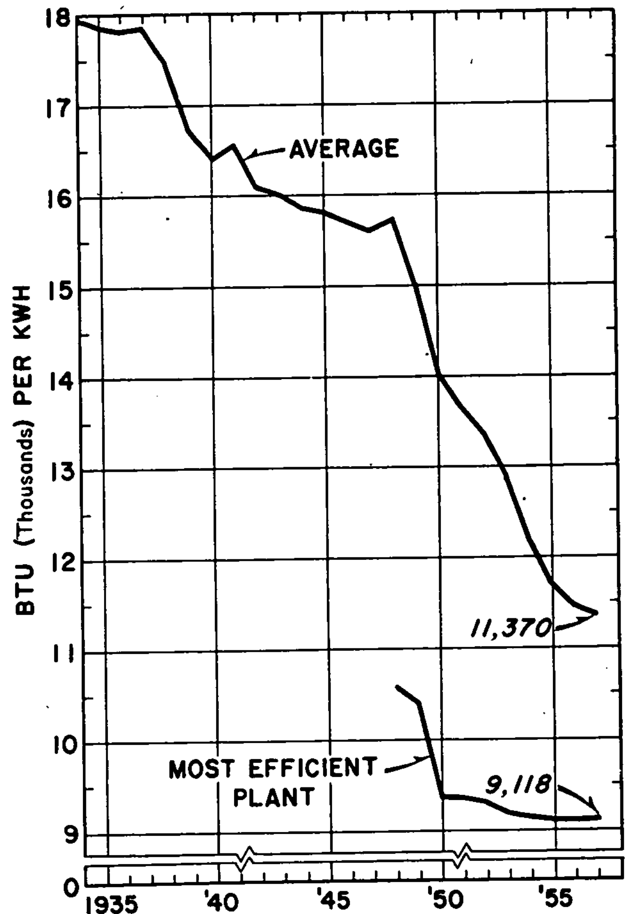
Pressure technology, having broken through the supercritical barrier, may be said to have undergone even more notable advances than those in temperature. Pressures of 1,100 p.s.i. were achieved in the early 1930's, but developments were not extended appreciably beyond this until the 2,400-p.s.i. Twin Branch No. 3 unit was installed in 1940, largely as an advanced experimental prototype. Although World War II delayed further development, this 2,400-p.s.i. installation paved the way for the highly successful postwar boiler technology in the 2,000-p.s.i. range, which prevailed until the 4,500-p.s.i. supercritical unit was installed at Philo in 1957. This unit, having a capability of 107,000 kilowatts (occupying the space formerly occupied by a 40,000-kilowatt unit of 1925 vintage), was developed as an experimental prototype which has led the way to construction of a number of larger size units of a similar type. This has been extended to 5,000 p.s.i., 1,200° F. in the 380,000-kilowatt Eddystone No. 1 unit referred to earlier. More particularly, it has provided the basis for the design of two 450,000-kilowatt units on the American Electric Power (AEP) system, where, because of the relatively lower value of thermal savings made possible only at the expense of higher costs for more expensive alloy materials required for higher temperatures, the temperature and pressure levels were backed off to 1,050° F. and 3,500 p.s.i. For similar reasons, a second Eddystone unit is being designed for 3,500 p.s.i. and 1,050° F.

The reheat cycle initiated early in this period has now become general practice and has made possible substantial gains in thermal efficiency. Single reheat applications came along as follows:

Date	Initial temperature	Reheat temperature
1940	940° F.	900° F.
1949	1,050° F.	1,000° F.
1953	1,050° F.	1,050° F.

More recently, the application of a double-reheat cycle has been developed. These include the experimental 1,150/1,050/1,000° F. at Philo; the experimental 1,200/1,050/1,050° F. for Eddystone No. 1, and the 1,050/1,050/1,050° F. for the 450,000-kilowatt units at Breed No. 1 and Sporn No. 5. These basic improvements in the heat cycle, along with many other refinements in boilers and turbines, have increased thermal efficiencies markedly. Compared with an average heat rate of 16.500 B.t.u. per kilowatt-hour for units installed in 1934, the average for units installed in 1958 was close to 9,900 B.t.u. per kilowatt-hour. This produced the striking total industry and best plant efficiency improvements shown in chart X. For the industry as a whole this chart shows a decline in B.t.u. per kilowatt-hour from 17,950 in 1934 to 11,090 in 1958—an improvement of over 38 percent. For one whole system, the AEP System, average overall system heat rate in 1958 was reduced below 10,000 B.t.u. per kilowatt-hour. This is all the more significant if we consider that it was only as recently as 1950 that the Philip Sporn Plant was the first to achieve an average plant heat rate below 10,000 B.t.u. per kilowatt-hour.

CHART X



UTILITY INDUSTRY THERMAL EFFICIENCY IN ELECTRIC ENERGY GENERATION

1934 - 1958

Along with improvements in thermal efficiency, the great increase in unit sizes has been one of the major factors in holding the cost per kilowatt of capacity down to levels approaching those of a decade ago, despite an almost doubling of construction costs in the postwar period. This is readily illustrated, as noted in the foregoing, by the space occupied by the Philo No. 6 unit, almost tripling the capacity previously installed in a given area. In addition to the savings in construction costs made possible by increases in unit capacity, savings in operating expense have also been made possible through a reduction in the manpower requirements from upwards of 1 man per 1,000 kilowatts 25 years ago to as low as 0.25 man per 1,000 kilowatt today. The indication is that this trend is not at an end, and that even lower manpower requirements per unit of capacity can be expected on the newer 450,000- and 500,000-kilowatt units. The reduction in manpower requirements has been materially advanced by the use of centralized and largely automatized control arrangements along with the general adoption in the postwar period of the single-unit boiler-turbine combination for even the largest units, including the 450,000- and 500,000-kilowatt units now under construction. The million-pound-per-hour steam boiler has now been replaced by the large steam generators rated at from 3 to 4 billion B.t.u. per hour input. The increase in efficiencies has managed to offset a substantial part of the effect of the increases in fuel cost since the end of the war.

Hydroelectric generation

Along with the large expansion of our steam-electric generation, progress has not been static in the further development of hydro resources in all areas of the United States where hydro potential is available. Installed hydro capacity expanded during the past 25 years from 9,345,000 kilowatts in 1934 to 29,318,000 kilowatts in 1958 (chart IX). With this there was an increase in total hydro energy generation from 32,684 million kilowatt-hours to about 140,000 million kilowatt-hours in the same period.

Among other major developments are those completed and under way on the Niagara and St. Lawrence Rivers. At Niagara, the Lewiston plant, of 1,950,000 kilowatts, will incorporate the largest hydro units to date, 150,000 kilowatts each, compared with Grand Coulee units of 108,000 kilowatts each. This plant and its associated plant, the Tuscarora pump-hydro 240,000-kilowatt plant, will make a total project of 2,190,000 kilowatts, the largest single project to be developed in this country as well as in this hemisphere. Completion of this project is scheduled for 1962. The St. Lawrence development at Barnhart Island comprises essentially two plants in one, each of the same rating—the Robert H. Saunders-St. Lawrence Generating Station in the Canadian portion, and the Robert Moses Generating Station on the American side. Both of these plants are now in full operation, each with a capacity of 912,000 kilowatts.

Elsewhere in the United States the principal areas of development have included the major projects in the Pacific Northwest, such as Bonneville, Grand Coulee, Cabinet Gorge, Ross, Brownlee, and many others; the Shasta Dam, along with numerous smaller projects, in California; Missouri River plants, such as Garrison and Fort Randall; Clark Hill and John Kerr in the Southeast; the numerous plants on the Tessessee and its tributaries involved in the Tennessee Valley Authority (TVA) complex; and, finally, the New England area.

With many of the more favorable hydro sites already developed, a trend toward more economical methods of dam construction has made a significant contribution to extending the economic feasibility of remaining sites. In particular, two types of construction may be cited: First, the rockfill construction in which the waterproofing is obtained by means of a deck on the upper face made of asphaltic cement to give it the necessary degree of flexibility without cracking. The other type consists of a combination rock and earth fill, the latter comprising a core of well-packed clay soil in between rockfill on both upstream and downstream sides.

Considerable interest also has been evidenced in pump-hydro developments, although total capacities involved so far are not great. Projects during the past 25 years include the Hiwassee plant of TVA, the Colorado Big Thompson project at Estes Park, the Tuscarora and Adam Beck projects on the Niagara River previously mentioned, and a new project under development at Smith Mountain, Va. The trend in later developments has been toward the use of a single unit to serve as both a generator-turbine combination and a motor-pump combination, as compared with separate units for each function.

Although a heavy program of hydro construction has been carried out in this country, generation has grown even faster, so that the proportion of U.S. overall power requirements contributed by hydroelectric plants has shown a substantial decline over the past 25 years. With the exception of the Pacific Northwest, this is the case even in areas of large hydro potential such as California, as well as in the TVA system, where more than two-thirds of the total power requirements are now generated by steam. Likewise, the Hydro Electric Power Commission of Ontario is basing future growth of generating capacity principally upon steam. The extent to which the expansion of steam-electric generation has outstripped the growth of hydro resources in the United States is indicated by the drop in percentage of total hydraulic generation from 37.5 percent in 1934 to 21.8 percent in 1958.

Transformers

In keeping with the growth of generator unit sizes as well as with overall growth of systems, power transformer sizes have been increased to capacity ratings hardly visualized 25 years ago. This has come about by improvements in design from the standpoint of insulation, efficiency in the use of materials, improvements in the quality and characteristics of materials, and, finally, by drastic changes in shipping methods, all of which have made possible larger and larger capacities within practical space limitations.

One of the first steps in this direction was the one-step reduction in basic insulation level (BIL) for high-voltage transformers, 115 kilovolts and above, which was made possible by more effective coordination of insulation strength and lightning arrester protective characteristics. An example of this was the use of a 550 kilovolt BIL, reduced from 650 kilovolts, for 138-kilovolt transformers, tried out successfully as early as 1934 and gradually adopted as standard practice thereafter.

Other important steps were the development in 1941 of grain-oriented steel, permitting a one-third increase in core flux density, and the introduction of the FOA design, combining forced-oil circulation and forced-air cooling. Further reduction in oil and material requirements was obtained by the use of special tanks designed to fit core and coils more closely than previous straight-walled tanks.

A bold step to insure the adequacy of these transformer designs to withstand exposure to lightning surges under field conditions was the introduction, in the early part of this 25-year period, of the practice of using impulse tests for controlling the quality of transformers in regular production as well as for research purposes on new development models. This has paid off in reducing transformer failures in this country caused by lightning to very small proportions.

With the solid background of research and technology in transformer design and construction, including the various developments leading to concentration of larger capacities in smaller dimensions, the manufacturers were able to take in their stride the design and construction of 345,000-volt transformers when these were first required in 1953. The first group of these transformers, designed with a basic insulation level of 1,175 kilovolts, 1½ steps below the full 1,550-kilovolt level, were 150,000-kilovolt-ampere 3-phase autotransformers, 345 kilovolts to 138 kilovolts with 37,500-kilovolt-amperes tertiary windings. Subsequent installations of larger 345-kilovolt transformers includes 3-phase 200,000-kilovolt-ampere auto transformers similar to the original 150,000-kilovolt-ampere units and a 3-phase 275,000-kilovolt-ampere 345-kilovolt generator step-up transformer.

In line with the general adoption of the unit arrangement for turbine, generator, and boiler installations, available sizes of single-unit transformers have kept pace with the increase in sizes of generators and turbines. These transformers have progressed from 315,000-kilovolt-ampere 3-phase units, in 1955, to the largest to date, 380,000-kilovolt-ampere 3-phase, both for generator step-up purposes. As in the case of large-capacity generators, the introduction of forced cooling, which has made possible the development of improved techniques in cooling—in this case primarily in the physical arrangement of conductors and insulation—has been an important factor in making these high-capacity ratings possible.

A further step in reducing the relative size, cost, and weight of transformers, particularly in the higher voltage ratings, is an additional lowering of BIL which is now being tried out, taking advantage of improvements in accuracy of protective levels of lightning arresters. For 345-kilovolt transformers, this has been a full two-step reduction in BIL, from 1,550 kilovolts to 1,050 kilovolts, compared with the 1,175-kilovolt level or 1½-step reduction based in earlier designs. At lower voltages, such as 138 kilovolts, 230 kilovolts, and others, a similiar two-step reduction in BIL is being tried out in some installations, including a number of 138-kilovolt transformers with 450-kilovolt BIL, two steps below the full insulation level of 650 kilovolts. Although the largest 345-kilovolt transformers now under construction using the 1,050 BIL are the 275,000-kilovolt-ampere 3-phase step-up units for the Breed 450,000-kilowatt generators, manufacturers today indicate willingness to undertake building such units in ratings as high as 550,000 kilovolt-amperes or even higher.

Transmission systems

Developments in generation, which have resulted in large-capacity units and in an increasing number of both steam and hydro stations with more than a million kilowatts of capacity, would not have been possible under the geographical limitations of water, land, and availability of fuel without major expansion of transmission systems capable of moving large quantities of power economically to centers of load. To a considerable extent, and particularly on systems where transmission distances were not excessive, the necessary expansion of transmission capacity has been obtained at voltage levels already in use, such as 115 kilovolts, 138 kilovolts, and 161 kilovolts; 230 kilovolts, initiated in California, was already in use on a number of systems 25 years ago.

While there exist a number of examples of major expansions in transmission capacity at existing voltage levels, these are exceptional. In general, the movement of increasingly large quantities of power at these lower voltages has become more and more burdensome from the standpoint not only of the multiplication in number and cost of transmission lines required but also of the serious right-of-way problems involved, particularly in areas of expanding populations and suburban residential buildup. For many systems, a satisfactory solution has been the adoption of 230-kilovolt transmission, more than 15,000 circuit-miles of which is now in operation in the United States. It has been a popular voltage, not only for superposition on systems up to 115 kilovolts, and even 138 kilovolts, but also for bulk power transmission on many hydro developments involving long distances both in this country and in Canada.

A notable exception to this pattern was occasioned by the Hoover Dam project in the early thirties, involving transmission of a large block of power some 275 miles to Los Angeles. For this purpose, 230 kilovolts was considered inadequate, and new ground was broken in developing a 287-kilovolt transmission system, including all related equipment. Although this system, including a third line added in 1939, was successful in operation, expansion elsewhere during the next decade continued at the 230-kilovolt level.

In the meantime, other systems still using 115- or 138-kilovolt transmission were recognizing the need for a higher transmission voltage, which to them did not appear could be met by either 230 or 287 kilovolts. This conclusion was reached by the AEP system and led to the establishment in 1947, in cooperation with several manufacturers, of the Tidd high-voltage test project in Ohio. There various aspects of transmission at voltages ranging from 265 kilovolts to 525 kilovolts were studied extensively over a period of several years. The resulting evaluation of the information obtained finally led to the adoption of 345 kilovolts as the new backbone transmission voltage for the AEP system. At the present time this voltage is being utilized, or planned for installation, not only on the AEP system but also in several other areas of the United States and in Canada. In addition to a total of some 2,000 circuit-miles now in operation at this voltage on the AEP and Ohio Valley Electric Corp. systems, it is now being used by Bonneville Power Administration, in the Northwest, by the Commonwealth Edison Co., by Ohio Edison Co., and by the British Columbia Electric Co., in Canada. Although this is the highest transmission voltage in the United States or Canada at the present time, studies are underway on a number of systems of 460 kilovolts and even higher voltages to handle possible long-term requirements.

System, control, protection, and communication

The development of today's far-flung interconnected transmission networks obviously involved much more than simply constructing transmission lines, substations, and units of generating capacity. The solution of a great many technical problems and the development of many types of specialized equipment were required in order to mold these basic elements into effectively controlled, economically operated systems capable of supplying adequate and reliable transmission and distribution service, and doing so under severe weather and other abnormal conditions. Among the problems involved were circuit interruption at new orders of magnitude of short-circuit current; protective relay schemes of greater accuracy, speed, and dependability; control, communication, and telemetering facilities for successful operation of individual systems; parallel operation of interconnected systems; and many other related problems.

The development of circuit breakers with increased operating speed and interrupting capacity has been one of the outstanding accomplishments. In 1934 the maximum interrupting ratings available up to 230 kilovolt were 2.5 million kilovolt-amperes, and 8-cycle interrupting time was a recently brought-out improvement over the 15 cycles or more which prevailed shortly before. Spurred by the transmission and stability requirements of the Hoover Dam project, in 1936 a radical advance was made in a special design of a 3-cycle 2.5-million-kilovolt-ampere breaker for operation at 287 kilovolts. For other duties at 230 kilovots and below, however, several years had to elapse before new designs, with both increased interrupting capacities and higher speeds, became available. In the development of these new breaker designs with much higher ratings, major field short-circuit tests supplementing laboratory development work played an important part. These included 138-kilovolt tests up to 3.5-million kilovolt-amperes at Philo in 1944, 230-kilovolt tests at 7.5-million kilovolt-amperes at Grand Coulee in 1948, 138-kilovolt tests up to almost 7-million kilovolt-amperes at Philip Sporn in 1954, and, finally, 345-kilovolt tests, also at Philip Sporn in excess of 13-million kilovolt-amperes in 1957. Contrasted with 2.5 million-kilovolt-ampere ratings in 1934, circuit breakers are available today in ratings of 15-million kilovolt-amperes at 138 kilovolt, 20-million-kilovolt-amperes at 230 kilovolts and 25-million kiovolt-amperes at 345 kilovolts. It is notable also that design improvements have produced these high-capacity oil circuit breakers in even smaller dimensioned tanks and with lower oil requirements than those of the 2.5-million-kilovolt-ampere breakers 25 years ago.

In addition, substantial advances have been made in the use of media other than oil for breakers. For example, more than 100 breakers using compressed air as the interrupting medium are now in operation or on order in the United States, ranging in ratings from 2.5-million-kilovolt-ampere 5-cycle opening, for 115-kilovolt design to 15-million-kilovolt-ampere 3-cycle ratings for 230 kilovolts and 300 kilovolts and 25-million-kilovolt-ampere 3-cycle ratings for 345 kilovolts. At the present time, development of circuit breakers using sulfur hexafluoride gas as the interrupting medium is underway and shows promise not only of higher interrupting capacities but also of superior performance from a maintenance standpoint.

Along with circuit breaker developments, substantial improvements have been made in protective relaying schemes for transmission systems. An early improvement was the speeding up of carrier-current differential relaying to 1-cycle operation, compared with the four cycles or more previously available. Other improvements include the introduction of a modified type of impedance relay which, combined with directional comparison schemes with much higher current settings, permits carrying heavier overloads or swings under nonfault load conditions without unwanted tripping.

One of the developments in the transmission and protection art, which is dramatic in concept and performance, is the successful ultra-high-speed reclosing of transmission lines, by which a faulted line is opened at both ends simultaneously to clear the fault and returned to normal operation by reclosing, all in a fraction of a second. In view of the sometimes ponderous dimensions of the high-switches controlling the opposite ends of a transmission line many miles in length and the high-arc energy involved in a short circuit caused by a lightning flashovef, the accomplishment of this opening and reclosing sequence in one-third to one-quarter of a second is an above-the-ordinary technical achievement, because lightning flashover, in spite of much progress in lightning research made during the past 25 years, remains the greatest menace to transmission reliability, not only throughout a great part of the United States and Canada but in other important areas of the world as well, the significance of this technique cannot be overemphasized, particularly in view of the increasing dependence placed upon continuous electric service in all phases of any modern, industrially developed society.

Beginning with the first trial installation in 1936 on a 138-kilovolt line with 8-cycle breakers, the use of ultra-high-speed reclosing has been extended until, at the present time, it has become standard practice for a large portion of the industry, particularly in moderate to severe lightning areas. With the availability of 3-cycle breakers and modern carrier relaying, the art today has advanced to overall reclosing times as low as 15 cycles (one-fourth second) in 138-kilovolt lines and 22 cycles on 345-kilovolt lines. Performance records of 90 to 95 percent successful reclosure are being obtained in areas where lightning is the principal cause of line faults.

In the field of control of power system generation, frequentcy, etc., the operation of large complex systems, and, particularly, interconnected groups of systems, would have been greatly hampered, if not rendered impracticable, without developments in techniques and equipment for automatic control of frequency and tieline loading which are in widespread use today. The need for such techniques became apparent even earlier than the beginning of this 25-year period, and early applications of automatic control were made at that time on several systems, including an interconnected group of some 30 companies operating in parallel in Ohio, Indiana, western Pennsylvania, and in adjacent States to the south, all with a then combined generating capacity of around 5 million kilowatts.

Cooperative efforts among the operating organizations of these systems were undertaken to develop and improve automatic control techniques, and this cooperation has continued, with the growth of the systems and the addition of new members to the interconnection pool, until today the group comprises 104 companies operating in 29 States, with a total combined generating capacity of more than 60 million kilowatts. Initial attempts at automatic frequency control by placing the burden on a single centrally located generating plant were quickly modified to spread the burden of frequency regulation to other stations. This approach has now expanded to the point where every important generating station in the interconnected systems group is assigned an appropriate share, or "band," of generating capacity to be raised or lowered in the event of a system frequency deviation above or below a normal frequency band. The basic function of modern frequency and tieline control is, of course, that of regulating the total generating output in each individual system in such a way that the total generation will match continuously the total system load, including scheduled loads on interconnection tielines.

Obviously, the successful development and application of these automatic control functions, along with many other requirements of modern system operation, have necessitated the accompanying development of adequate communication systems. One of these functions is that of economic dispatching of generation on individual systems. This process of scheduling plant loadings for best overall economy has been brought to varying stages of development, in some cases by continuous manual supervision from a central dispatching center using the incremental slide rule in conjunction with an incremental transmission loss computer to obtain maximum economy and in other cases by incremental loading computers installed to carry out the economic dispatching automatically. Although great progress has been made, this function of system control is still in a state of development and experimentation, with various systems being proposed and a few of them under trial.

Here, again, adequate communication is of outstanding importance. Carrier current over powerlines has been used for many years for telephone communication, relaying, telemetering, load control, etc., and is still the reliable and much-utilized medium in this field. Equipment, including transmitters and receivers, has been greaty improved in performance, particularly with respect to signal-to-noise ratio.

In many systems, however, carrier-current channels have become inadequate, both as to the number available and as to the quality of circuits provided. This has led to the increasing use of microwave communication systems, for which suitable equipment and license authorizations became available some 10 years ago. These systems today provide high-quality voice transmission free from atmospheric and manmade interference, and can handle a large number of channels for all communication requirements, including telemetering, system control, etc. At present, some 700 microwave stations are in service on transmission systems in this country alone. With reliability and technical performance equal to or better than any other alternative means of communication, it is expected that these systems will be greatly expanded to meet continuing growth in communication requirements.

Another form of communication, developed almost entirely within the last 25 years, is the mobile radio system, by which communication is maintained between fixed centers of operation and mobile units in the field. These systems have been of tremendous assistance in the efficient deployment and supervision of manpower for all functions of utility work, including construction, system operation, and both routine and emergency maintenance. Beginning with a few experimental installations 25 years ago, commercial equipment has since been developed and greatly improved, with changes from AM to FM and increased sensitivity, selectivity, etc. A recent count shows some 9,000 fixed stations and 125,000 mobile units, plus a number of portable units, in service today.

The role of computers in the power industry

The use of network analyzers for power system planning had begun to a limited extent at the beginning of this 25-year period, in 1934, when some three or four such analyzers had been made available. Today, some 35 of these are in use, several of the more recent designs being equipped with a large number of automatically controlled generators and other improved features to facilitate analysis of load and voltage problems on today's complex and expanding systems. In addition to their use throughout the power industry as an indispensable tool for power system planning, these analyzers in some cases have also served as effective teaching media in engineering schools.

Much more recently, the application of digital computers to power system planning problems has made rapid strides. For example, the powerful high-speed IBM 704 computer has been very successfully programed for the calculation of power flow in networks, as well as for other problems in network analysis such as stability problems, and it now seems capable—and perhaps destined—to take over much of the job of network analyzers. The computer solution is, in fact, superior from the standpoint of economy and accuracy for load-flow problems and has been proved capable of solving other problems, such as extremely complex stability analyses which have been entirely beyond the capabiity of the network analyzer or any other practicable method of solution.

In system operation, digital computers are being used for certain calculations in connection with economic dispatching of power system generation, as previously described. They have been of particular value in the calculation of transmission loss factors. Digital computers are being more and more extensively applied, of course, in the commercial and accounting phases of the industry, and in some cases they have done a unique job in calculating distribution transformer loading from customer billing records. Altogether, the use of digital computers appears to have opened up an extensive new field for analysis, not only in system planning problems but for many other types of decisionmaking problems as well.

Distribution

Just as the great expansion in generation over the past 25 years would not have been possible without parallel developments in transmission, similarly the efficient and economical delivery of this energy to ultimate consumers would have been severely handicapped if it had not been accompanied by the extensive and important developments in distribution which have taken place.

One of the major advances, as in the case of large power transmission, has been the development of higher distribution voltages. For example, 2,300-volt delta circuits have practically disappeared by conversion to 4,000-volt "Y" circuits with common neutral. At the same time, a very extensive growth has taken place in the use of the distribution voltages in the 7.2/12-kilovolt "Y" class, beginning largely as a rural distribution voltage, but subsequently developing into extensive use today as a highly economical voltage for urban distribution as well.

Although nowhere near as extensive as 12-kilovolt "Y" distribution, a substantial beginning has been made in the use of 14.4/24.9-kilovolt "Y" in a number of rural areas where it has proved to be practicable and economical. It has also proved economical in some areas where existing 13.8-kilovolt delta systems have been converted to 24-kilovolt "Y".

A start, at present principally in the stage of study and discussion, has been made looking to use of a still higher distribution voltage, 19.9/34.5-kilovolt "Y". Trial installations at this voltage are now underway in the Northwest.

Major improvements in service reliability have been brought about by the use of high-speed circuit reclosures, not only for line-sectionalizing service but also for substation feeder breakers. By this means, circuit clearing is being accomplished at three times the speed of conventional circuit breakers, along with fast restoration of service for transient fault conditions.

In the area of distribution transformers, very important developments have taken place in design improvements, giving better electrical characteristics, reduced physical size, and greater reliability. The use of grain-oriented steel, strip-wound cores, and more efficient insulating materials has practically doubled the capacity available within a given dimension; at the same time, losses and impedance values have been reduced. In one case, as an example, even a fairly recent 167-kilovolt-ampere distribution transformer design has been replaced in exactly the same tank size with a 250-kilovolt-ampere unit.

Although underground distribution in concentrated urban areas was fairly prevalent 25 years ago, particularly in larger cities, it has been greatly expanded during this period, both in large metropolitan areas and in moderate-size cities and towns.

The use of shunt capacitors, both switched and unswitched, has expanded to a great extent during the past 25 years, stimulated by improved manufacturing methods. This has resulted in the development of progressively larger unit sizes, increasing from 15 to 25 kilovolt-amperes, 25 to 50 kilovolt-amperes, and most recently to 100 kilovolt-amperes, all at the prevailing distribution voltages up to 15 kilovolts. At the same time, in contrast to the rising costs for other equipment, the cost of capacitors in dollars per kilovolt-ampere has actually been lowered.

Another important development, extensive in its effect, has been the almost explosive increase in the use of synthetics for cable conductor and other insulating requirements. These include polyethylene, neoprene, polyvinyl chloride, butyl, and many others. Greatly improved characteristics in aging, resistance to chemicals and sunlight, flammability, and many others have been realized.

Aluminum has superseded copper to a large extent for many distribution purposes, including service drops, where it is becoming almost universal practice. Aluminum is also used as a sheathing for paper-insulated cable.

Finally, in secondary voltage practice, considerable use is being made of the higher level 277/480-volt systems. It has not yet been introduced as an official standard, but its coming as an approved practice in the not-too-distant future is foreshadowed.

Utilization

In the past 25 years, and more especially in the period since World War II, electric energy has penetrated deeply into every phase of modern living. In part 1 of this testimony I developed the thesis that electric power is but one of a number of important factors in modern life. But it is nevertheless an important factor. It is essential not only to power our industry but to perform in commerce, on the farm, and in the home the many tasks that have now come to be regarded as essential elements in our day-to-day living. The applications of electric energy range widely, both in function and in magnitude; it would be difficult to conceive our society without the availability of an adequate supply of electric energy. As developed in part 2 of this testimony, there is little doubt that the requirements for electric energy and its applications to more and more functions will continue to expand. The growing requirements for new metals such as titanium and magnesium, along with the rising demands for aluminum, all of which require electrical processes for their production, and the processing of low-grade ore such as taconite, will expand the need for electric energy in industry markedly. Beyond this, the need to expand our productivity to provide the rising standard of living that we have come to expect for a growing population in which the hours of work are falling and the proportion of the population of labor-force age is declining, will also require the application of substantial and increasing quantities of electric energy.

Similar considerations apply on the farm and in commerce. In the home, our rising standards of living are intimately associated with the expanding use of electric energy for the many devices that reduce the work required to maintain the home—to cook, to clean, to preserve foods, and to provide entertainment and information. In both commerce and the home, year-round weather conditioning is becoming increasingly important. The shopping center protected from the weather and maintaining constant temperatures throughout the year, through electric cooling and heating, is just at the early stages of development, and the all-electric home to provide similar comforts is also on the verge of rapid development and extension. All of this indicates a continuation of the rapid long-term increase in electric energy requirements which is likely to continue for a long time.

But this result cannot be expected to develop automatically in the natural course of events. A great deal of effort in research, development, and in utilization of new concepts and discoveries will be required on the part of many technicians, engineers, and technologists associated with the industry. In utilization, particularly, much remains to be done to develop further those devices which show promise of contributing importantly to our national productivity, welfare, and well-being. To cite an example, an important step forward would be the development of an efficient heat storage system which would make possible the combination of an electric heat pump and solar heating system.

Looking ahead

Although in the past quarter century the industry has made very substantial technological strides which have given the country perhaps the finest series of systems for making available to its economy an abundant and highly economical supply of electric energy, many technological challenges loom up for the quarter century ahead and for the period beyond that. To some extent what I have been saying foreshadows these developments. As to a number, I have some further observations.

Table XVI, in part 2 of my testimony, leads to the conclusion that fundamentally the American power systems of the next two decades will to a large extent continue to be powered by fossil-fuel-burning stations. Furthermore, as shown in table XVII of part 2, there is today every indication that coal will have to carry an increasingly greater share of the energy burden as we go into the next quarter century, and this percentage will not materially decline even in the year 2000, even though in electric energy generation its share of the total raw energy supply will decline owing to the expected development of nuclear power.

These quantities of fuel seem destined to grow to new heights in the American economy (900 million tons in 1975 and 1,200 million tons in the year 2000 (table XVII)) if the historical trends that have determined and shaped the history of growth, particularly of electric energy use in the United States, are to continue. Every technological development leading to economies in capital use and in operation will have to be further exploited to achieve such results. Thus we can look for developments in new steam cycles, such as the combination steam and gas turbine cycle, and we can look for developments in the utilization of higher temperatures and higher pressures of steam beyond those in the most advanced projects described earlier.

There are excellent possibilities of further improvements in efficiency by the exploitation of higher pressures, as high perhaps as 15,000 pounds per square inch, but these in order to be economically exploited have to be accompanied by higher temperatures. It is true that this involves us in metallurgical difficulties. But there is no reason for believing that progress will not be made in our knowledge of properties of metals and alloys. We should be able to develop new alloys that can be used in manufacturing boilers, turbines, and auxiliary equipment so as to make possible economic exploitation of these higher temperatures and pressures. Larger units too, beyond the 600,000-kolowatts projected today, are going to be brought into use.

Table XVI and XVII also bring out that there is excellent prospect that by the year 2000 over 50 percent of the total electric energy and over 20 percent of the total energy used in the United States will be nuclear. This change in the position of atomic power vis-a-vis other fuels is likely to add up eventually to a major, although gradually achieved, technical and economic shift. Over the next 20 to 25 years this should make it possible for us to use atomic power, first as a supplement to conventional power, later as a major contributor to our power resources, and still later, but this perhaps will not occur until after the year 2000, as the principal source of electric energy. The effect of this development in atomic generation should be to make possible better conservation and more orderly development of fossil fuel resources: more orderly because there need be no element of panic about them, which might not be the case were the entire energy economy dependent upon fossil fuels.

From an economic standpoint, the effect should also be healthy, since in effect the coming along of the development of atomic power will create some relatively flexible ceilings to the prices of our conventional fuels, which should promote technological development and control of costs in their exploitation.

But other exciting developments in energy generation are in prospect. With all the newness of the principle of generating heat by atomic fission, nuclear-generated energy is merely a substitution of concentrated nuclear fuel for more conventional fuel. Thus, we are continuing the reign of the steam engine which began with Watt 200 years earlier. Fundamentally, the expansive power of steam is used to generate mechanical energy to be converted into electrical energy. In practically all nuclear power reactors developed so far we continue to use the basic heat engine patented by James Watt in 1769 and which for 200 years since then has been used to convert heat—first into mechanical energy and later into mechanical-electrical energy.

In the last 12 months, however, the doors have been opened on three avenues that may ultimately lead to advances in energy conversion that may have effects on energy generation of the future of possibly greater significance than the discovery of atomic fission. ("Future" is used here in the sense of the next hundred years or so.) These are the developments in thermionic generation, thermoelectric generation, and the exploitation of the magnetohydrodynamic principle for the generation of electric energy. Each of these is highly intriguing in its prospects; and although they depend on different principles, they have this important fact in common: all three offer prospects of direct conversion of heat energy into electric energy.

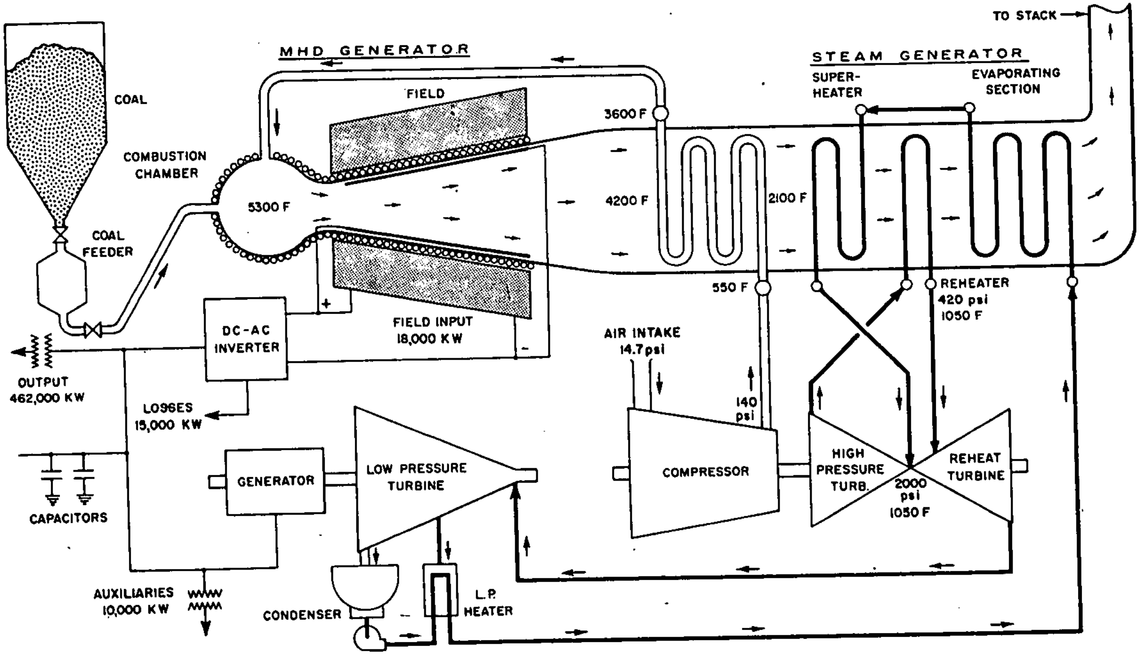
Thermionic emission is the phenomenon of electron emission from the surface of an electron-conducting material due to thermal energy of the electrons within the material. This phenomenon was first observed by Edison (hence the Edison effect) and later, in 1901, fully described by Richardson. New developments along two lines have been reported in the past year for the direct conversion of heat to electricity by this means. Work at Los Alamos Laboratory culminated in the design of a cesium-filled thermionic converter which was operated in a reactor and produced an output estimated at 40 watts. Similar work has been carried out with high-vacuum, close-spaced diodes, which have achieved outputs of several watts using various heat sources, one of which consisted of concentrated rays from the sun. Thus from several sources of energy, electric energy has been directly produced using thermionic converters.

In the case of thermoelectric generation, it is interesting that the basic discovery was made by Seebeck as far back as 1820. By accident, Seebeck achieved with his thermoelectric couple thermal efficiencies comparable to those of the then contemporary steam engine. But the long-range significance of his accomplishments could not be forecast, and as steam engines improved in efficiency, the thermocouple was relegated more and more to the background, until it became nothing more significant than a temperature-measuring device. However, a number of theoretical developments in solid state physics and quantum mechanics and the development of devcies like the semiconductor have now made it possible to think seriously of the thermocouple again as the basis of a new system for energy, and for the inversion, if you please, of electric energy into heat, and through the thermocouple, therefore, into cooling.

In magnetohydrodynamics no such solid achievement has taken place as has occurred in thermionic generation; yet the possibilities for new developments in generation of electric energy are even more exciting. The concept of magnetohydrodynamics is simple enough. Faraday's discovery of electromagnetic induction brought to light the fundamental law that when a conductor and a magnetic field are moved, one with respect to the other, an electric voltage is induced in the conductor; and when a load, in the form of a motor, lamp, or appliance, is connected to the terminals of the conductor, an electric current flows through it.

Faraday's law of induction does not tie down the conductor to any special form—a loop of cooper wire, for example. The conductor could be a conductor of fluid—a gas or a liquid. The motion of such a fluid with respect to a magnetic field constitutes the phenomenon of magnetohydrodynamics. Any arrangement for obtaining any high-temperature, high-velocity gas made conducting (either by virtue of its high temperature or by virtue of seeding with conducting materials, or by both, and passing such a high-velocity gas through a strong magnetic field constitutes a magnetohydrodynamic generator.

To obtain a practical evaluation of the potential gains as well as of the problems inherent in a thermodynamic cycle utilizing a magnetohydrodynamic generator, a 3-month study has recently been carried out jointly by American Electric Power Service Corp. and the Avco-Everett Research Laboratory. A diagrammatic sketch of a preliminary coal-burning magnetohydrodynamic generator is shown in figure 1. This, it will be noted, combines a magnetohydro-



MAGNETOHYDRODYNAMIC GENERATOR
COAL BURNING OPEN CYCLE
FIG. 1

MHD GENERATION	365,000	KW
STEAM TURBINE GENERATION	97,000	KW
TOTAL	462,000	KW
NET HEAT RATE	6200	BTU/KWH

dynamic generator, operating to generate direct current with no moving parts except the compressor required to supply the velocity of the high-temperature gas and the gas moving past the magnetic field, with a conventional reheat steam turbine to obtain a highly efficient cycle. The cycle really performs like a combination steam turbine-gas turbine cycle in which the stationary magnetohydrodynamic generator takes the place of the high-temperature gas turbine.

By virtue of the high operating temperatures—the initial gas temperature entering the magnetohydrodynamic generator being of the order of 5,200 ° F.—a low heat rate of about 6,200 B.t.u. per kilowatt-hour is indicated, a 25 percent improvement on the heat rate of the most efficient plants now projected. This would be subject to further improvement as experience is gained with the operation of this kind of equipment.

I want to stress that these data which I have cited, including the schematic plan of generation indicated in figure 1, are the result of the most preliminary kind of study and that a great deal of further work and research will be necessary to determine the technical feasibility and, later, the economic practicality of any such project.

One other point I would like to make in connection with the magnetohydrodynamic generator principle is that it is not confined to any particular kind of fuel. Thus an atomic reactor could be the source of the high-temperature gas. But because of the economies that this opens up, both in the use of fuel and in eliminating many of the costly parts of a conventional plant, it is entirely possible that the effect on conventional power generation may be greater than on atomic generation.

Because of these exciting prospects a small group of 10 private electric utilities, operated mostly in the Middle West, have reached substantial agreement to sponsor the next phase of this research in a cooperative arrangement with the Avco-Everett Research Laboratory, and additional work on this should commence very soon.

In the field of transmission of electric energy the great progress that has been made in recent years in the development of high voltage, which has given us the highly successful 345–360 kilovolt alternating current transmission lines in operation today in the United States, will surely be followed by an extension of transmission at this voltage and at higher voltages. Increased power system load, increased size of generating units, and even larger concentrations of generating capacity in a single location, and the pressing need to develop further transmission economies, all these factors which have been behind the development of high voltage to date, are going to continue as important factors in the future. Thus it appears almost certain that today's 345–360-kilovolt transmission systems will in the next 20 years, and surely in the next 40 years, be followed by transmission lines operating at from 500,000 to 650,000 volts and possibly even higher voltages. A great deal of research and development, looking toward working out all the technical problems associated with such advances, is now in progress, and further work will have to be started in the next few years.

Further development work in the techniques of distribution of the much larger quantities of electric energy that are likely to be used in the next four decades will have to take place—and I feel certain will take place—and this is even more true with regard to utilization.

Allow me in closing to repeat what I stressed in part 2, that utilization has of necessity to precede generation, and here development can be looked for in every branch of human and economic activity I am confident greater utilization and many more ingenious and efficient means of utilizing energy, particularly electric energy, will be found. Unless this development takes place, the projections of energy use and energy requirements cannot be realized. I believe, however, that these developments will almost certainly take place in a way to bring about energy uses and requirements of close to the order I have indicated throughout my testimony.

Representative Patman. We are very much indebted to you for this fine information sir.

You mentioned about fuel being about 40 percent of the cost of electric power. Have you ever ascertained the capital cost, including particularly the cost of interest rates in electric power?

Mr. Sporn. With a fairly high load factor and with fuel costs between 16 and 20 cents per million B.t.u. capital costs will run about the same as fuel costs and capital costs and costs other than fuel will be about 15 percent above fuel costs; so that a figure that can be and is being achieved today with 20 cents per million B.t.u. fuel in the Ohio Valley at a very high load factor, say at 8,500 hours is a total cost of energy of 4.3 mills per kilowatt-hour at the bus bars, of which the fuel and capital cost each will be roughly 2 mills, and the costs other than capital and fuel three-tenths of a mill, a total of 4.3 mills.

Representative PATMAN. I wish you would repeat that. I didn't get it clearly. Can you draw a comparison particularly between the cost of capital and the fuel cost? You did that in the figures that you gave, but do it in another way.

Mr. SPORN. I wonder, Congressman, if I could not refer you to table I, which shows this very, very clearly. Table I shows a series of costs for various load factors or rates of loading.

Representative PATMAN. I see. You have it here in your table.

Mr. SPORN. Yes, sir.

Representative PATMAN. That explains it all right.

Mr. SPORN. You will find whereas I just gave you for the record a figure of 4.3 mills, using very rough figures, the figure that I show in table I is actually 4.49 mills, but I think that the table is somewhat more conservative than my statement of a minute ago.

The cost other than fuel in the table is taken as four-tenths of a mill. I would be inclined under certain cases to shave that by one-tenth of a mill, which would bring that down to 4.39 mills as against the figure I gave you of 4.30.

Representative PATMAN. Are your concerns feeling the pinch of the high interest rates?

Mr. SPORN. I think that any industry that utilizes capital to the same extent as a utility industry does—and this is true of several other industries, for example, the natural gas transmission industry and the communications industry—will be affected. As I am sure you know, in our industry it takes roughly $4 of capital to produce $1 of annual revenue. So if you want a rough figure of the capitalization of a utility operation that grosses $100 million you won't go very far off if you guess that it has a capital of $400 million that is utilized in its business.

The electric utility industry uses a large amount of capital to obtain $1 of revenue, and is in an expanding phase. Even when times are below normal, the utility industry still has found it necessary to expand to meet the requirements of the economy. As a matter of fact, in many cases, in below normal times, the expenditures for expansion and further mechanization to improve efficiency are the means to help bring the economy out of its trough, so to speak.

No industry that is in that kind of a situation can be unconcerned about the rate of interest. I do not believe that up to the present time there has been any appreciable slowing down in the growth of the utility industry as a result of the recent increases in the interest rates, one of the reasons being that the effect has been averaged out and has not been felt in the overall operations because the capital employed, for example, in the electric utility industry today is of the order of $40 billion. So the change in the cost of $1 billion or $2 billion of capital of that total in the course of a year does not make itself immediately felt.

But I do not believe that it is a matter that one can be indifferent to, Congressman. This is my point.

Representative PATMAN. I feel that the utilities render a great public service and give the people generally an opportunity to participate in the profits by getting their capital in the marketplace. In other words, borrowing money and selling stock to the public.

Some get it through just increasing their prices, profits, and surplus in one way or another, and the consumer in that way paying the cost of the expansion. In the case of the utilities, you get most of your money in the market, do you not, practically all of your money in the market?

Mr. SPORN. Except for the amounts that come in from internal sources, like depreciation, or some retained earnings.

Representative PATMAN. Yes.

Mr. SPORN. But I think any industry like the utility industry that requires so large an amount of additional capital to keep on expanding, cannot possibly operate without going to the public, that is, to the people who will buy their bonds and their stocks, in order to keep up their expansion and provide the service that they are dedicated to taking care of.

Representative PATMAN. The increased rate of interest, if it continues upwards, will eventually cause power rates to increase, will it not?

Mr. SPORN. Well, I think the increased rate of interest will either cause power rates to go up or what is perhaps possible will prevent their continuing to the same extent as in the past the trend of reduction in prices of the utility commodity, the electric service.

As I have pointed out in some of the statements I presented, the utility industry has done this amazing job of continually reducing the price of its product.

Representative PATMAN. I noticed that. It is about 50 percent.

Mr. SPORN. It cannot do this by magic; it cannot do it by a system of mirrors. It can only do it by bringing together a half-dozen major elements, all of which have to work together to make this possible.

One of the elements is expansion in use. Another element is great technological progress. A third element is commanding and enjoying the confidence of the investing public so that the capital can be obtained at a reasonable rate.

There are many other elements of that kind. They all have to come together, Congressman. When any one of them is adversely affected, the overall picture is not necessarily affected in that same ratio, but it obviously contributes an adverse element and may, therefore, counterbalance some of the other factors which would normally bring about reduction in rates.

Representative PATMAN. We often hear about the 50-cent dollar and the 48-cent dollar. But in power production, the people get about $2 of benefit for every $1 paid, are they not; that is, weighing it against your reduction in cost?

Mr. SPORN. Yes, sir. The reduction is even greater than indicated because of the decline in the value of the dollar that has taken place.

Representative PATMAN. Mr. Riley has a question.

Mr. RILEY. Mr. Sporn, I am very much interested in what you had to say about nuclear energy as a source after 1975, when you thought that an optimistic estimate might cause it to supply about 20 percent of the total amount used in 2,000.

Mr. SPORN. Twenty percent of the total amount of energy; not electric energy. Yes, sir. I believe that is an optimistic figure.

Mr. RILEY. I understand. And you warn against neglect of the need to rely to the extent of at least 80 percent on other sources, and particularly on fossil fuels.

Mr. SPORN. Yes, sir.

Mr. RILEY. Two or three questions occur to me in that connection. Do you have something specifically in mind in the way of public policy needed to foster the adequate supply of these fuels?

Mr. SPORN. Well, the main policy I have in mind is a sound, overall approach. I have heard people supposedly well informed say, "Well, we are not concerned with coal and oil and gas. After all, they will all pass out of the picture. The energy that we are thinking about that will take care of us in the future is nuclear energy."

I think this thinking is altogether too broad and not probing enough. It was with this thought that we carried out the studies that I have indicated in my testimony, to try and determine, even on the basis of the most optimistic kind of projections for nuclear development, and we think we are familiar with what is going on, intimately familiar, what part nuclear energy can play in the overall energy economy of the United States; because it is the overall energy economy, I think, that helps to determine much of the kind of industrial economic society we are in this country, how strong we are, how productive we are.

I came to the conclusion, and the basis for it is indicated in the record, that at the most it can be, by the year 2000, about 20 percent. The first thing I believe needs to be done is for us to say "This is really an enormous amount."

As I point out in one of the tables, this represents almost the equivalent of 900 million tons of coal a year. This is a great deal of coal. We are not producing this year more than half of that. If that is the case, don't we have to make sure that that other 80 percent which really will determine how we stand—the 20 percent isn't going to be the determining factor—that that other 80 percent has been fostered all along, that we haven't taken some bad steps here, writing off, perhaps, oil or gas, or writing off coal, on the theory that this is just something that belongs to the horse and buggy stage.

This country of ours has this terrific future. We have projected these enormous increases in energy use. But I have pointed out that these energy uses cannot possibly be supplied even in the year 2000, except to the extent of about 20 percent, by any other sources except those that we know, that we now have available.

We have these great sources of energy. They are major elements in our economy. All of them need to be fostered and encouraged and developed for the sake of the present and for the sake of the future, and the future which we will never have if we don't succeed in successfully bridging these next four decades. It just isn't possible to jump the next four decades and come into a great future in the year 2100 that is based on atomic energy.

Somehow we have to live through the time that intervenes between now and then, and in the next 40 years we will have to rely very heavily on fossil fuels. They are not fossils in the sense of being outmoded by any means. They are terrific agents for advancing the welfare and the well-being of man and of this country of ours.

Mr. RILEY. Thank you.

Representative PATMAN. Mr. Sporn, you will receive the transcript of your statement, and if we desire to ask you further questions, a member of the committee who is absent or a member of the staff, I assume you will be happy to answer it?

Mr. SPORN. Yes, sir. I shall be happy to do so.

Representative PATMAN. Thank you very much for your appearance here today.

Mr. SPORN. Thank you very much, Mr. Chairman.

Representative PATMAN. We have as our next witness Mr. Francis L. Adams, Chief, Bureau of Power, Federal Power Commission.

STATEMENT OF FRANCIS L. ADAMS, CHIEF, BUREAU OF POWER, FEDERAL POWER COMMISSION, ACCOMPANIED BY EDGAR T. HUGHES, CHIEF, DIVISION OF ELECTRIC RESOURCES AND REQUIREMENTS; AND NORMAN C. NELSON, CHIEF, SECTION OF POWER, SUPPLY AND REQUIREMENT, FEDERAL POWER COMMISSION

Representative PATMAN. We are glad to have you, Mr. Adams. You may proceed in your own way, sir, in reading your statement.

Mr. ADAMS. Thank you, Mr. Chairman. I wish to express my appreciation to the committee for inviting me to come here today to discuss this subject.

May I, before I proceed, introduce two members of the staff of the Commission's Bureau of Power, who are here today, who may assist me in answering questions if need be, Mr. Edgar T. Hughes, Chief of our Division of Electric Resources and Requirements, and Mr. Norman C. Nelson, Chief, Section of Power Supply and Requirements.

You have asked me to prepare a statement dealing with the place of hydroelectric power in the Nation's future power supply. In presenting this information, I will endeavor to make it useful to the purpose of these hearings which, I understand, is the examination of the adequacy of the U.S. energy resources to supply anticipated needs, and the effect of improved technology on the production and efficient use of our energy resources.

From the designated title of his statement, it might appear that my remarks should be directed primarily to hydroelectric power. However, I am sure you realize that the amount of hydroelectric generating capacity now developed and to be developed in the future depends on several economic and technological considerations. There must, of course, be a market for power having the characteristics of that which could be produced from hydroelectric projects. In determining the best use of a hydroelectric project, careful study must be made of variations in the available waterpower and also variations in the power requirements of the market area. These are problems which are regularly investigated by the Federal Power Commission in connection with the licensing of hydroelectric projects, and in cooperative work with other agencies in the planning of Federal river development projects.

There is also another important factor which must be considered before a hydroelectric project is built, and this concerns its economic evaluation. Until a few years ago, the electric power requirements of the country were supplied either by hydroelectric plants or by thermal plants using the conventional fuels—coal, oil, and gas. Recently, another energy source, nuclear fuel, has come into the picture. While this complicates the engineering and economic studies, the problem is still the same and that is to select the type of prime mover which will be the most economical means of providing the electric power needed, taking into consideration both capital costs and operating costs. Before it is decided that electric generating capacity should be installed at a river development project, studies are made to compare the cost of the hydroelectric power with the cost of power from alternative sources such as conventional steam-electric plants.

Thus, the subject I have been asked to discuss—hydroelectric power—is one that involves consideration of not only the Nation's water-power potential but also the entire electric power industry—its present status, past growth, and prospects for the future.

First, I should like to point out that electricity is not, in the ordinary sense, a basic energy source such as the fossil fuels. In the case of hydroelectric power, it comes fairly close to being a basic energy source, since it is produced by converting the power of falling water into electric power and no natural resources are consumed in the process. The production of electric power by thermal plants, however, depends upon the availability of basic energy sources—coal, oil, and gas, and now nuclear fuel—and these natural resources are consumed in the process.

As long as these energy sources are available, there will be an adequate supply of electric power in the United States to meet any foreseeable needs. It is the usual practice of electric utility systems to maintain reserve capacity sufficient to meet their power requirements at all times, having regard for unforeseen increases in load as well as outages of generating capacity and other electrical equipment. Only in very rare instances growing out of unusual or emergency conditions has there ever been a shortage of electric power in any area or region of the country. There are isolated instances of fairly serious local power failures, such as the recent experience in New York City during which an important area was without electric service for a short period due to simultaneous failure of a considerable number of underground distribution cables. I could cite other instances of power failures which resulted in temporary interruptions of electric supply to consumers, such as the loss of the Schoellkopf hydroelectric plant of Niagara Mohawk Power Corp. due to a rock slide. Electric utilities are well equipped to deal with a wide variety of emergencies, including mechanical failures as well as damage caused by natural forces, and their ability to restore service quickly after such emergencies is well known.

Before proceeding further, I should like to make a few observations on the importance of electric power to the Nation's economic well-being. Our high standard of living today is in no small part due to the availability of an ample supply of electric power. When it is realized that the annual per capita use of electric energy in the United States at present is around 4,200 kilowatt-hours, it can be appreciated that our way of life would be completely changed if we had to provide other means of doing the work now done by electricity. The use of electric energy in every aspect of the economy has been growing rapidly, and there is no doubt that electric energy has contributed greatly to the industrial, economic, and social growth this country has attained.

As far as increased industrial production is concerned, electric power has been a tremendously important factor. Total industrial use of electric power in 1920 was only 33 billion kilowatt-hours. In 1958, it had grown to 358 billion or nearly 11 times the amount used in 1920. On the other hand, the Federal Reserve Board index of industrial production was 41 in 1920 as compared to 134 in 1958, which gives a ratio of approximately 3.25 to 1. Thus, the increase in the use of electric power in industry during the 38-year period was far greater than the increase in physical production of goods. The United States was certainly not a backward country industrially in 1920, and the more than 200 percent increase in the Nation's industrial output from 1920 to 1958 is no small accomplishment. But it could not have been done without the increased use of electric power per unit of production. Electric power has made possible the continued addition of new and improved machines which have assisted the Nation's workers in producing more and more goods for the Nation's economy.

With respect to total use of electric energy, not just industrial use, the Federal Reserve Board index of industrial production may not be as useful an index as gross national product (GNP). GNP is a measure of total output and includes personal consumption expenditures for goods and services; new construction, expenditures for producer durable equipment; and Government purchases. All of these items affect in varying degree the use of electric power. In 1920, total electric power consumption in the United States was 58 billion kilowatt-hours. By 1958, consumption had grown to 728 billion. GNP, in terms of 1958 dollars grew from 128 billion in 1920 to 442 billion in 1958. A little arithmetic reveals that during this period the kilowatt-hours consumed per dollar of gross national product increased from 0.45 to 1.65. It is, of course, impossible to say how much of the increase in gross national product is attributable to increased use of electric energy, especially when it is realized that expenditures for electric energy amount to but a small percentage of the gross national product—something over 2 percent in 1958. But there is no doubt that electric power has become a very important factor in the Nation's total productive capacity.

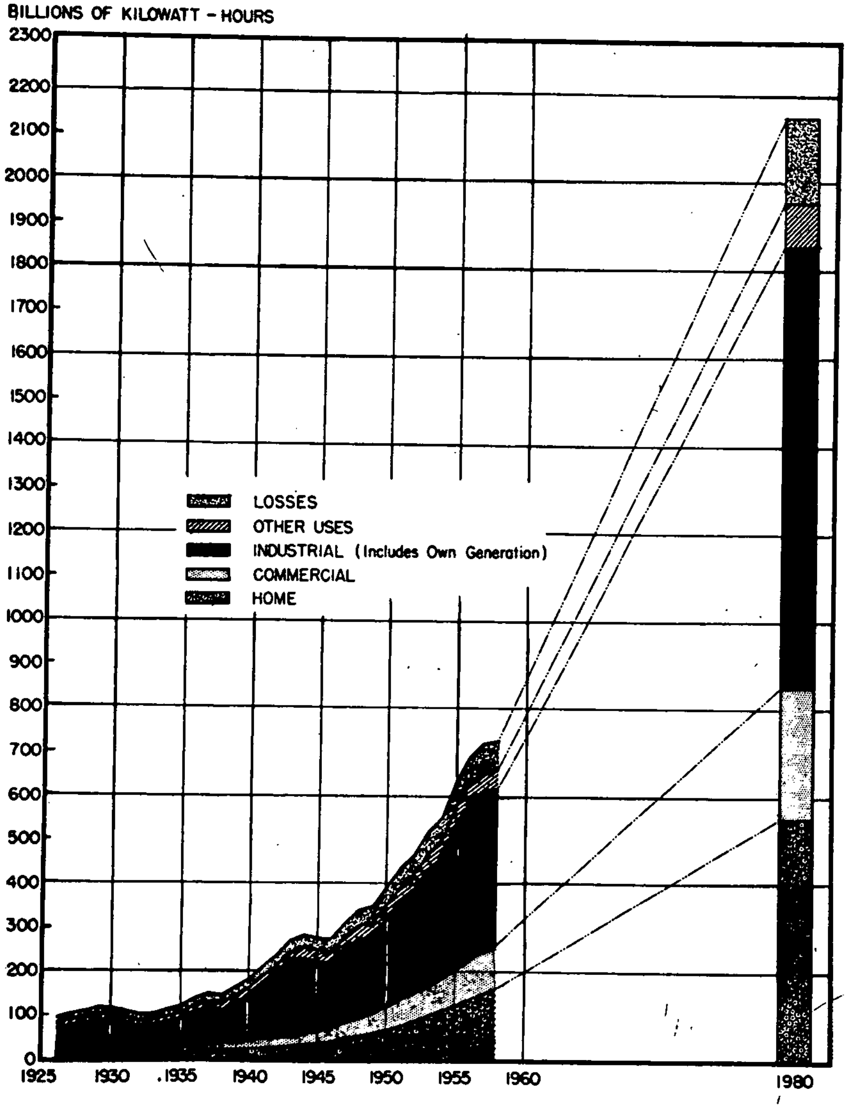
I shall now proceed with a general discussion of the composition of the Nation's power requirements and supply, both past and future. Attached to this statement are several charts which will illustrate the points discussed.

At the end of 1958, electric utility systems had a total installed capacity of 143 million kilowatts which was divided, according to type of generating plant, approximately as follows: 29 million hydroelectric, 111 million steam-electric, and 3 million internal combustion. About 105,000 kilowatts of nuclear capacity are included in the steam-electric capacity. In addition, industrial plants had a capacity of 18 million kilowatts, of which approximately 1 million was hydroelectric, 16 million steam-electric, and 1 million internal combustion. From the preceding figures it is seen that total U.S. generating capacity at the end of 1958 was 161 million kilowatts. These figures do not include Alaska and Hawaii which became States in 1959. Alaska has about 350,000 kilowatts of generating capacity; Hawaii, 400,000. The total 1958 production of power by electric utility systems in the United States was 725 billion kilowatt-hours, exclusive of about 2 billion produced by Alaska and Hawaii. The United States also exports and imports some power to and from Canada and Mexico. There was a net import of approximately 3 billion kilowatt-hours in 1958.

To assist it in making studies of the utilization of electric power, the Federal Power Commission obtains information on use by various consumer classifications (chart 1). These include the home, commercial establishments, industrial plants, and a number of other categories including farm, electrified railroad transportation, and street lighting. Over the years, home use has grown faster than any other category. Our first good record of use of electricity in this classification is for the year 1926, when the average home used about 430 kilowatt-hours (chart 2). In 1958, due to the great increase in the use of appliances in the home, including water heaters, ranges, refrigerators, washing machines, and clothes driers; and to better lighting and growth of electric space heating load, average home consumption had increased to about 3,300 kilowatt-hours. During this period home use grew from 12 percent of total sales by utility systems to more than 27 percent in 1958. Commercial use has increased from 14 percent of the total in 1926 to 17 percent in 1958, and the average commercial establishment now uses 16,000 kilowatt-hours per year compared to 3,100 in 1926. Sales of electric power to industry represented 59 percent of the total in 1926, and although the classification is still by far the largest, it has fallen to 48 percent of total consumption at present. This does not include power generated by industrial plants. Taking this load into consideration, industrial use of electric power amounted to 54 percent of the national total in 1958.

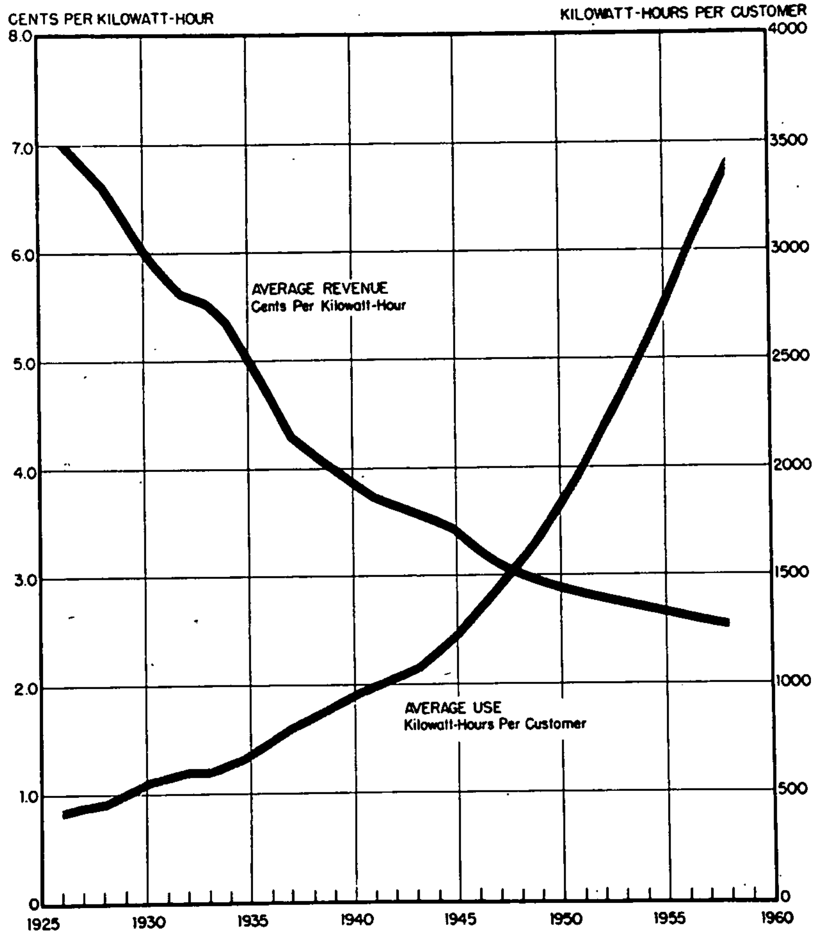
GROWTH OF ELECTRIC ENERGY REQUIREMENTS BY TYPE OF USE

UNITED STATES
1926–1958 ACTUAL, 1980 ESTIMATED



2

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



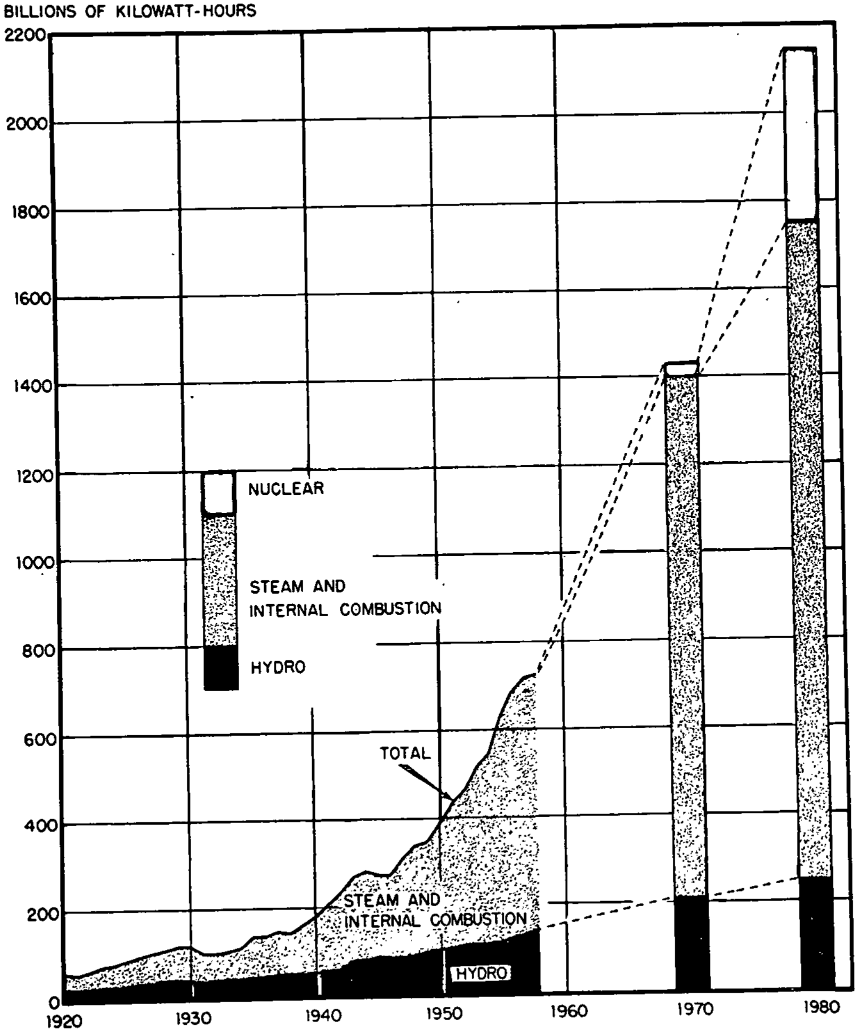
It is often stated that the load of the electric utility industry has had an historical growth equivalent to a doubling every 10 years. This gives a somewhat inaccurate picture of what has happened in the past. For example, the electric load in 1912 was 4.8 times the load in 1902, and the load in 1938 was not quite 1.4 times that in 1928. Growth since World War II has averaged better than a doubling in every 10 years, but the present rate appears to approximate a doubling in 10 years.

There are many factors which influence electric load growth. One of the most important is population. The country's population has been growing at an unusually rapid rate since World War II, and it is expected to continue to grow at a substantial rate for many years. As various segments of our economy expand, electric power consumption will also increase and its rate of growth will be faster than that of the overall economy. The latest available load forecasts of the Federal Power Commission, which relate to the United States, exclusive of Alaska and Hawaii, anticipate that annual electric utility requirements will exceed 2 trillion kilowatt-hours by 1980. In addition, industrial plants may generate as much as 150 billion, giving a total national requirement of more than 2.15 trillion kilowatt-hours (chart 3). It is estimated that in the period 1959 through 1980, electric utilities will have to add a total of more than 300 million kilowatts of generating capacity in order to meet the anticipated load growth. Industrial plants will probably add from 15 to 20 million, making a total of about 320 million kilowatts to be added in a 22-year period. This may seem like a large amount when compared with the 161 million kilowatts of generating capacity available at the end of 1958. It may be noted, however, that load forecasts of the Federal Power Commission appear to be conservative when compared with forecasts prepared by representatives of the electric utility industry. Some of the industry projections for 1980 are as much as 50 percent greater than those of the Federal Power Commission.

3

PRODUCTION OF ELECTRIC ENERGY IN THE UNITED STATES UTILITY AND INDUSTRIAL

1920–1958 ACTUAL 1970 AND 1980 ESTIMATED



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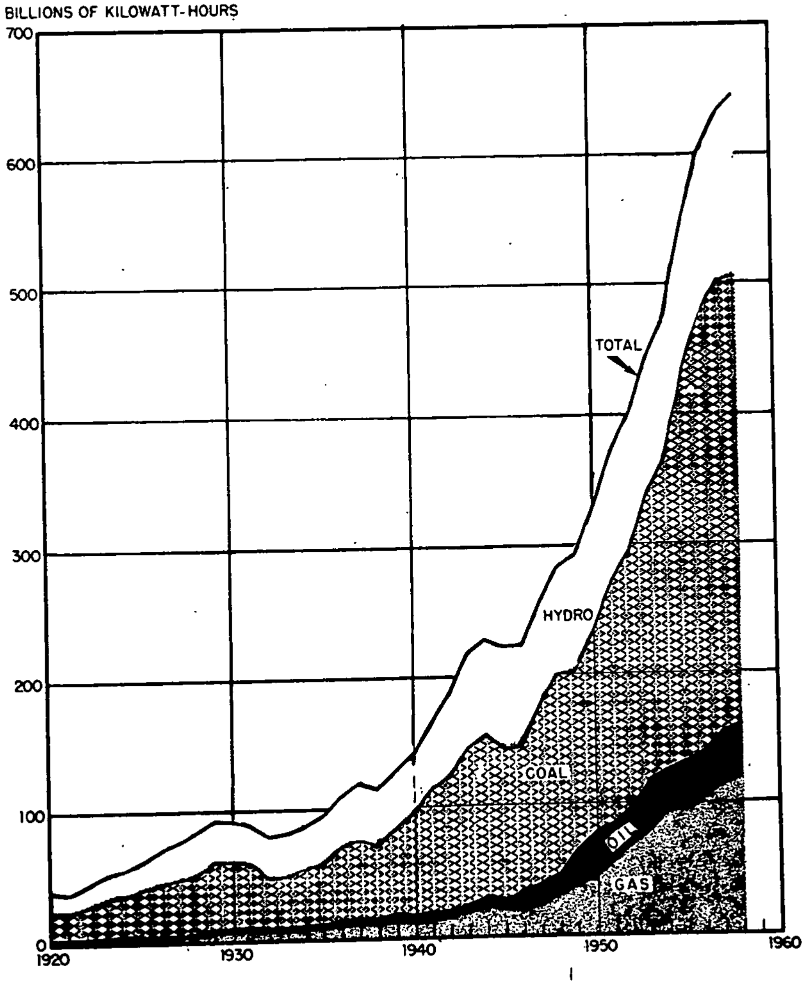
The Commission's estimates of future electric loads are prepared in its regional offices with coordination and supervision by the Washington staff. The regional offices utilize the detailed records of past growth of all the utility systems in their respective regions, and they are frequently in contact with the utilities in order to obtain their views regarding the outlook for the future. They also analyze the resources of the individual regions, past economic growth, and future prospects.

The estimates represent the best opinion of the regional offices, and we are not surprised that FPC estimates are lower than those of the industry, for a number of reasons. One of the most important reasons is that the Federal Power Commission, while it is interested in assuring an adequate supply of electric power, does not actually promote the use of electricity, sell electricity, or sell electric products. The forecasts of the electric power industry appear to be in the nature of goals that the industry feels may be reached through intensive sales efforts. Sales goals are often higher than actual accomplishments, although in the case of electric power, actual loads have generally been higher than the estimates of the Federal Power Commission, as well as those of other parties. Unusual circumstances, primarily caused by war and the effects of war, as well as measures for avoiding future wars, are factors that were either not foreseen or not adequately taken into consideration in the assumptions on which such estimates were based. In any event, it must be recognized that load forecasting is not an exact science and is subject to a wide range of opinion as to what the future may hold.

I have stated that between now and 1980 electric utilities in the United States will have to add more than 300 million kilowatts of generating capacity and that industrial plants may add some 15 to 20 million. Figures such as these are quite easily derived from estimates of future electric energy needs. However, to break down the future generating capacity by type of prime mover is a more difficult problem. Nevertheless, I will venture an estimate, based on studies made by the Commission's Bureau of Power, that about 265 million kilowatts of the additional electric utility capacity to be installed by 1980 will be in steam-electric plants, 35 million in hydroelectric plants, and between 3 and 4 million in internal combustion plants.

Most of the 265 million kilowatts of steam-electric capacity will be in conventional steam-electric plants utilizing coal, oil, or gas, but a substantial portion will be supplied by nuclear plants. Over the years coal has been the predominant fuel, although its relative position has declined somewhat (chart 4). Back in 1920 coal accounted for nearly 90 percent of the energy generated in electric utility steam-plants compared to 65 to 70 percent today. Oil use has fluctuated widely in the past, but it has never amounted to more than 14 percent of the total and has been holding at about 8 percent in the last few years. Natural gas has consistently risen in importance. In 1920 it accounted for only 2 percent of fuel used by electric utilities compared to 23 percent today, and its relative position has not changed materially in recent years. I am not in a position to forecast the extent of use of each of the three fuels in the future, but it might be assumed for study purposes that the future relative positions of the conventional fuels will remain about the same as they are now.

ELECTRIC UTILITY GENERATION BY SOURCE OF ENERGY UNITED STATES 1920-1958



The problems involved in the development of economically competitive nuclear power are many and complex and we are still in the research and development stage. Among the many types of power reactors, none can yet be singled out as the best from the standpoint of operation and economics. Both construction costs and fuel costs are quite uncertain at this time; also, there are many metallurgical problems to be solved, and it will be some time before sufficient operating and maintenance experience is gained to reach conclusions as to reliability and costs. Estimates of the amount of nuclear generating capacity that might be in service by 1980 vary widely—from about 5 percent of the total power supply to several times that figure. In an address which I made in November of last year before the annual meeting of the Northern West Virginia Coal Association, I made an estimate that total nuclear plant capacity on utility systems in the United States might be in the neighborhood of 50 million kilowatts by 1980. I am not aware of any developments in the past year that would justify a revision of that estimate.

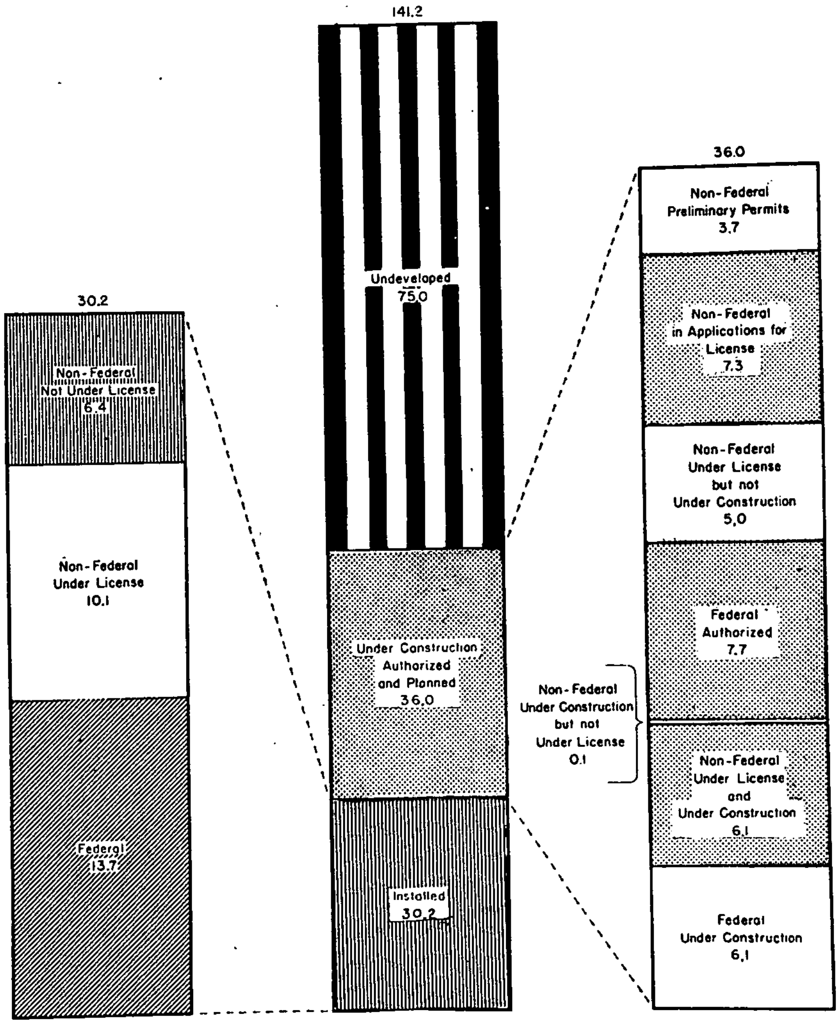
I will now turn to hydroelectric power and its probable place in the Nation's future power supply. The first hydroelectric station in the United States was a 12.5-kilowatt plant on the Fox River in Wisconsin, constructed in 1882. By 1902, the first year for which fairly reliable information is available on the electric power industry, total hydroelectric capacity was over 1 million kilowatts, largely in industrial establishments. With the development of long-distance transmission of electric power, industrial plants began to locate at market areas and in areas where raw materials were available. Thus we find that although industrial hydroelectric capacity reached a total of about 1 million kilowatts a few years after 1902, there has been practically no incerase since that time. On the other hand, electric utility systems have steadily increased their hydroelectric capacity to a total of about 29 million kilowatts in 1958. The distribution of this capacity by class of ownership is approximately 47 percent Federal, 42 percent private and 11 percent non-Federal public bodies.

Chart 5 shows the breakdown of existing hydroelectric capacity by licensed projects and projects not under license. Federal capacity, of course, is not subject to Federal Power Commission licensing. It totaled about 13.7 million kilowatts on January 1, 1959. The remaining 16.5 million kilowatts of hydroelectric capacity is made up of 6.4 million non-Federal capacity which is not under license and 10.1 million licensed non-Federal capacity. The chart also shows that the United States has a total estimated potential hydroelectric capacity of slightly more than 141 million kilowatts. The figures on this chart include Alaska and Hawaii. Alaska has a developed hydroelectric capacity of about 68,000 kilowatts and Hawaii 17,000. Total undeveloped hydroelectric power in Alaska is estimated to be about 19 million kilowatts and in Hawaii about 300,000 kilowatts.

5

HYDROELECTRIC GENERATING CAPACITY IN THE UNITED STATES (INCLUDING ALASKA AND HAWAII) DEVELOPED AND UNDEVELOPED JANUARY 1, 1959

IN MILLIONS OF KILOWATTS



You may be interested in how the undeveloped waterpower of the United States is distributed by geographical regions. Chart 6 shows this for January 1, 1958. The figures are broken down into capacity already developed and that remaining to be developed. Time was not available to bring this chart up to date, but I believe it serves the purpose of giving you an indication of the relative importance of the several regions with respect to their hydroelectric power potential. The Pacific region has the largest existing development and also leads in undeveloped resources. Its total hydroelectric potential is approximately 44 million kilowatts.

The undeveloped waterpower figures for the United States represent totals for individual plant sites. Consequently, the total figures can be considered as fairly reliable. It should be noted, however, that the estimates of undeveloped waterpower include projects on which engineering and economic feasibility has been demonstrated, as well as projects at sites where physical conditions indicate engineering feasibility and give promise at some time of economic feasibility. The estimates with respect to the latter class of projects are subject to revision either by increase or decrease as additional information becomes available concerning streamflow, reservoir sites, costs, and other pertinent factors. However, we do know enough about potential projects to be able to estimate with some confidence that about 36 million kilowatts of additional hydroelectric capacity will be built between now and 1980. If that estimate is fulfilled, the Nation's developed waterpower will total about 65 million kilowatts by 1980, or 46 pecent of the total hydroelectric potential.

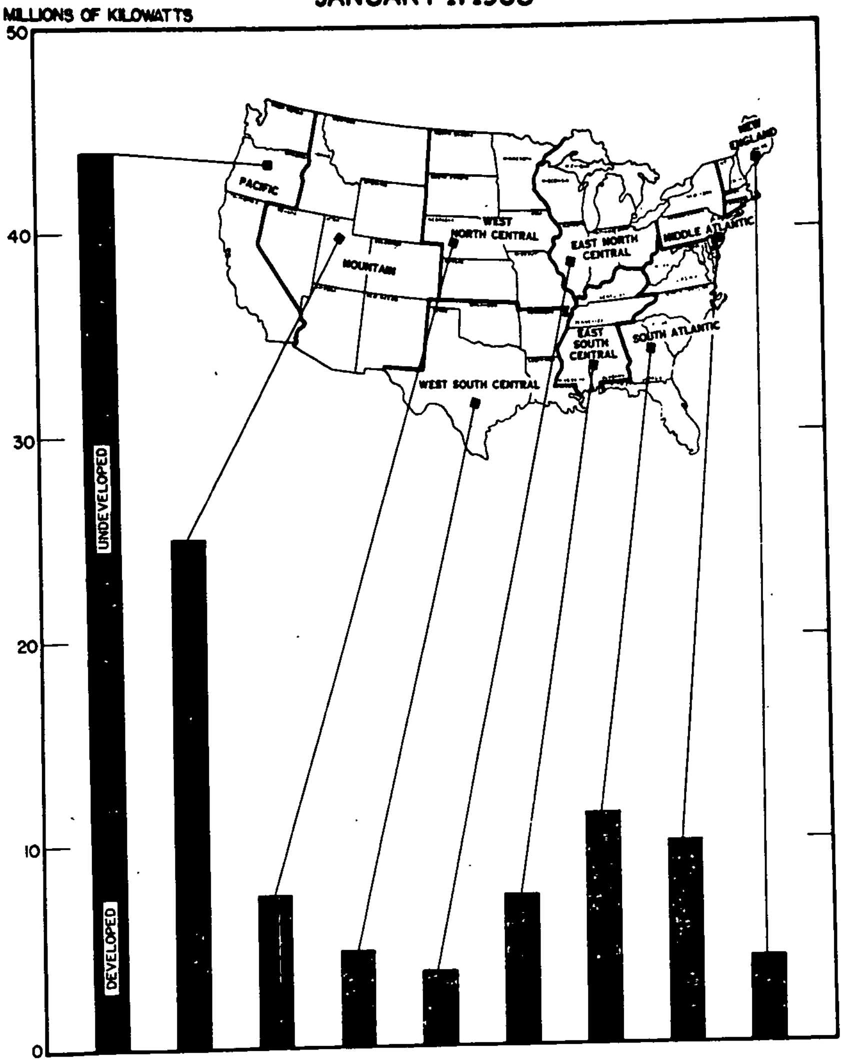
The makeup of the expected hydroelectric capacity additions by 1980 is shown in chart 5 and I will read the figures. The total capacity under construction as of January 1, 1959, was 12.3 million kilowatts, of which Federal projects represented 6.1 million, non-Federal licensed projects 6.1 million, and non-Federal projects not under license 0.1 million. Federal plants authorized for construction total 7.7 million kilowatts and non-Federal projects which have been licensed but are not yet under construction total 5 million. An additional 11 million kilowatts probably will be constructed by 1980. Of this total 7.3 million represents non-Federal applications for license to build and 3.7 million preliminary permits that either have been granted by the Federal Power Commission or have been applied for.

It is of importance to know how much energy is available from present hydroelectric plants and how much we expect from future plants. Hydroelectric plants are valuable not only for their generating capacitl but also for their energy production, and there is a wide variation over the country with respect to the amount of power in terms of kilowatt-hours that can be generated per kilowatt of installed capacity. A publication of the Federal Power Commission entitled "Hydroelectric Power Resources of the United States—Developed and Undeveloped," last issued in 1958, lists each existing and undeveloped project and shows for each the installed capacity, average annual generation, and gross head. For the country as a whole in an average year the existing hydroelectric plants will generate a number of kilowatt-hours equal to about 5,000 times the installed capacity in kilowatts. In other words, average hours use of existing capacity is close to 5,000 per year.

6

DEVELOPED AND UNDEVELOPED HYDROELECTRIC POWER BY GEOGRAPHIC DIVISIONS

JANUARY 1, 1958

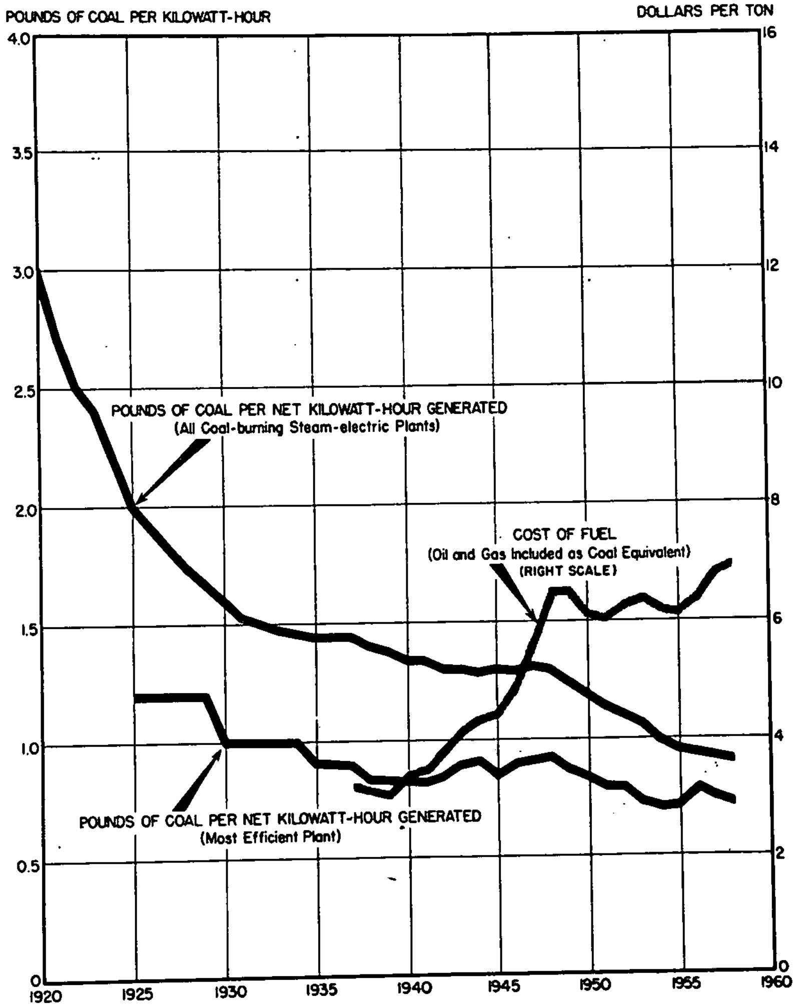


You may be interested in knowing that steam-electric plants also operate at close to 5,000 hours use of capacity. They could, except for planned maintenance and emergency repairs, be operated continuously over the 8,760 hours in the year; but in actual experience they are operated as required by the electric loads, having due regard for the power available from hydroelectric plants in the same area. Hydroelectric plants are, of course, operated to take full advantage of the riverflow taking into consideration needs other than power, such as irrigation, navigation, and flood control. As might be expected, the hydroelectric plants that can provide the most output per kilowatt of installed capacity are usually the more attractive plants and are the first to be constructed. This is true in spite of the fact that there are many low plant-factor hydroelectric plants which are very valuable to electric utility systems in supplying the peak portions of the load. Hydroelectric plants expected to be built between now and 1980 will not generate as many kilowatt-hours per kilowatt as present plants, the estimated figure for an average water year being in the neighborhood of 3,700, compared to the 5,000 for plants now built.

I understand that this subcommittee is also interested in the impact of technology on the production and efficient use of the Nation's energy resources. In this respect the electric utility industry has a remarkable record of accomplishment which has enabled it to hold down its costs in spite of the increased cost of nearly all other segments in our economy. Almost all items of utility cost, exclusive of taxes, have tended to decrease in terms of dollars per kilowatt-hour of output, and the total price paid by all consumers of electric power in the United States has shown almost consistent decreases. In 1958 the average price paid by all consumers amounted to 1.71 cents per kilowatt-hour as compared with 2.71 in 1926, a decrease of about 37 percent during a period when the general cost of living increased considerably. For a time, during World War II and a short time thereafter, both operating costs per kilowatt-hour and construction costs increased, but the price of electricity to the user did not rise. The average price per kilowatt-hour sold to ultimate users was lower in 1950 than in 1940 and lower in 1958 than in 1950. Capital costs have been held down by resort to larger and more efficient generating units, higher transmission voltages, improvements in plant design, and economies all along the line. Chart 7 shows the effect of increased efficiencies on the amount of coal required to generate a kilowatt-hour. Another factor in power costs is the increased kilowatt-hour consumption per customer which has naturally reduced the unit cost per kilowatt-hour, since it costs less per kilowatt-hour to serve large-use customers than low-use customers.

7

ANNUAL COAL RATE 1920-1958
COST OF FUEL 1937-1958
ELECTRIC UTILITY GENERATING PLANTS IN THE UNITED STATES



In order to market the output from the much larger generating units being constructed, power will have to be transmitted over longer distances and transmission voltage levels will continue to be raised as in the past. The highest voltage transmission lines in the United States today are 345 kilovolts, but tests are now being conducted jointly by manufacturers and utilities to study the feasibility of extrahigh transmission voltages in the 460-kilovolt to 750-kilovolt range.

With larger units and higher transmission voltages there will be a greater degree of interconnection and coordination among utility systems of the country. The Federal Power Commission has a responsibility under the Federal Power Act to promote and encourage interconnection and coordination among power systems for the purpose of assuring an abundant supply of electric energy throughout the United States with the greatest possible economy and with regard to proper utilization and conservation of natural resources. The Commission's staff has made many interconnection studies in the past and has several in progress at the present time. Among the many advantages to be gained through interconnections of power systems are the sharing of economies through use of the most efficient generating units, reduction in capital costs by use of larger units, a better scheduling of equipment installations, sharing of reserves, and taking advantage of diversity in system loads and waterflow at hydroelectric plants. By operating together, the combined system peak becomes less than the sum of the individual peaks of the separate systems, and this reduces the total amount of generating capacity needed to serve the interconnected systems.

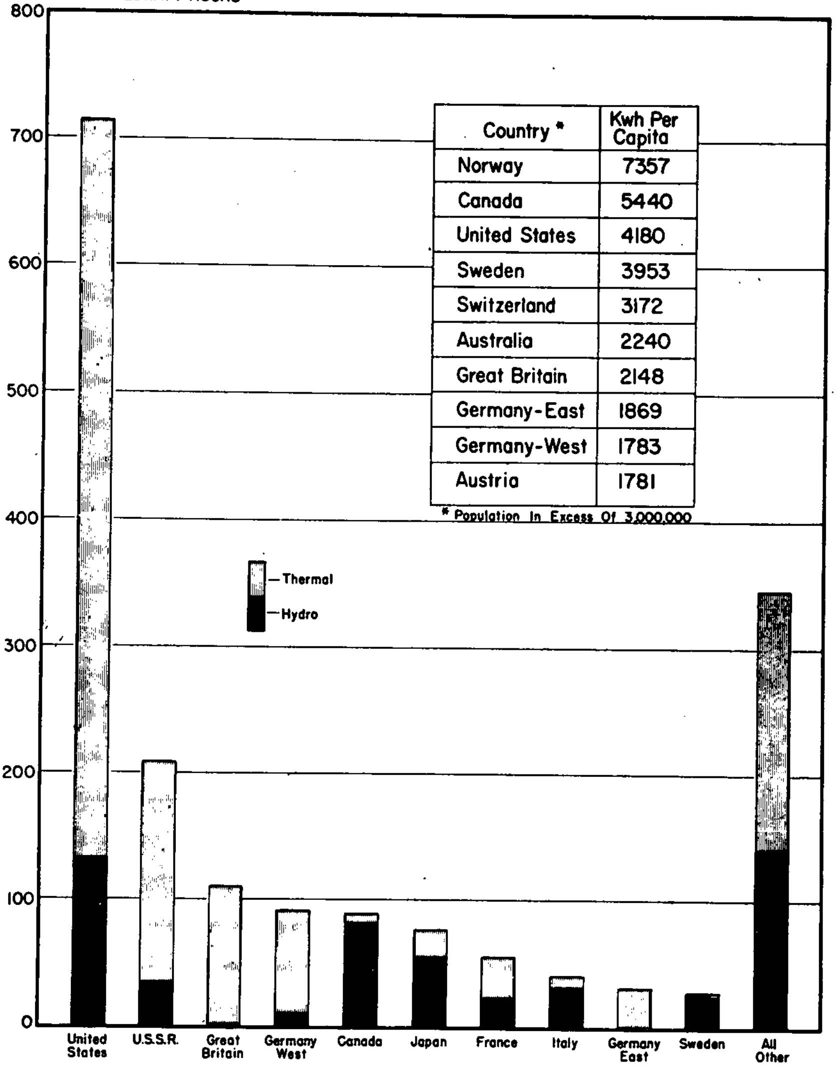
With respect to system peaks, sales efforts of utilities are continually directed toward promoting the use of appliances and equipment that will consume the greatest number of kilowatt-hours, at the same time causing the smallest possible increase in system demands. With due regard to the time needed for proper maintenance of electrical equipment, unit costs are lower when capacity is utilized to the fullest extent over the entire year. There are wide variations in electric utility system loads during the day and the week and even over the months due to our living habits in the home, shopping habits, hours of operation of industrial plants, and varying weather conditions. From a seasonal standpoint, air-conditioning loads have become very important and have caused a change from the normal winter peak to a summer peak in many areas of the country.

At the time of World War II, the great majority of utility systems in the country had winter peaks. Toward the end of the war, there was a shift from winter to summer peaks in certain areas particularly in the Southwest. Since then, summer peaks have consistently been gaining on winter peaks in most areas of the country. For purposes of illustration, I will cite a few figures which apply to what we in the Federal Power Commission term power supply areas. These are areas which have been established by the Commission and represent groups of utility systems that are substantially interconnected. It happens that there are 48 power supply areas in the United States although the boundaries generally do not follow State lines. In 1947, only 10 areas had summer peaks. In 1957, as many as 23 of the areas had summer peaks. For the entire United States, the winter peak in 1947 was 48.4 million kilowatts and the summer peak 44.5 million. In 1957, the summer peak was 108.2 million kilowatts as against a winter peak of 108 million. Comparison of the 1947 and 1957 peaks is somewhat misleading, however, because the recession which began in the later part of 1957 served to reduce the winter peaks. Nevertheless, it is clear that summer peaks have been increasing faster than winter peaks and are expected to do so for at least a few more years. As summer peaks are overtaking winter peaks, the electric utilities are endeavoring to promote electrical applications which will increase winter loads. One of these, and perhaps the most important, at the present time, is electric space heating. But the situation is not static, and as time goes on utilities will continue to watch load patterns and take measures designed to assure the greatest possible economies in producing and delivering electric power to the consumer.

To sum up the power situation in the United States, there is ample reason to believe that the power supply will be completely adequate to meet the Nation's growing loads, and that engineering talent will continue to be utilized to improve electric utility operations and bring about economies in cost. This country with one-sixteenth of the world's population has more than a third of the world's electric generating capacity. Chart 8 illustrates how the United States ranks among the 10 leading power producing countries of the world. It is far ahead of Russia, which ranks second. On a kilowatt-hour per capita basis the United States is also well ahead of Russia with 4,180 kilowatt-hours per capita in 1957 compared to 1,045 for Russia. It is interesting to note, however, that two other countries have a higher production per capita than the United States, namely Norway and Canada. This is brought about largely by high power consuming industries, such as aluminum refining, in these countries.

8

WORLD POWER DATA
TEN COUNTRIES WITH GREATEST ELECTRIC ENERGY PRODUCTION
1957



Country *	Kwh Per Capita
Norway	7357
Canada	5440
United States	4180
Sweden	3953
Switzerland	3172
Australia	2240
Great Britain	2148
Germany-East	1869
Germany-West	1783
Austria	1781

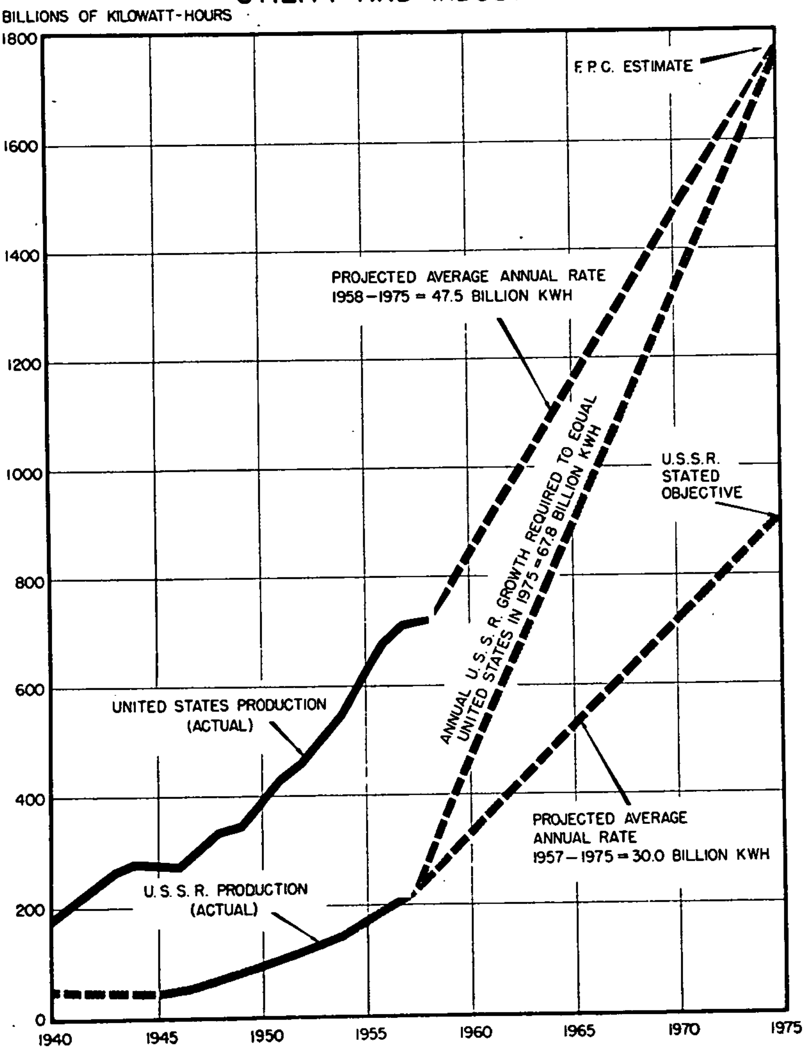
* Population In Excess Of 3,000,000

During the past year there has been much discussion of whether Russia is catching up with the United States in the production of electric power. Chart 9 gives a comparison of electric energy production in the United States with that in the U.S.S.R. over a period of 17 years in the past and 19 years in the future. The 1975 estimate for the United States was made by the Federal Power Commission's Bu-

9

COMPARISON OF ELECTRIC ENERGY PRODUCTION IN THE UNITED STATES AND THE U. S. S. R.

UTILITY AND INDUSTRIAL



reau of Power while the corresponding figure for Russia is based on a statement made by Mr. A. S. Pavlenko, Minister of Power Stations, U.S.S.R., at the World Power Conference held in Montreal, Canada, in September, 1958. Mr. Pavlenko gave his figure as the Russian objective, rather than an estimate. Figures on which the chart are based show that in 1945 our superiority in terms of total electric energy production was 228 billion kilowatt-hours, in 1958 it had increased to 491 billion, and by 1975 the margin is expected to be at least 870 billion kilowatt-hours. It appears from this chart that there is little likelihood that Russia will overtake this country within the next 20 years in the production of electric power.

That concludes my statement, Mr. Chairman.

Representative PATMAN. Thank you very much, Mr. Adams. Your testimony is very helpful. About this booklet you mentioned, do you have one of those with you?

Mr. ADAMS. The undeveloped water power booklet?

Representative PATMAN. Yes.

Mr. ADAMS. It is a rather voluminous and detailed booklet that would take some time to bring up completely, but I believe that two of the summary tables in the booklet might be especially interesting for your record.

Representative PATMAN. If you will cite them, we would like to have them.

(The tables referred to follow:)

Percent development of hydroelectric power resources, Jan. 1, 1957

Division and State	Developed installed capacity (kilowatts)	Undeveloped estimated capacity (kilowatts)	Total estimated capacity (kilowatts)	Percentage development
United States	26, 547, 845	90, 599, 800	117, 147, 645	23
New England	1, 535, 710	2, 728, 400	4, 264, 110	36
Middle Atlantic	1, 482, 531	8, 509, 500	9, 992, 031	15
East North Central	935, 484	2, 798, 650	3, 734, 134	25
West North Central	1, 315, 046	6, 201, 650	7, 516, 696	17
South Atlantic	3, 625, 768	7, 585, 700	11, 211, 468	32
East South Central	3, 581, 508	3, 920, 300	7, 501, 808	48
West South Central	949, 620	3, 800, 700	4, 750, 320	20
Mountain	3, 707, 408	21, 332, 950	25, 040, 358	15
Pacific	9, 414, 770	33, 721, 950	43, 136, 720	22
New England:				
Maine	500, 211	1, 262, 600	1, 762, 811	28
New Hampshire	447, 823	594, 500	1, 042, 323	43
Vermont	201, 775	453, 700	655, 475	31
Massachusetts	234, 616	259, 500	494, 116	47
Rhode Island	6, 792	0	6, 792	100
Connecticut	144, 493	158, 100	302, 593	48
Middle Atlantic:				
New York	1, 034, 624	5, 003, 000	6, 037, 624	17
New Jersey	8, 678	225, 000	233, 678	4
Pennsylvania	439, 229	3, 281, 500	3, 720, 729	12
East North Central:				
Ohio	13, 874	341, 000	354, 874	4
Indiana	35, 464	600, 000	635, 464	6
Illinois	43, 131	1, 208, 800	1, 251, 931	3
Michigan	423, 909	328, 050	751, 959	56
Wisconsin	419, 106	320, 800	739, 906	57
West North Central:				
Minnesota	189, 670	230, 850	420, 520	45
Iowa	142, 421	454, 200	596, 621	24
Missouri	196, 800	2, 937, 800	3, 134, 600	6
North Dakota	240, 000	358, 800	598, 800	40
South Dakota	333, 046	1, 227, 500	1, 560, 546	21
Nebraska	207, 199	702, 500	909, 699	23
Kansas	5, 910	290, 000	295, 910	2

Percent development of hydroelectric power resources, Jan. 1, 1957—Continued

Division and State	Developed installed capacity (kilowatts)	Undeveloped estimated capacity (kilowatts)	Total estimated capacity (kilowatts)	Percentage development
South Atlantic:				
Delaware	600	0	600	100
Maryland	274, 165	360, 000	634, 165	43
District of Columbia	3, 000	0	3, 000	100
Virginia	423, 054	1, 205, 900	1, 628, 954	26
West Virginia	207, 560	2, 160, 000	2, 367, 560	9
North Carolina	1, 226, 050	973, 900	2, 199, 950	56
South Carolina	961, 729	786, 200	1, 747, 929	55
Georgia	518, 449	2, 009, 700	2, 528, 149	21
Florida	12, 661	90, 000	102, 661	12
East South Central:				
Kentucky	542, 380	1, 320, 500	1, 862, 880	29
Tennessee	1, 738, 788	507, 300	2, 246, 088	77
Alabama	1, 300, 340	1, 682, 600	2, 982, 940	44
Mississippi	0	409, 900	409, 900	0
West South Central:				
Arkansas	390, 740	1, 483, 500	1, 874, 240	21
Louisiana	0	45, 500	45, 500	0
Oklahoma	166, 500	767, 000	933, 500	18
Texas	392, 380	1, 504, 700	1, 897, 080	21
Mountain:				
Montana	851, 510	5, 799, 100	6, 650, 610	13
Idaho	778, 080	7, 964, 450	8, 742, 530	9
Wyoming	143, 237	977, 900	1, 121, 137	13
Colorado	248, 365	1, 801, 400	2, 049, 765	12
New Mexico	24, 830	187, 500	212, 330	12
Arizona	982, 790	3, 390, 700	4, 373, 490	22
Utah	88, 376	1, 077, 400	1, 165, 776	8
Nevada	590, 220	134, 500	724, 720	81
Pacific:				
Washington	4, 193, 996	18, 722, 800	22, 916, 796	18
Oregon	2, 043, 954	6, 292, 850	8, 336, 804	25
California	3, 176, 820	8, 706, 300	11, 883, 120	27

Percent development of hydroelectric power resources Jan. 1, 1957, by major drainages and selected river basins

MAJOR DRAINAGES

Drainage and river basin	Developed installed capacity (kilowatts)	Undeveloped estimated capacity (kilowatts)	Total estimated capacity (kilowatts)	Percentage development
United States	26, 547, 845	90, 599, 800	117, 147, 345	23
North Atlantic	2, 563, 239	7, 366, 100	9, 929, 339	26
South Atlantic	2, 051, 239	3, 337, 100	5, 388, 339	38
Eastern Gulf	742, 618	2, 960, 300	3, 702, 918	20
Ohio River	4, 192, 807	5, 867, 600	10, 060, 407	42
Great Lakes-St. Lawrence	1, 306, 723	4, 917, 400	6, 224, 123	21
Hudson Bay	16, 306	17, 800	34, 106	48
Upper Mississippi River	620, 160	778, 200	1, 398, 360	44
Missouri River	1, 640, 927	8, 846, 600	10, 487, 527	16
Lower Mississippi River	656, 870	4, 937, 600	5, 594, 470	12
Western Gulf	345, 810	1, 493, 100	1, 838, 910	19
Colorado River	1, 781, 645	5, 407, 000	7, 188, 645	25
Great Basin	477, 336	279, 600	756, 936	63
North Pacific	7, 414, 285	35, 632, 500	43, 046, 785	17
South Pacific	2, 737, 880	8, 758, 900	11, 496, 780	24

SELECTED RIVER BASINS

Drainage and river basin	Developed installed capacity (kilowatts)	Undeveloped estimated capacity (kilowatts)	Total estimated capacity (kilowatts)	Percentage development
Kennebec	208, 455	401, 500	609, 955	34
Androscoggin	146, 081	390, 100	536, 181	27
Merrimack	94, 678	297, 300	391, 978	24
Connecticut	653, 589	758, 400	1, 411, 989	46
Hudson	388, 011	642, 500	1, 030, 511	38
Susquehanna	628, 380	2, 264, 100	2, 892, 480	22
Potomac	16, 106	771, 500	787, 606	2
Yadkin-Pee Dee	228, 667	353, 000	581, 667	39
Santee	850, 753	606, 800	1, 457, 553	58
Savannah	483, 070	975, 000	1, 458, 070	33
Apalachicola	148, 918	815, 100	964, 018	15
Mobile-Alabama	572, 597	2, 019, 600	2, 592, 197	22
Ohio (except Tennessee and Cumberland)	493, 939	5, 042, 100	5, 536, 039	9
Tennessee	3, 205, 408	272, 000	3, 477, 408	92
Cumberland	493, 460	553, 500	1, 046, 960	47
Colorado (Texas)	202, 250	188, 200	390, 450	52
Red	229, 000	789, 800	1, 018, 800	22
Arkansas	178, 430	1, 037, 000	1, 215, 430	15
White	249, 440	1, 448, 000	1, 697, 440	15
Missouri	1, 640, 927	8, 846, 600	10, 487, 527	16
Wisconsin	150, 177	74, 300	224, 477	67
Colorado	1, 781, 645	5, 407, 000	7, 188, 645	25
Sacramento-San Joaquin [1]	2, 653, 830	7, 760, 800	10, 414, 630	25
Columbia	6, 123, 512	31, 575, 400	37, 698, 912	16
Total, listed basins	21, 821, 323	73, 289, 600	95, 110, 923	23

[1] Including Tulare Lake and Buena Vista Lake Basins.

Representative PATMAN. The next witness is Mr. Carl T. Kallina, Chief, Bureau of Rates and Gas Certificates, Federal Power Commission.

STATEMENT OF CARL T. KALLINA, CHIEF, BUREAU OF RATES AND GAS CERTIFICATES, FEDERAL POWER COMMISSION

Representative PATMAN. Mr. Kallina, you may proceed in any way you choose.

Mr. KALLINA. Thank you, Mr. Chairman.

Mr. Chairman, it is a distinct privilege and honor to come today and speak to you about the industry with which I have been connected as a practicing engineer for the past 25 years, of which 19 have been with the Federal Power Commission.

The views expressed in this paper are mine and do not necessarily represent those of the Federal Power Commission or other members of its staff.

It appears that appreciation of the natural gas industry of today and its plans for the future require a look at its history. The first practical use of gas as fuel occurred around 1800 when a factory in England was lighted with gas distilled from coal. The first gas company came into being in April 1812 with the granting of a charter by the English Parliament. The first gas company in the United States received its charter in 1816 from the City Council of Baltimore. By 1853, nearly 300 companies had been formed in the United States to produce and distribute manufactured gas to nearly 5 million customers. Gas service during 1958 was rendered to 32 million customers, of which approximately 90 percent were served with natural gas and the remainder received manufactured gas, liquefied petroleum gas (through mains), or mixed natural and manufactured gas.

George Washington is purported to have made one of the first public records of natural gas by his comments on the "burning spring" found in West Virginia. He was at that time, however, more interested in the independence of the Nation than in exploring the possibility of becoming an "independent producer."

In 1821, natural gas was first produced from a 27-foot well near Fredonia, N.Y., transmitted through wooden logs to two stores and used for gaslights in greeting General Lafayette. In 1858, the first natural gas corporation was formed near the same location. In 1865 prospectors drilling for oil near West Bloomfield, N.Y., discovered natural gas at a depth of about 480 feet. Disappointed at not finding oil, the project was abandoned. In 1870, a "giant step" in the development of the gas industry was taken when the West Bloomfield well, still flowing, was purchased by the Bloomfield & Rochester Natural Gas Light Co. which laid a pipe to Rochester, N.Y., a distance of about 25 miles. This pipe was constructed of white pine, bored to about 8 inches inside diameter and about 12½ inches outside diameter. The joints were similar to the present-day bell-and-spigot type of cast-iron pipe. The only use for the gas at that time was for lighting but because of its low luminosity, the project was abandoned. The first long-distance iron pipeline was constructed 2 years later extending a distance of 5½ miles from Newton to Titusville, Pa.

Early ventures such as these marked the rudimentary beginnings of what has since developed into present-day transmission of natural gas in large volumes over great distances. Natural gas pipelines laid between 1872 and 1890 were relatively short and did not exceed 8 inches in diameter. The pipe was wrought iron with screw coupling joints and the usual pipeline pressure was about 80 pounds per square inch. Today, interstate pipelines of diameters up to 36 inches are being built, and operating pressures on most systems are 700 to 900 pounds per square inch with parts of some systems being operated at pressures as high as 1,350 pounds.

The first high pressure transmission system was constructed in 1891 by the Indiana Natural Gas & Oil Co. consisting of two parallel lines each 8 inches in diameter for the transmission of gas 120 miles from fields in northern Indiana to Chicago. The initial pressure in this pipeline was 525 pounds per square inch.

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In 1904, Kansas Natural Gas Co. was formed for the purpose of constructing a 16-inch pipeline from the Allen, Neosho, and Wilson County fields in Kansas to Kansas City and Joplin, Mo. Additional lines were constructed thereafter so that by 1907 Kansas City, Mo., was completely converted to natural gas. Several other similar ventures were initiated during this time bringing natural gas from southeastern Kansas and northern Oklahoma to Wichita, Newton, and Hutchinson. Additional extensions were made from the northern Oklahoma areas to Missouri. In 1912 with a plan to combine production, transmission, and distribution facilities and adequate reserves of its own, eastern capital entered the midcontinent gas business. Immediately integrated natural gas systems began to be developed, such as Oklahoma Natural Gas Co., in central Oklahoma, the Lone Star Gas Co. in north-central Texas and southern Oklahoma and the Arkansas Natural Gas Co. in Arkansas and western Louisiana. The principal cities served by these systems were Oklahoma City and Tulsa, Okla.; Dallas and Fort Worth, Tex.; Shreveport, La.; and Little Rock, Ark.

Meanwhile, in 1913 large quantities of natural gas having been discovered in California, a pipeline of approximately 150 miles was constructed from Taft, Kern County, to Los Angeles. The most prolific discoveries were, however, those developed in West Virginia, Pennsylvania, and Ohio and lines were constructed to serve large sections of these States, including Pittsburgh, Pa.; Huntington, Charleston, and Wheeling, W. Va.; and Cleveland, Columbus, Cincinnati, Dayton, and Youngstown, Ohio.

By 1925, pipelines of varying lengths up to 300 miles were in operation in 23 States serving 3½ million customers with more than 1 trillion cubic feet of natural gas per year. At this time, also, the great natural gas reserves from the Monroe field of Louisiana and the Panhandle field near Amarillo, Tex., were being developed. The discovery of these fields with their indicated tremendous reserves encouraged study with respect to technological improvements in high pressure transmission to determine the feasibility of transmitting the gas to new and more distant markets. A rapid expansion was soon underway leading to the development of the major systems now operating. By 1934 there existed approximately 150,000 miles of field, transmission, and distribution lines in 32 States, with some transmission systems having lines as large as 24 inches in diameter and extendng 1,200 miles. By 1944, these pipelines were delivering over 2½ trillion cubic feet of natural gas.

According to the American Gas Association (AGA), today's gas industry has $21½ billion in gross assets, and, based on plant investment, is America's fifth largest industry. The natural gas pipeline network of the United States delivers natural gas in or into 47 of the 50 States, with Maine and Vermont anticipating service in the foreseeable future. With the apparent success now being had in the experimental phase of transportation of natural gas as liquid methane via seagoing tanker, it is not inconceivable that in the not-too-distant future our newest State, Hawaii, will complete the cycle.

There were many factors which led to this phenomenal growth since the early 1920's, the most important of which was the development of high tensile strength and thin wall, large diameter pipe, including weldability thereof. This, together with the continued increase in pipe diameters that could be utilized, enabled reliable and economic transmission of the gas from the producing areas to the distant major markets. For example, a 24-inch line has about 3 times more capacity than a 16-inch line under similar operating conditions, and the cost of transportation about 35 percent more economical in the 24-inch line. Secondly, gas came into prominence as a fuel for other than lighting because of its desirability for certain industrial processes and domestic uses, particularly cooking and eventually house heating. Presently, the air-conditioning market is being developed. Natural gas, since becoming a major fuel source, has been generally lower in cost in comparison with other fuels. Even today in most areas of the country, gas continues to hold a competitive advantage over other fuels, although in some localities this advantage has disappeared, particularly for certain industrial uses, and in others is approaching a balance. While the 1920's was a period of growth in the gas industry, the national financial situation in the 1930's appears to have retarded considerably the growth that otherwise might have been expected. For example, of approximately 15 million customers served by gas utilities in 1932, only about one-third were served with natural gas. As stated above, approximately 90 percent were served with natural gas in 1958. It was not until the late 1930's that a perceptible increase in natural gas sales as related to total gas sales is evidenced. Accordingly, by accident of circumstance or keen foresight on the part of Congress, the Natural Gas Act, approved in June 1938, resulted in the establishment of Federal regulation of natural gas by the Federal Power Commission commencing virtually at the outset of the tremendous impact of today's natural gas industry on the economy of the Nation. Today's natural gas pipeline network aggregates 571,500 miles of main, excluding so-called service pipe—that extending from the main to the consumer's meter. By comparison, the total miles of railroad trackage in the United States is approximately 366,000, including main tracks, yard tracks, and sidings.

While the Federal Power Commission has jurisdiction over the construction and operation of facilities for the transportation of natural gas in interstate commerce and does not have jurisdiction over facilities utilized for production and gathering, local distribution and other lines not used in interstate commerce, it should be apparent that the growth of the natural gas industry network of pipelines in the United States may be pinpointed by the certificate activities of the Federal Power Commission. Such certificate activities involve the issuance of authorizations to natural gas companies for the construction and operation of all or any part of their systems required for the transportation or sale for resale of natural gas which at any time traverses a State boundary.

The original certificate section of the Natural Gas Act was limited to those cases in which the proposed line would enter a market area already served by a natural gas company. This section was amended, effective February 7, 1942, giving the Commission the overall authority it now administers. From 1938 to 1942, only four certificates were issued. The 1942 amendment provided, among other things, that "grandfather" certificates shall be issued to natural gas companies bona fide engaged in operations subject to Commission jurisdiction on February 7, 1942. A total of 140 such applications were filed. Of this number most all received their "grandfather" certificates.

A subsequent amendment to the Natural Gas Act on March 27, 1954, provided that companies operating with natural gas transported in interstate commerce received within or at the boundary of a State wherein all the natural gas ultimately received is consumed, the company so operating is exempted from the provisions of the Natural Gas Act providing the rates and service of such company are subject to regulation by a State commission. This amendment to date has exempted 124 companies from Commission jurisdiction. Since 1942 a number of new companies subject to Commission jurisdiction commenced operations and some existing companies merged, so that at the present time there are about 105 individual pipeline companies engaged in the transportation or sale of natural gas in interstate commerce.

Since February 7, 1942, the Federal Power Commission has authorized the construction of nearly 85,000 miles of pipeline, and more than 6,035,000 horsepower in compressor units at an aggregate cost of approximately $7,212 million. The facilities so authorized were designed to add more than 33 billion cubic feet of daily delivery capacity to the individual systems involved. This additional capacity does not represent the quantity of additional gas delivered to the Nation's markets as in some instances the capacity was added to two or more systems before it reached the market.

In the fiscal year ended June 30, 1951, the Commission issued 173 certificates for 8,695 miles of line and 736,100 horsepower in additional capacity units at a cost in excess of $725 million. This was the largest single year with respect to facility additions. In the fiscal year ended June 30, 1959, however, approximately 5,000 miles of line and 614,000 additional compressor horsepower were installed but the cost was estimated in excess of $763 million. This is the largest proposed dollar investment certificated by the Commission in a year since the 1942 amendment to the act.

Estimates prepared by the Commission in connection with its presentation to Congress for budget purposes do not predict any diminution of the Commission's pipeline certificate activities for the next 3 fiscal years. The AGA in a bulletin issued August 1959 has projected estimates as to the miles of gas main of all types for the period from 1958 through 1970. These figures are:

Year	Field and gathering [1]	Transmission	Distribution	Total
1958	52.0	165.4	354.1	571.5
1970	91.4	282.4	537.7	911.5

[1] Excludes field and gathering facilities of producers. Reflects only field and gathering mains of pipelines and distribution companies.

Further indication of the continued growth of the interstate shipments of natural gas is evidenced from statistics by the U.S. Bureau of Mines which show that interstate shipments of natural gas increased 8 percent in 1957 and that of the total marketed production, interstate shipment, comprised 57 percent as compared with 56 percent in 1956. This trend has been continuing. Preliminary figures indicate that interstate shipments will comprise almost 60 percent of the marketed production in 1958. The AGA also predicts an increase of 4 million customers over the 32 million being served in 1958 within the next 3 years. Accordingly, except for the pessimism generated by the questions of economics with respect to rising prices to ultimate consumers, there does not appear to be any foreseeable obstacle to the continued growth of the Nation's pipeline system. This is not to imply that this economic problem is not realistic but as yet it does not appear to have had a deterrent effect upon continued expansion by the pipeline industry.

Consideration of the growth of the Nation's network of pipelines would not be completed without discussion of the influence underground storage of natural gas near centers of large natural gas consumption has had on the ability to meet demands, particularly during peak periods of the heating season.

Underground storage is accomplished primarily by utilizing depleted or partially depleted gas or oil fields, but on some occasions marked success has been had of utilization of storage in other geologically acceptable strata. These storage areas are an integral part of the interstate pipeline systems and have quite obviously replaced the need for many thousands of miles of pipeline which otherwise would have had to be constructed to meet the demands that have been served. Storage operations increase the transmission system's total annual deliverability through the storage cycle of input and withdrawal thereby permitting high load factor operation of the pipeline systems.

According to AGA, the ultimate capacity of fields currently in use in the states of Ohio, Pennsylvania, Michigan, and West Virginia account in the aggregate for 60 percent of the national total. During the years from 1947 to 1950 there was an average number of 92 pools in 12 States with estimated ultimate capacity of 507 billion cubic feet, and in 1958 there were 205 pools in 19 States with an estimated ultimate capacity of 2,718 billion cubic feet. While in 1958 the increase in ultimate capacity of storage was the smallest increment for a decade, the AGA anticipates such slackening is temporary. On the other hand, others have interpreted this decrease in the development as an ominous factor indicating that the costs of storage added to the now higher priced pipeline gas will gradually diminish the economic feasibility of new underground storage development. Presuming this possibility may occur, research now underway to provide other means of meeting seasonal loads may provide the answer to this economic problem. Such research includes the utilization of liquid methane transported by surface carriers and the more economical manufacture of equivalent gaseous fuels. Such matters and no doubt others are actively being researched.

The attached table from the 1959 issue of Gas Facts prepared by AGA sets forth the demands for natural gas in the United States by areas and by classes of service for the calendar year 1958. This table has the volumes converted to therms, a therm being equivalent to 100,000 B.t.u. As might be expected, the long-established market areas near the past and present producing areas have the greatest demand as related to their populations. Also as expected, the west-south-central region has a high industrial consumption resulting from its proximity to the major production areas. It is interesting to note that the residential consumption in the east-north-central region is more than twice that of any other region. On the other hand, the markets where natural gas service has not been available for any appreciable length of time, such as New England, Idaho, Oregon, Washington, the Carolinas, and Florida, have not developed to a point comparable to the longer established markets. It is not expected that these "Johnny come latelys" shall achieve the same saturation of gas customers because of several factors, the most important of which is the competition from other fuels more readily available to these areas and the more competitive price of other fuels. Furthermore, insofar as residential consumption is concerned, it is a more difficult selling job to induce consumers to replace existing appliances than it is to install the appliances for a particular fuel initially.

There is, however, no area in the country that is not seeking additional natural gas supplies. Rather than following the common concept of the supplier seeking the market, it is often stated that today's natural gas market is a seller's market. The natural gas marketing situation might be visualized as a giant octopus whose body constitutes the markets in the country with its giant tentacles reaching out to the supply areas with constant dissatisfaction at the ability of these members to satisfy its hunger for more natural gas. For example, even though Illinois, Michigan, and Missouri show a relatively high residential demand, there are thousands of domestic consumers seeking gas, primarily for house heating. These demands are not something new but have virtually continued unabated and unsatisfied since the end of World War II. This situation has prevailed despite herculean efforts of pipeline companies and distributors to meet these demands.

There are now under construction facilities to increase the daily capacity to serve New England and middle Atlantic areas by 406,000 M c.f. per day. Incidental thereto, the South Atlantic and east central areas will also benefit from this capacity increase. Similarly, facilities are now under construction which will provide 495,000 M c.f. per day to the east north central region, 369,000 M c.f. per day to the west north central region, and 435,000 M c.f. per day to California. In addition, other applications have been filed, on which Commission action is pending, for authorization to construct additional facilities which propose to make 702,000 M c.f. per day additional capacity available to the middle Atlantic, South Atlantic, and New England areas; 650,000 M c.f. per day to the east north central region; 100,000 M c.f. per day to the east south central region; 150,000 M c.f. per day to the mountain region, and 1,295,000 M c.f. per day to the Pacific region, most of which is destined for California. Accordingly, with the exception of the west south central region with its prolific gas production, there have recently been authorized or are pending with the Federal Power Commission applications to increase capacity to serve every area in the country. Of course, the west south central region, served by large intrastate systems, is increasing its demand more rapidly than any of the other areas except California. Time and time again those of us dealing with the natural gas business refer to the demands in California as insatiable and that term may be an understatement. In summary, it may be stated that for the foreseeable future, it is reasonable to predict that the demands for natural gas will continue in all areas of the country at least at the same rate as it has for the past decade in each area.

The growth of natural gas as energy source for our national economy is illustrated by the fact that at the start of the century about 3 percent of the total energy needs of the Nation came from this source while 89 percent came from coal, 5 percent from oil, and 3 percent from waterpower. In 1920 natural gas provided only 4.4 percent against coal's 80.7 percent, oil's 13.3 percent, and waterpower's 3.9 percent. At the beginning of 1958 natural gas' contribution to the Nation's energy supply zoomed to about 28 percent, coal decreased to 27 percent, oil became the prime supplier at 41 percent of the total, with waterpower maintaining its position at about 4 percent. Nearly 90 percent of the resources necessary to meet this national demand for natural gas comes from the five States of Texas, Louisiana, Kansas, New Mexico, and Oklahoma. Of these five, over 45 percent of the known reserves are located in Texas and 22 percent are located in Louisiana including offshore reserves.

In 1945 the AGA established a committee on natural gas reserves. This committee issues an estimate prepared annually showing the changes of reserves in the past calendar year. These changes involve extensions and revisions of previously discovered reserves, discoveries of new fields, and new pools in old fields and the net change in underground storage reserves. The first report of the AGA committee estimated the proved reserves of recoverable natural gas as of December 31, 1945, at 147.8 trillion cubic feet. The latest report estimates the recoverable reserves as of December 31, 1958, at 254.1 trillion cubic feet. The increase in 1958 was 7.6 trillion cubic feet, the majority of which occurred in Louisiana and Texas with a net gain of 5.6 trillion cubic feet. During the past 4 years gross additions to proved natural gas reserves have aggregated 86 trillion cubic feet equivalent to 1.95 times net production during the same period. Of the 18.1 trillion cubic feet increase in reserves during 1958, 5.6 trillion resulted from new discoveries and the remainder from extension and revisions of previous estimates with a minor portion attributable to the change of underground storage. A number of geologists and other personnel associated with the industry have also made estimates of total ultimate recoverable natural gas reserves of the United States. Such estimates have been in the neighborhood of 1,400 trillion cubic feet with one reported at 1,700 trillion cubic feet.

Estimating the volume of gas reserves, rather than being an exact science, requires the application of trained judgment to limited fundamental knowledge of underlying conditions. The term "proved" reserves is not subject to precise definition, for an area cannot be proved until it has been completely developed. Particularly in new fields where experience is limited, the difficulty in determining the limits of the reservoir in itself is a major obstacle in estimating the reserves.

Reserve estimates as absolute figures in large dimensions have little significance unless they can be interpreted in relation to the volume of annual production representing the drain upon the reserves. It is common practice to divide gas reserves by current annual production and to designate the result as the life of the reserves. This way of expressing reserves has basic limitations which must be clearly recognized. While new gas reserves continue to be discovered, consumption is also following an upward course. Some authorities are of the opinion that as long as new additions exceed production there need be little cause for concern about this hypothetical ratio. As a rough yardstick or as often stated as a working signal this statement is acceptable. More accurately, however, it must be recognized that the volume of gas which can be taken from the reserves in a year's time is physically limited to a somewhat definite rate of production. The deliverability of wells, moreover, declines as the fields approach depletion and therefore long before the presently known reserves are exhausted, the supply will be incapable of meeting an undetermined rate of demand.

It is the opinion of some authorities that a minimum of additional or new reserves of between two and three times the net production during the same period is necessary to compensate for the decline in deliverability which is certain to take place among the old reserves. While it may be argued that with the decline in deliverability as the reserves are exhausted, the demand will have to be reduced. As discussed above, the diminution of this demand is not presently apparent, although the additions to new reserves as compared to net production is just about two times. It is not unreasonable to assume that as long as the trend in the discovery of new reserves is upward, the ability to meet demands is not seriously threatened. From 1952 through 1957 the reserve life index decreased from 23.2 years to 21.4 years with the first increase being indicated, since that time, with a 1958 increase to 22.1 years.

It is not unlikely that this factor has had considerable influence on the efforts of the American companies who seek additional reserves in our neighboring countries of Mexico and Canada. As yet, the importation of gas from these countries is not too significant. Applications are now pending for additional imports from Canada and it is anticipated that these imports, if looked upon favorably by Canada and Mexico, will enable the American industry to maintain a satisfactory balance with respect to the age-life index of the gas reserves available for our markets and in turn protect the ability to meet increasing demands as deliverability of known reserves becomes depleted.

The role of the producer in the growth of this industry is of tremendous importance. While some of the pipeline companies have their own production, not one can depend on company-owned production as its principal source. It is the independent producer who must explore for and develop the life blood of the pipelines and distributors. Of approximately 10,000 rate schedules on file with the Federal Power Commission by independent producers, approximately 3,000 represent individuals and/or individual companies who are the principal selling party. In 1957, however, only 15 of this number sold 48.2 percent of the gas delivered to interstate pipelines while 82 companies sold 80.2 percent.

That concludes my statement, Mr. Chairman.

(The attachment accompanying Mr. Kallina's formal statement follows:)

Natural gas sales of utilities, by State and class of service, 1958 (excludes sales for resale)

[Millions of therms]

Division and State	Total	Class of service			
		Residential	Commercial	Industrial	Other
United States	77,807.3	26,320.0	7,346.9	40,416.0	3,724.4
New England	796.2	473.0	80.4	218.5	24.3
Connecticut	163.7	82.8	14.3	66.3	.3
Maine	0	0	0	0	0
Massachusetts	506.5	318.1	50.7	121.3	16.4
New Hampshire	25.3	14.0	2.9	2.0	6.4
Rhode Island	100.7	58.1	12.5	28.9	1.2
Vermont	0	0	0	0	0
Middle Atlantic	6,790.9	3,591.6	826.8	2,265.1	107.4
New Jersey	572.3	335.5	77.0	159.2	0.6
New York	2,464.9	1,621.4	345.0	433.8	64.7
Pennsylvania	3,753.7	1,634.7	404.8	1,672.1	42.1
East North Central	15,386.4	7,962.7	1,728.2	5,556.1	139.4
Illinois	4,214.1	1,826.1	303.1	2,072.5	12.4
Indiana	1,343.2	538.3	124.5	667.4	13.0
Michigan	2,867.9	1,731.3	353.7	766.6	16.3
Ohio	6,307.0	3,496.3	872.1	1,858.5	80.1
Wisconsin	654.2	370.7	74.8	191.1	17.6
West North Central	9,209.1	3,227.0	995.1	4,273.9	713.1
Iowa	1,322.0	490.9	211.0	520.5	99.6
Kansas	2,864.1	723.4	210.2	1,559.3	371.2
Minnesota	1,359.9	534.3	135.0	654.8	26.8
Missouri	2,337.7	1,025.6	226.5	996.1	89.5
Nebraska	1,065.2	346.9	141.5	461.0	115.8
North Dakota	67.5	33.6	23.9	6.1	3.9
South Dakota	192.7	63.3	47.0	76.1	6.3

Natural gas sales of utilities, by State and class of service, 1958—Continued

[Millions of therms]

Division and State	Total	Class of service			
		Residential	Commercial	Industrial	Other
South Atlantic	5,138.9	1,940.8	505.2	2,597.2	95.7
Delaware	54.7	31.4	2.6	20.5	.2
District of Columbia	179.5	129.1	40.8	3.5	6.1
Florida	433.3	26.1	9.4	378.9	18.9
Georgia	1,659.0	490.6	169.0	988.1	11.3
Maryland	582.7	398.2	49.8	131.5	3.2
North Carolina	221.6	46.0	17.9	153.8	3.9
South Carolina	323.9	34.1	19.4	268.6	1.8
Virginia	547.4	249.8	60.9	214.2	22.5
West Virginia	1,136.8	535.5	135.4	438.1	27.8
East South Central	5,387.9	1,440.5	548.1	3,042.5	356.8
Alabama	1,684.8	372.8	130.8	1,166.0	15.2
Kentucky	1,121.4	547.8	145.8	384.7	43.1
Mississippi	1,224.0	216.8	105.5	819.7	82.0
Tennessee	1,357.7	303.1	166.0	672.1	216.5
West South Central	20,136.6	3,023.6	1,060.3	15,226.2	826.5
Arkansas	1,786.5	278.2	135.7	1,348.6	24.0
Louisiana	4,951.3	506.6	132.1	4,176.4	136.2
Oklahoma	2,062.8	586.8	215.0	1,115.8	145.2
Texas	11,336.0	1,652.0	577.5	8,585.4	521.1
Mountain	5,126.4	1,325.6	562.9	2,710.0	527.9
Arizona	882.7	157.4	79.0	635.2	11.1
Colorado	1,445.5	452.1	231.8	726.2	35.4
Idaho	162.9	6.4	10.3	146.2	0
Montana	466.2	163.3	91.1	192.7	19.1
Nevada	95.3	11.7	5.2	76.8	1.6
New Mexico	1,209.6	185.8	72.8	506.1	444.9
Utah	584.2	255.6	34.9	293.7	(1)
Wyoming	280.0	93.3	37.8	133.1	15.8
Pacific	9,834.9	3,335.2	1,039.9	4,526.5	933.3
California	9,038.0	3,242.4	983.9	3,878.5	933.2
Oregon	228.9	46.6	14.6	167.6	.1
Washington	568.0	46.2	41.4	480.4	0

[1] Less than 50,000 therms.

NOTE.—For earlier years please refer to table 94 in the "Historical Statistics of the Gas Industry."

Representative PATMAN. Thank you very much, sir.

Your testimony is very fine and will be very valuable to this committee. We are indebted to you for it, sir.

Tomorrow's hearing, here in this room, will be an analysis of the domestic oil industry by Mr. Richard J. Gonzalez, of the Humble Oil Refining Co.; a conservation of the approximate role of Government in developing adequate competitive energy sources, by W. J. Murray, Jr., commissioner of Railroad Commission of Texas.

Arthur Kline, Commissioner, Federal Power Commission; the status and prospects of oil shale technology.

Russell J. Cameron, president, Cameron & Jones, Inc., Denver, Colo.

World petroleum needs, supplies, and organization, as related to the domestic scene, Bernard N. Darbyshire.

The committee will stand in recess until 10 o'clock in the morning.

(Thereupon, at 12:15 p.m., the committee was recessed, to reconvene at 10 a.m., Wednesday, October 14, 1959.)

ENERGY RESOURCES AND TECHNOLOGY

WEDNESDAY, OCTOBER 14, 1959

CONGRESS OF THE UNITED STATES,
SUBCOMMITTEE ON AUTOMATION AND ENERGY RESOURCES
OF THE JOINT ECONOMIC COMMITTEE,
Washington, D.C.

The subcommittee met at 10 a.m., pursuant to recess, in room P–63, the Capitol, Hon. Wright Patman (chairman of the subcommittee and vice chairman of the committee) presiding.

Present: Representative Patman.

Representative PATMAN. The committee will please come to order. We have as our first witness Mr. Richard J. Gonzalez, treasurer and former economic adviser of the Humble Oil & Refining Co. Mr. Gonzalez, we are glad to have you. You may proceed in your own way.

STATEMENT OF RICHARD J. GONZALEZ, TREASURER, HUMBLE OIL & REFINING CO.

Mr. GONZALEZ. It is an honor and a privilege to be invited by this committee to discuss the domestic oil industry. As a former professor of economics, I am greatly interested in the activities of your committee. Your present hearings are of particular interest to me because I have spent a large amount of time since 1937 analyzing the petroleum industry in my capacity as economic adviser to Humble Oil & Refining Co. I have also served on various occasions as a consultant to governmental agencies and as a participant in numerous studies by committees of the National Petroleum Council and of industry associations. I welcome this opportunity to discuss past developments, present conditions, and future prospects for the oil industry.

ROLE OF OIL AND GAS IN OUR ECONOMY

Oil and gas now supply two-thirds of the mineral energy produced in the United States. They have contributed immeasurably to economic progress during the past century. Therefore, these fuels are of prime concern in your study of energy resources. A brief review of the past will reveal the importance of oil and gas to our Nation.

The discovery of oil in Pennsylvania in 1859 provided a useful new fuel. At first, oil supplies were limited and rather expensive. Throughout the 19th century, the principal petroleum product was kerosene, used for illumination in place of whale oil and coal oil.

The great Spindletop field discovered in Texas in 1901 initiated an era of phenomenal growth. Exploration spread rapidly thereafter to new areas and added steadily to the list of oil-producing States. Crude oil is now produced in more than 30 States. The volume of production this year will be about 50 times as much as at the beginning of the century. About 70 million motor vehicles operate on gasoline, more than 30 million residences are supplied with natural gas, and every individual is affected in many ways by the petroleum industry.

Liquid fuels made possible mobile power, from small engines to the huge motors of diesel locomotives and airplanes. They have brought us from the horse-and-buggy days to the jet age and have revolutionized our way of life. Petroleum fuels were responsible for a vast expansion of public and private transportation, the mechanization of agriculture, and increased productivity in industry.

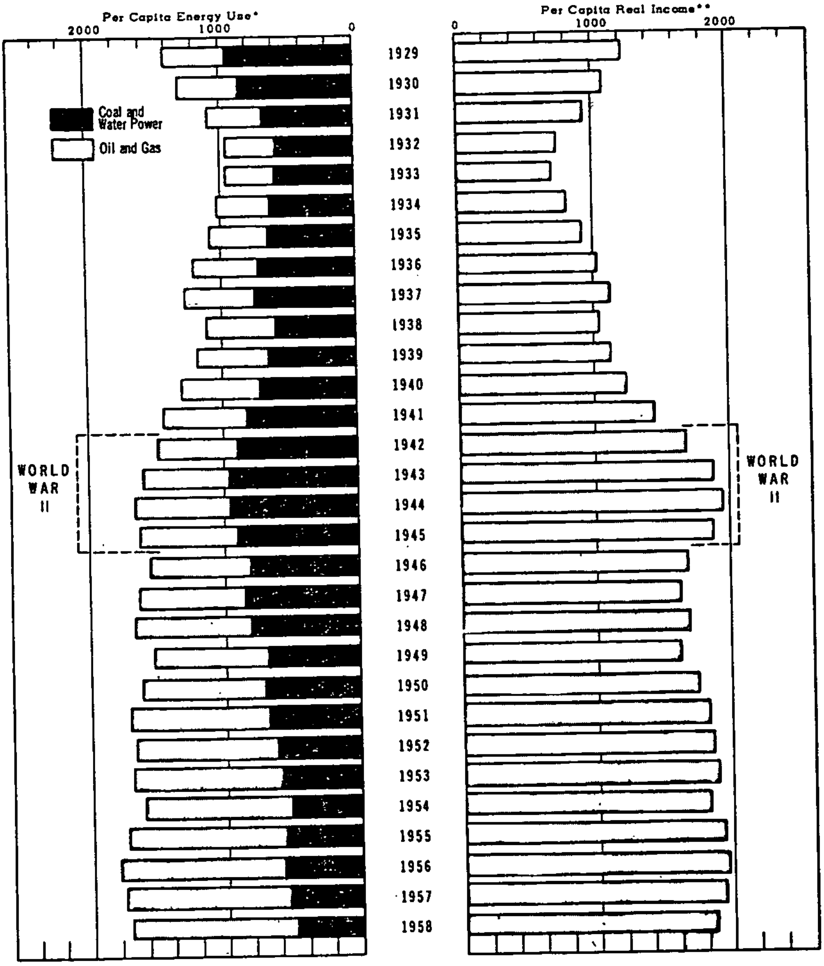
Inanimate emergency multiplies our productive capacity. Admiral Rickover has noted that man's muscle power is equivalent to one-twentieth horsepower. When we drive an automobile or use other machinery, we literally command an army of servants. A jet pilot, for example, controls energy equivalent to about 700,000 men. Without machines and reasonably priced energy we could not have a 40-hour workweek, holidays, vacations, and coffee breaks. Certainly, we would not have our present standard of living—a standard far beyond any dreams of our hardworking ancestors a century ago.

The interrelation of living standards with energy consumption can be observed in the United States and throughout the world. Chart 1 shows the close correlation of these two factors in the United States over the past 30 years. Real income per capita in dollars of the same purchasing power has almost doubled since 1938. In the same period, per capita use of oil and gas has more than doubled and the use of all forms of energy has increased greatly, despite a decline in the relative consumption of coal. Chart 2 shows that energy consumption and income are closely related in countries throughout the world. The wide range is shown by the contrast between the United States and Canada on one hand and Burma and India at the opposite end of the scale. The relationships in both of these charts show that a gallon of oil or its equivalent in coal or gas provides the energy base for a dollar of income. Therefore, a barrel of crude oil containing 42 gallons (or the equivalent amount of energy in the form of about 6,000 cubic feet of natural gas or 450 pounds of coal) provides the energy base for about $42 of real income.

A major change in the relative importance of energy sources has occurred during the past generation, as shown by chart 3. In 1926,

CHART 1

REAL NATIONAL INCOME AND ENERGY CONSUMPTION PER CAPITA HAVE BEEN CLOSELY RELATED IN THE UNITED STATES



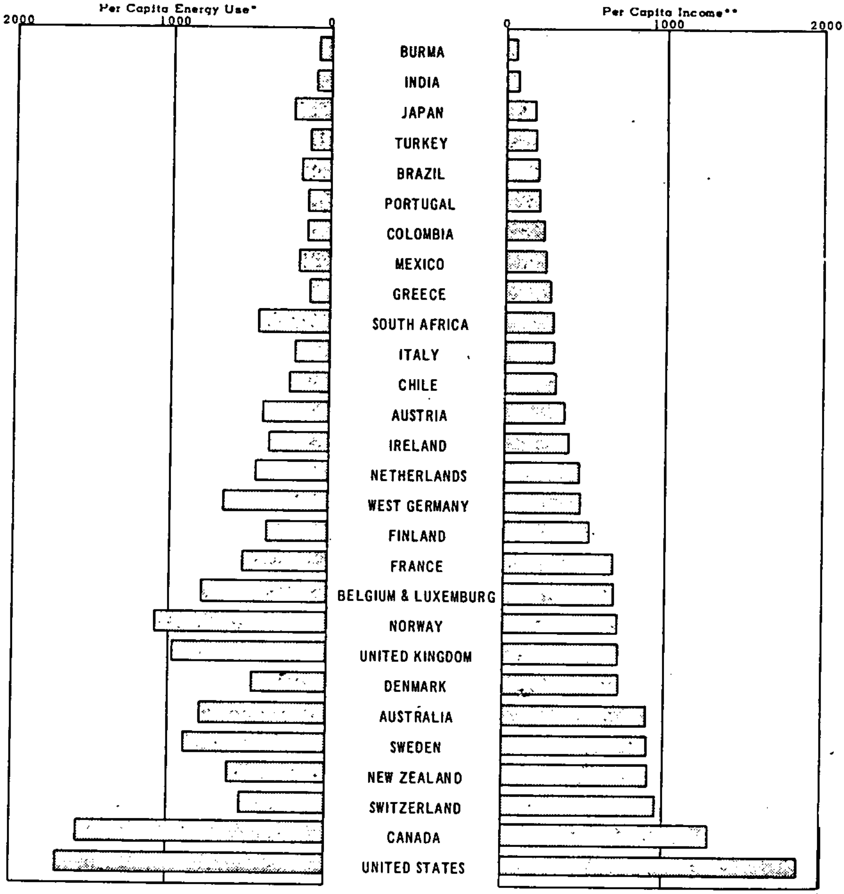
*Consumption of oil, gas, coal and water power expressed in gallons of crude oil.

**National income in 1954 dollars.

Sources: Bureau of Mines and Department of Commerce.

CHART 2

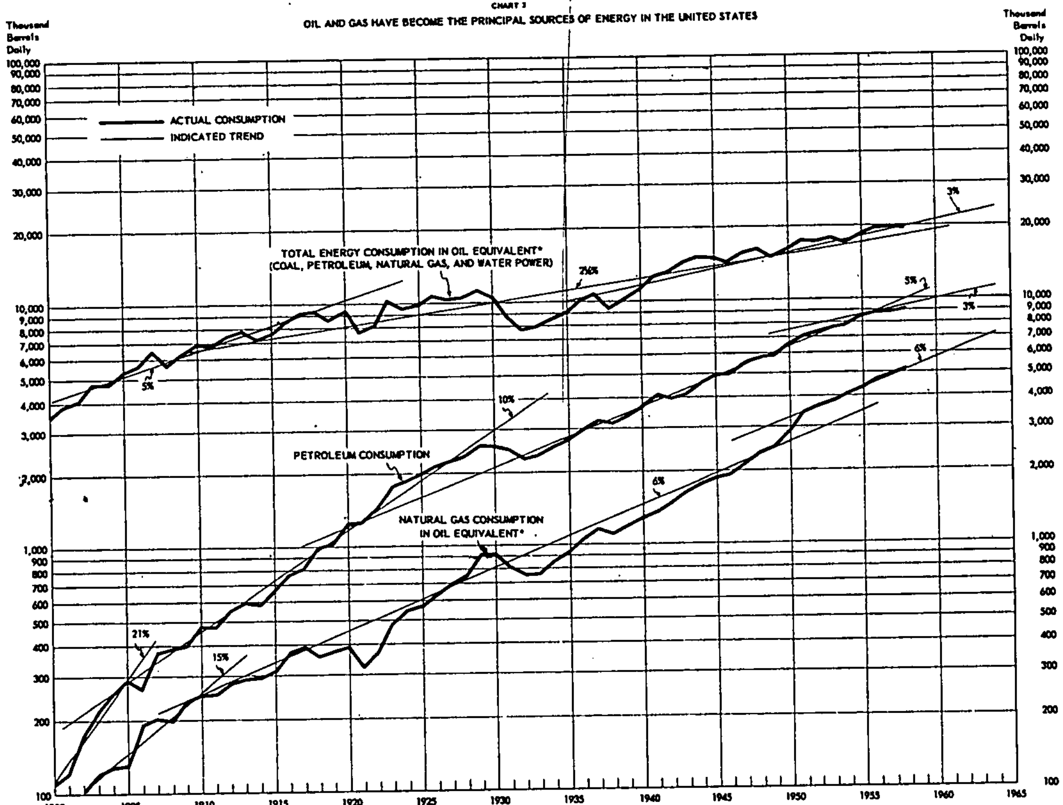
ENERGY CONSUMPTION AND INCOME
ARE CLOSELY RELATED THROUGHOUT THE WORLD



*Consumption of all forms of energy expressed in gallons of crude oil.
**National income measured in U.S. 1952 dollars.
Source: Joint Committee on Atomic Energy (1952 Data).

CHART 3

OIL AND GAS HAVE BECOME THE PRINCIPAL SOURCES OF ENERGY IN THE UNITED STATES



* All forms of energy other than petroleum have been converted to oil equivalent on the basis of relative heat content.
Source: Bureau of Mines.

coal production was 658 million tons and accounted for 70 percent of energy output in the United States. Since then, energy requirements have doubled but the output of coal has declined. Coal production this year will account for less than 30 percent of energy production. Oil and gas now account for two-thirds of energy production and for about 72 percent of energy consumption in the United States. Coal was surpassed as a supplier of energy in this country by crude oil in 1952 and by natural gas in 1958.

ACHIEVEMENTS IN PRODUCTION

A review of the past emphasizes the progressive growth of the industry. Achievements of the first century are shown on chart 4 in terms of crude oil production and proved reserves. A division into 33-year periods representing three "generations" facilitates discussion of the record.

In the first generation up to 1892, chance played the leading role in discovery. Most of the wells were quite shallow, principally in Pennsylvania, New York, Ohio, and West Virginia. Total discoveries during this period were only about 1 billion barrels.

In the second generation, from 1893 through 1925, the search for oil was characterized by a gradual change from empirical to scientific methods and by the geographic extension of production to new areas, particularly in California, Texas, Louisiana, Oklahoma, and Kansas. Discoveries in this period were almost 13 times as much as the billion barrels of the first 33 years. Production increased proportionately.

The most recent generation, beginning in 1926, witnessed the major expansion of production and proved reserves. Expanding markets, scientific progress, and sound conservation regulations were the basis for this progress. Geophysics supplemented geology in exploration with remarkable results, and petroleum engineering transformed drill-

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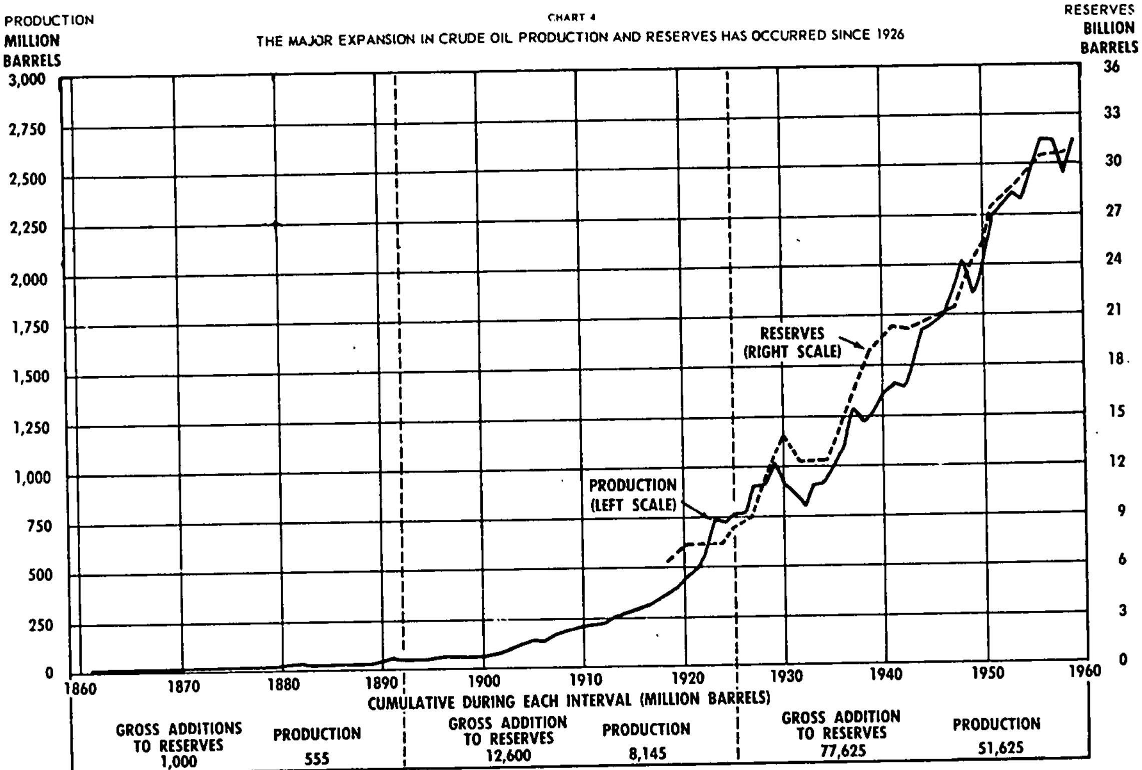
CHART 4

THE MAJOR EXPANSION IN CRUDE OIL PRODUCTION AND RESERVES HAS OCCURRED SINCE 1926



Sources: Production, "World Oil"; Reserves, American Petroleum Institute 1936-1958, various published estimates prior to 1936.

ing and producing practices. About 77 billion barrels of new crude oil were added to cumulative discoveries during the past 33 years, or more than five times as much as the total for the prior 66 years. Most of the major fields have been discovered in this period, including the great east Texas field which was located in 1930. In addition, the number of smaller fields discovered has increased greatly.

Cumulative discoveries of crude oil to the beginning of 1959 were 91 billion barrels. A third of this total was the result of discoveries, extensions, and revisions in the past 10 years, another third was accounted for in the preceding 15 years, and the remaining third can be attributed to the prior 74 years. In other words, the rate of development of domestic oil resources has accelerated as more oil was discovered and produced.

The ability to develop additional resources as required to meet demand reflects a response to market conditions and the application of greater knowledge and better technology. A discovery reduces by one field the large unknown number remaining to be located, but it often provides clues that are helpful in locating other fields that have previously eluded explorers. Through technology, the industry continuously opens up new frontiers in area, in depth, in exploration methods, and in processes for recovering more oil from existing fields.

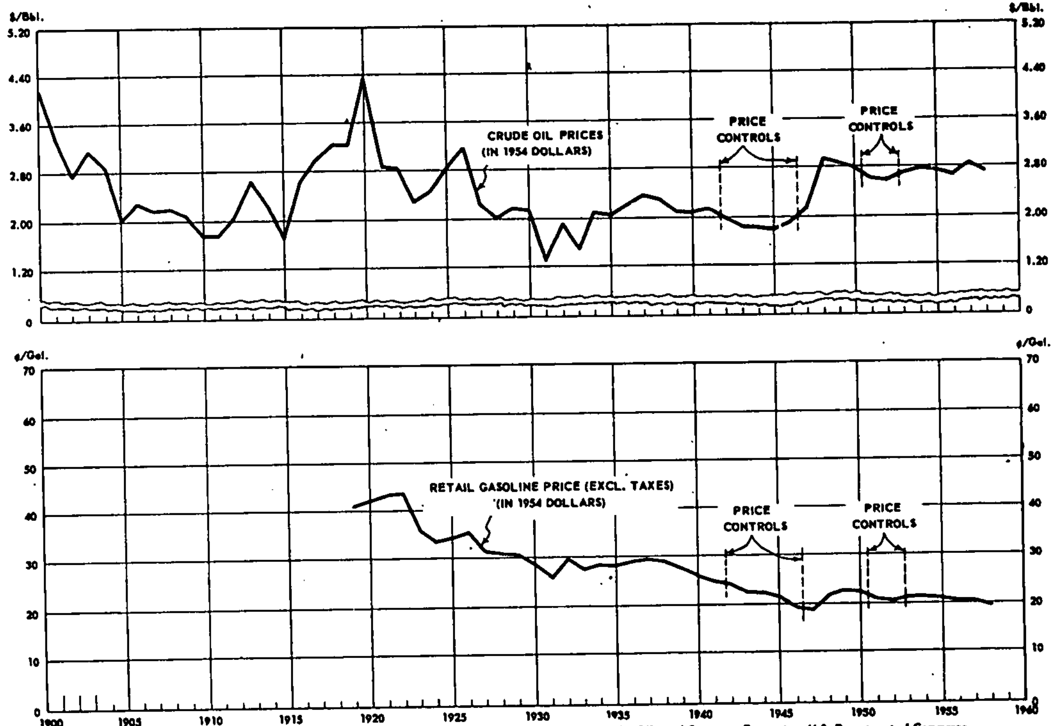
THE RECORD OF PRICE PERFORMANCE

Oil and gas could not have reached their present dominant role in energy markets without being attractively priced as well as highly useful and convenient. The industry has demonstrated a surprising ability to provide increasing supplies at stable real prices over a long period of time, despite the tendency toward rising costs inherent in extending the search to deeper formations and new areas. The record of price performance can be shown by several charts.

Chart 5 shows the real prices of crude oil and gasoline measured in dollars of constant purchasing power. Crude oil has experienced numerous fluctuations, but its real cost in recent years has been about the same as the average for the period from 1900 to 1926. The dis-

CHART 5

REAL PRICES* OF CRUDE OIL AND GASOLINE HAVE BEEN VERY ATTRACTIVE



* Measured in 1954 dollars by applying the Gross National Product Implicit Price Deflators developed by the Office of Business Economics, U.S. Department of Commerce.

Sources: "World Oil" and American Petroleum Institute.

tinct rise in real prices immediately after World War II merely offset the subnormal level that prevailed during the depression and the period of wartime price controls.

The real price of crude oil has declined since 1948 to a current level about 10 percent lower. The trend of the past decade reflects highly competitive market conditions rather than a reduction in real costs. Competitive conditions will probably continue to keep the real price of crude oil relatively constant.

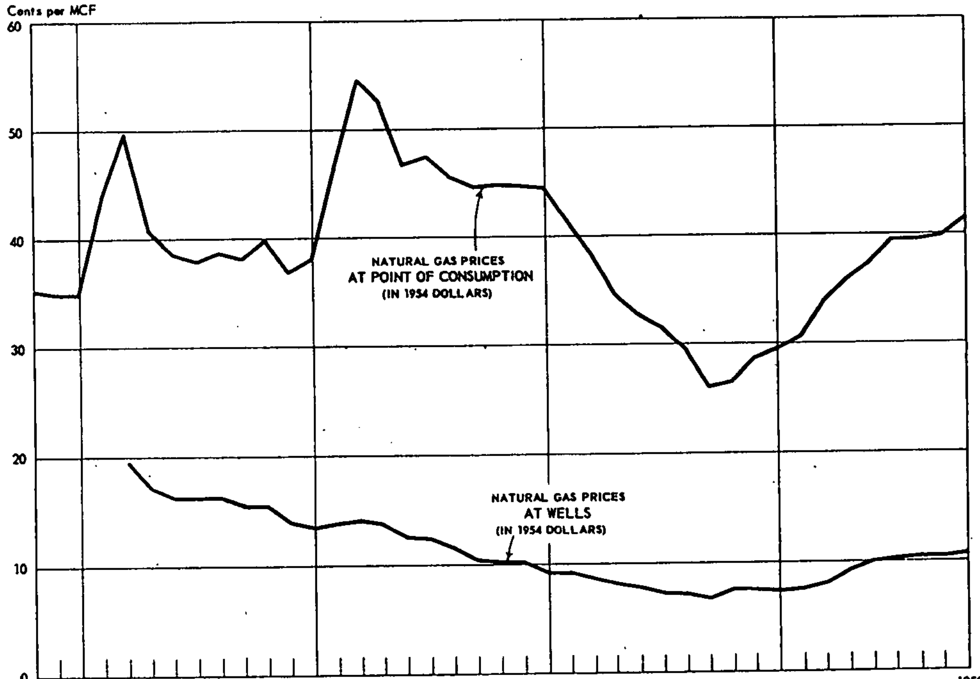
The lower portion of chart 5 reflects the real price of gasoline to consumers, exclusive of Federal and State excise taxes. A steady downward trend persisted in this price from 1922 to 1947. Since then, the real price of gasoline has been quite stable. The level this year will be about the same as in 1947.

Up until 1922 the real price of gasoline was more than twice the current level. Even during the depression, it was about 50 percent higher than at present. In addition to being cheaper in real terms, gasoline is now much better in quality. Consequently, motorists have been able to enjoy heavier and more powerful cars at reasonable operating expenses for gasoline. Unfortunately, the burden of taxes on gasoline has reached the point of diminishing returns. This burden contributes to the increasing popularity of economy cars. If economy cars come to constitute a larger proportion of the vehicles in operation, taxes on motor fuel may yield less revenue in the future than at present, notwithstanding the best efforts of the oil industry to keep gasoline attractively priced.

Chart 6 shows the real price of natural gas, both at wells and at the point of consumption. The real price of gas received by producers dropped steadily until 1946. Thereafter, an advance has carried the real price back to the levels that prevailed about 20 years ago. The real price paid by consumers for delivered supplies has shown a number of fluctuations. The latest swing has raised real prices to consumers by almost 16 cents per thousand cubic feet since 1947, by comparison with an increase of only 4 cents in the real price of gas in the field. The rise in delivered prices reflects the extension of

CHART 6

REAL PRICES* OF NATURAL GAS ARE STILL BELOW THE AVERAGE OF THE 1930'S



*Measured in 1954 dollars by applying the Gross National Product Implicit Price Deflators developed by the Office of Business Economics, U.S. Department of Commerce.

Sources: Bureau of Mines and Department of Commerce.

service to many new areas far from the source of supply. Added transportation and delivery charges have outweighed the change in prices received by producers by about 3 to 1 as a cause of higher real prices to consumers.

Petroleum operators usually produce both crude oil and natural gas. In selling both products, they offer customers a choice between gas and liquid fuels. The choice these customers make depends on relative prices as well as convenience. Because of the competition between oil and gas, consideration should be given to the average realization on the joint output of both fuels. Chart 7 reflects this realization in both current and real dollars. The combined revenue from these fuels divided by the heat content measures the average realization. The heat content averages about 5,800,000 British thermal units for a barrel of crude oil and 1,035,000 B.t.u. for a thousand cubic feet of gas.

The rapid growth of gas, which sells for much less than crude oil at the wells, has operated to stabilize the current average price and to reduce the real price received by producers on their total energy output. In 1958, the real price of petroleum liquids and natural gas was below the average of the prior 10 years, equal to the realization in 1930, and well under the level that prevailed from 1918 to 1929. These relations show that the price performance of the petroleum industry has been even more remarkable for its total energy output than for oil and gas considered separately.

The preceding evidence on the real price of crude oil, gasoline, and natural gas provides proof of the efficiency of the petroleum industry in meeting increasing demands at reasonable prices.

KEY FACTORS IN PETROLEUM PROGRESS

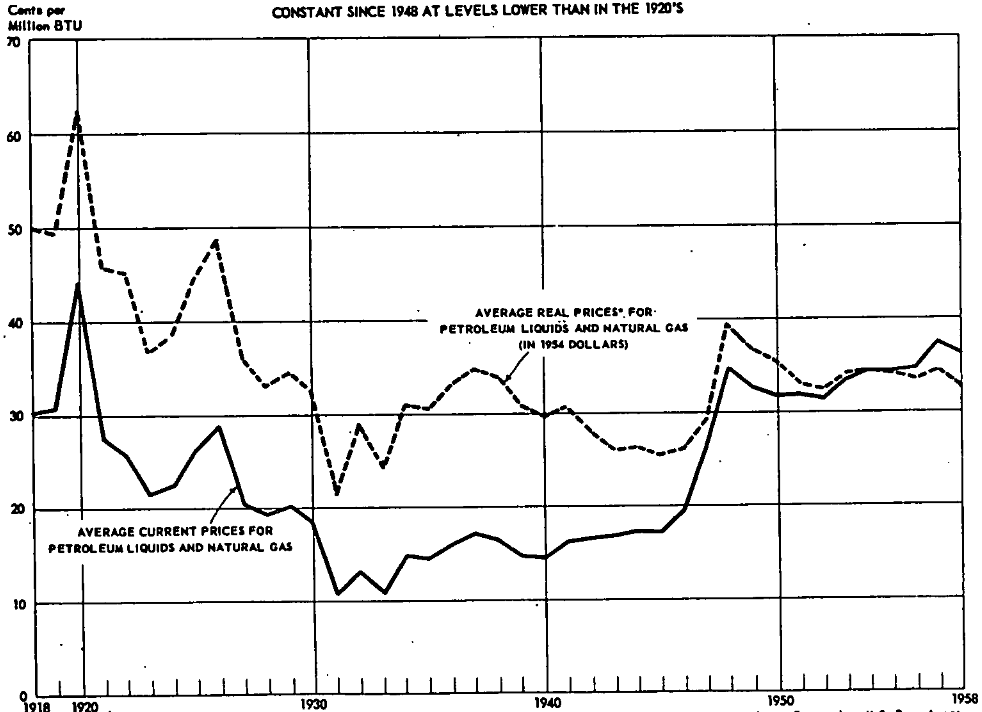
Several factors have been of primary importance in the progress of the American petroleum industry. A brief review of these factors will provide an understanding of the requirements for future progress.

The existence of large areas of sedimentary formations favorable to the accumulation of oil and gas provided the necessary physical environment for the development of production. Many cubic miles of these formations still offer promising prospects, both in areas already producing and in new areas.

Enterprise and ingenuity on the part of American investors led to exploration of potential resources that had lain dormant for millions of years. Despite unusual risks, entrepreneurs developed a great industry. The United States quickly surpassed other nations in petroleum production and consumption. American companies later played a leading role in the development of the petroleum industry in foreign countries. Freedom to compete and to try out new ideas contributed to the discovery of resources and to improvements in technology.

CHART 7

AVERAGE REALIZATION ON PETROLEUM LIQUIDS AND NATURAL GAS HAS BEEN RELATIVELY CONSTANT SINCE 1948 AT LEVELS LOWER THAN IN THE 1920'S



*Measured in 1954 dollars by applying the Gross National Product Implicit Price Deflators developed by the Office of Business Economics, U.S. Department of Commerce.

Sources: Bureau of Mines and Department of Commerce.

Dynamic technology has been another characteristic of the petroleum industry. Improvements are still being made steadily in all operating practices. Recent electronic techniques are now being used, for example, to secure better records and interpretations of the seismic waves used in geophysics. Last year a well was drilled to 25,000 feet, three times deeper than the record of 30 years ago. Offshore operations in water that is sometimes more than a hundred feet deep illustrate how technology makes available for use important resources that could not previously be developed commercially.

Wise tax regulations encouraging investors to risk funds in the search for and development of new resources have also been essential to the growth of the industry. Without percentage depletion and related tax provisions, producers of energy and other mineral resources would be seriously handicapped in attracting capital. In that case, we could not have developed the fuels and other mineral resources essential for industrial progress.

Sound conservation laws of the principal producing States have also contributed to the stability of the industry to develop domestic resources efficiently. Effective conservation regulations geared to greater knowledge about economical spacing of wells and efficient producing practices will continue to be essential in order to prevent waste and to permit maximum recovery at reasonable costs for the benefit of consumers.

The opportunity to compete freely in the energy market without arbitarary restraints has encouraged efficiency. The constant competitive struggle among oil products of different kinds, natural gas, coal, and water power has proved of benefit to consumers and the Nation. Nuclear power and other scientific developments offer the prospect of additional competition among alternative sources of energy. This interfuel competition stimulates each industry to do its best in attracting and holding customers on the basis of price and service.

Because of concern that the rate of development of domestic resources considered necessary for national security might be endangered, the Federal Government has recently adopted a program designed to limit the participation of imported oil in domestic markets to about the relative position already attained. This program regulates the amount of competition from foreign sources but does not interfere with the traditional freedom of competition among domestic energy resources. An area of recent Government action that does affect competition among domestic fuels is regulation of the price received by producers for gas sold in interstate commerce. Such regulation will probably hurt rather than help consumers by decreasing available supplies and by forcing them to use more expensive fuels in place of gas. The issues involved are too complex for a brief discussion, but they need to be considered with care in an effort to be sure that regulations intended to promote the public interest are reasonable and interfere as little as possible with normal economic processes.

THE CURRENT SITUATION

The preceding review has demonstrated that the domestic oil industry is still expanding after a century of progress. New resources are being developed at a high rate and technological improvements continue to make possible attractive real prices for petroleum products and natural gas. A review of the current situation provides further evidence of the ability of domestic petroleum resources to maintain their present role in the energy market for the foreseeable future.

Demand in the United States this year will total about 3.5 billion barrels of petroleum fuels and about 11.5 trillion cubic feet of natural gas. Oil consumption exceeds 2 gallons per day for every resident of this country. The rate of growth in oil demand now appears to have slowed down to about 3 percent annually as a result of keen competition from natural gas and coal. A continuation of this slower rate of growth seems likely now that oil and gas account for such a large part of the total energy consumption in the United States. The previous growth rate of about 5 percent a year, which the domestic industry had come to look upon as customary, was possible only while oil was increasing its participation in the energy market.

Supply is more than ample to meet demand. In fact, one of the main problems currently is to relate the expansion of productive capacity to the slower growth rate for demand. The long time lag before a shift in exploration and drilling affects production means that several years may be required for a satisfactory adjustment to the new situation. Domestic production is curently limited by lack of markets to considerably less than maximum efficient capacity.

Productive capacity for crude oil is estimated to be about 10 million barrels daily compared with the average output of approximately 7,100,000 barrels daily this year. A substantial part of the present reserve producing capacity or about 3 million barrels daily is considered desirable for national security reasons. Ability to increase production substantially on short notice proved of great value in World War II, in the Korean incident, and in the Suez crisis. Reserve producing capacity has increased in recent years above the level needed for emergencies because of the time required to adjust to the slower growth of demand and because of technological developments that permit more rapid production from many fields. Factors contributing to more rapid efficient production include formation fracturing, pressure maintenance, and secondary recovery projects. The National Petroleum Council has estimated that the drilling of 41,000 to 50,000 wells annually would serve to maintain capacity if the industry were called upon to produce around 10 million barrels daily of crude oil in an emergency.

Drilling this year will be at a rate of approximately 51,000 wells. New well completions will be slightly higher than in 1958, but still considerably below the levels of the preceding 4 years. Exploration and drilling have declined in recent years due to several adverse factors, but they could readily be increased again if better demand warranted additional activity.

Estimated proved reserves recoverable from known fields by the producing methods currently being applied are officially rated at about 31 billion barrels of crude oil, 6 billion barrels of natural gas liquids, and 254 trillion cubic feet of natural gas. These proved reserves are the highest in the history of the industry. They provide only a minimum estimate of the industry's current working inventory. Existing fields alone will unquestionably produce much more oil than attributed to them currently because of large future revisions that can confidently be counted upon as developments fully define the reservoirs and as improved recovery methods increase the proportion of economically producible oil. Therefore, estimated proved reserves should not be mistaken as a measure of future oil supplies since they underrate known fields and do not even attempt to take into account possible production from discoveries still to be made.

The industry has traditionally carried known reserves which allow it to meet current requirements by withdrawals at the rate of about 8 percent a year for crude oil and around 4 percent a year for natural gas. Experience has demonstrated that current development can offset production at these rates and provide enough additions to reserves to expand capacity in keeping with demand. It would be unwise and unduly expensive for the industry to follow a deliberate policy of developing reserves prematurely. The present high level of spare capacity resulted not from choice but from an inescapable lag in adjusting to new circumstances. Unit costs are adversely affected by the current situation, placing the industry in a less favorable competitive position than if reserve capacity were no greater than needed for emergencies.

PROSPECTS AHEAD

The record of achievement and the dynamic technological developments still underway provide a solid basis for confidence about the ability of the domestic industry to meet the needs of an expanding economy. Increasing supplies of oil and gas can continue to be made available at reasonable prices provided no handicaps are created by adverse changes in the economic forces which contributed to the remarkable progress of the first century. Present reserves and productive capacity place the industry in an excellent position to take care of increasing demands so long as incentives for reasonable development of new resources are not impaired.

As already noted, demand for oil products will probably increase at a rate of about 3 percent a year in the future. Competition from natural gas liquids and from foreign oil may well result in a slower rate of growth in requirements for domestic crude oil, probably about 2.5 percent a year. In that case, domestic producers may be called upon to supply about 30 billion barrels in the decade of the 1960's and 37 billion barrels in the 1970's if foreign oil continues to be limited to the same percentage of the domestic market as currently provided by administrative controls.

In order to supply these amounts and maintain a reasonable relation of reserves to production, the industry may need to develop during the next 20 years around 80 billion barrels of new crude oil through discoveries, extensions, and revisions. Realization of these volumes will require considerable effort and very large expenditures, but the task can surely be managed with a reasonable expansion of operations.

In the decade of the 1950's now being completed, gross new additions to crude oil reserves have been about 30 billion barrels. By maintaining merely this same rate, the industry can develop 60 billion barrels of new crude oil in the next 20 years. This rate along would provide three-fourths of the anticipated needs, including additions to reserves. A moderate expansion in the rate of development of new resources in future years, when warranted by higher demand, will surely enable the industry to take care of requirements for the foreseeable future.

Higher production of oil and gas in the future is feasible in view of the existing capacity and reserves, the important improvements being made in methods for recovering more oil from presently known fields, the current rate of development of new resources, and the tremendous prospective areas that still offer good promise for additional supplies. The present estimates of proved reserves generally represent an average recovery of only about one-third of the oil in place. Therefore, the projects being initiated to improve recovery in many old fields will later result in large upward revisions of estimated reserves. Furthermore, large new supplies can be counted upon from new discoveries in both old and new provinces. The Continental Shelf area of Louisiana and California and the new State of Alaska offer great opportunities for new discoveries. Other geologic provinces will also provide important additional discoveries. Several authoriative studies indicate that potential resources remaining to be developed exceed greatly all past production. In 1951, the U.S. Geological Survey pointed out that we have not reached the limits of our ability to expand ultimately recoverable reserves and that we can expect to develop sufficient quantities of oil and gas for many years to come.[1] In 1956, the Department of the Interior reached the following significant conclusion:

> Considering that trends in production and discovery are still headed upward, and that significant improvements in recoverability are now being accomplished or promised in the future, a total of 300 billion barrels as the ultimate reserve of the United States and of the adjoining Continental Shelves seems to be a reasonable figure.[2]

In 1958, an interesting book by Bruce C. Netschert, a member of the staff for Resources for the Future, presented his estimate of a resource base of 500 billion barrels of crude oil to which the industry can apply its ingenuity and science.[3] This study also estimated that the total future supply of natural gas in the light of present knowledge is on the order of 1,200 trillion cubic feet, or approximately a hundred times the current rate of production. The Department of the Interior concluded that the ultimate reserves of gas in the United States are at least 1,000 trillion cubic feet.

The preceding estimates show that the United States can continue to count on adequate domestic supplies of oil and gas in the future. Cumulative production of crude oil in the United States amounted to 60 billion barrels by the end of 1958. According to the estimates of the Department of the Interior quoted above, the remaining recoverable oil reserves of the United States should be about 240 billion barrels, or four times as much as the production of the first hundred years. The impartial evaluation of future prospects by governmental and private experts after careful study of the subject should serve to answer any proposal that national policy should be based on fears of an imminent shortage of oil or of gas in the United States.

The preceding analysis indicates a good prospect that domestic petroleum resources can keep pace with demands for as long as it is worthwhile to look forward into the uncertain future. Beyond the

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[1] U.S. Geological Survey, "Fuel Reserves of the United States," 1951, p. 35.
[2] "Peaceful Uses of Atomic Energy," vol. 2, p. 82 (report of the Panel on the Impact of Peaceful Uses of Atomic Energy—Background Material).
[3] Bruce C. Netschert, "The Future Supply of Oil and Gas," 1958.

next 20 years, no one can predict the changes that will occur in the uses and sources of energy in our dynamic economy. Substantial quantities of oil and gas will still remain to be developed after 1980, but the needs for such resources cannot be predicted at this time. For example, the known reserves of shale oil in the Rocky Mountain area, recently estimated at about 900 billion barrels by the U.S. Geological Survey, may become commercial sources of energy within 20 years, possibly with the help of nuclear explosions. The fuel cell, or some means to harness solar energy effectively, may bring great changes in the use of different energy resources. Therefore, no good purpose is served by speculating about when the United States will finally run out of oil. Instead, plans and policies can be formulated on the knowledge that adequate domestic oil and gas supplies will be available for the foreseeable future if reasonable incentives continue to exist for further development. Unless the sytem of interfuel competition that has worked so effectively in the past is upset by Government regulation, adjustments in the use of alternative available fuels will continue to occur gradually and to the benefit of consumers in response to changing economic conditions.

A recent paper by Charles W. Merrill of the Bureau of Mines analyzing trends in real prices of representative mineral commodities concludes that the record of the past provides a basis for forecasting a continued downward trend. The conclusions of his study were expressed as follows:

> This long record of downtrends in the prices of basic mineral raw materials is most encouraging to those looking into the future. Here is positive evidence to refute the alarmists who propose hoarding of mineral resources in the name of conservation. Although wastefulness is not to be condoned, there is little to sustain the argument that use of minerals leads to an impoverished future. Those countries that have put their minerals to work have the high standards of living today and the bright futures.[4]

CONCLUSION

Oil and gas have contributed immeasurably to the economic progress of the United States. They have become the principal sources of energy as a result of their usefulness and their attractive prices. Increasing supplies of these fuels will continue to contribute to economic progress and national security for the forseeable future.

The domestic industry has demonstrated great ability (1) to expand both known reserves and production as warranted by the needs of our economy and (2) to keep real prices of oil and gas reasonable. Recurring fears of future oil shortages have consistently been dispelled by the development of new resources. Present reserves and productive capacity are greater than ever before and quite adequate in relation to current levels of demand.

The prospects are good that the domestic industry can continue to meet expanding demands in the years ahead provided reasonable incentives exist for the large expenditures that will be required to conduct the necessary exploration and drilling. This favorable prospect might not materalize, however, unless the sound policies that have contributed to petroleum progress in the past continue in effect. Adverse

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[4] Charles W. Merrill, "Trends in Real Prices of Representative Mineral Commodities, 1890–1957," presented at the annual meeting of the American Institute of Mining, Metallurgical, and Petroleum Engineers, San Francisco, Feb. 15–19, 1959.

changes in the tax provisions on production or restrictions limiting markets that may be supplied by oil and gas on a competitive basis could have a serious impact on the development of new resources, on the cost of energy to consumers, and on general economic progress.

National policies that encourage the development of domestic energy resources and allow competition among alternative fuels to the maximum extent consistent with national security have proved of great benefit to the Nation and to all consumers. Fortunately, the outlook for domestic energy resources does not call for a change in basic policies. On the contrary, careful analysis leads to the conclusion that our future progress will be served best by continuation of the same basic policies that have been so successful in the past in providing the United States with ample supplies of energy at reasonable costs.

Representative PATMAN. Thank you very much, sir.

(A supplemental letter received from Mr. Gonzalez appears at p. 350 of these hearings.)

Representative PATMAN. We have as our next witness Commissioner William J. Murray, Jr., a member of the Railroad Commission of Texas, since 1947. Mr. Murray formerly taught petroleum engineering at the University of Texas and was Reserves engineer (Texas, Louisiana, New Mexico, and Mississippi), Petroleum Administration for War. He is also chairman, Petroleum Research Committee.

STATEMENT OF WILLIAM J. MURRAY, JR., MEMBER, RAILROAD COMMISSION OF TEXAS

Mr. MURRAY. Thank you, Mr. Chairman.

The investigations of this committee are of great importance to the future welfare of this Nation. Consequently, I consider it a great honor and privilege—but a heavy responsibility—to testify on the subject just announced which is exactly as it was assigned to me. It is much too broad to be comprehensively covered in 30 minutes, nor do I believe it could be adequately covered by one witness, even if much better qualified than the one who appears before you. However, 30 minutes is adequate to summarize conclusions of crucial significance to every citizen of this Nation and to civilization as a whole. These conclusions are not new but have been convincingly stated by United Nations commissions, U.S. Government investigating committees, and nonprofit impartial scientific research foundations. But even though these conclusions have been previously clearly stated and supported by exhaustive statistical data, they have not yet soaked into the consciousness of the American public nor have the recommendations of high level Government committees been implemented by the Congress of the United States. Apparently there is little hope that Government can be expected to carry out is appropriate role in developing adequate energy sources until the public thoroughly understands the significance of energy to its future.

Consequently, the first role of Government is to see that the public is informed and that continuing studies are made by committees of the Congress, such as this one, who have vision, knowledge, understanding, and a capable and diligent staff, so that the committee conclusions will be sound and, most important, will be accepted and the recommendations implemented by the Congress of the United States.

In order to conform with necessary time limitations, and also to prevent loss of interest through tedious references, statistics, and quotations, relatively little documentation will be included in this presentation. But sufficient footnotes will be contained to indicate that I am not so presumptuous as to make these statements on my own authority.

The present explosive increase in world population presents a far graver threat to the survival of civilization than do the awesome explosions produced by nuclear fission and fusion, or the apparent lag of this Nation's space-age development. During World War II, Japan overran much of Asia trying, so the historians tell us, to find living room for its teeming millions. During the last 2 years, an already crowded world added as many people as the entire population of Japan, or twice that of France. When we celebrate Veterans Day next month, most of us here will clearly remember the first armistice and may be impressed with how swiftly the intervening years have slipped by. During the same length of time in the future that has elapsed since 1918, world population will reach the unbelievable total of 7 billion if birth rates continue at present levels and death rates continue their present decline. If present birth rates continue until 1975 and then begin to decline, it is estimated that world population will be in excess of 6 billion by the year 2000. Even if birth rates should immediately begin to decline at rates more rapid than any United Nations study has indicated probable, world population would still rise to 5 billion by the end of this century.[1 2 3] If present growth rates continue, the United States will have a population of 350 million at that time.[4]

The fact that we yet have surplus food in this Nation frequently blinds us to the fact that we are living in a world of want with from two-thirds to four-fifths of the present world population of 2.8 billion people already at near-starvation levels. Thus the dire implications of the present explosive growth in world population cannot be ignored by anyone who has the intelligence and courage to face reality.[5 6]

This witness is no authority in the field of population growth, can offer no recommendations as to what to do about it, and realizes that this is a field beyond the scope of the committee's inquiry. However, it was felt appropriate to touch on population growth for two reasons: First, it would be suicidal folly for society to continue to ignore this matter simply because of its unpleasant implications; and second, because it is only with a background of an understanding of population trends that we can recognize the crucial significance of energy to our Nation and to civilization. The experts tell us that the one chance civilization has in the future, if it does avoid annihilation through nuclear warfare, is to (1) arrest the current explosive rate of population increase, (2) utilize the potentials of scientific technology,

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[1] United Nations, Department of Economic and Social Affairs. "The Future Growth of World Population" (Population Studies No. 28), New York, 1958.

[2] "World Population Situation and Prospects," memorandum by Secretary General. Dec. 22, 1958.

[3] Population Bulletin (vol. XV, No. 2), "World Population Review," March 1959.

[4] Population Bulletin (vol. XV, No. 3). "U.S.A. Population Growth," May 1959.

[5] Sax, Dr. Karl, professor of botany, Harvard University, "Food for the World." Paper presented before the University of Houston symposium, "The Next 100 Years," Houston, August 1959.

[6] Newspaper account of United Nations Committee report.

and (3) make available to all of the world prodigious increased quantities of mechanical energy.[7 8 9 10 11]

This is truly an age of energy. The standard of living of every people in the world can be accurately measured by their relative per capita consumption of mechanical energy. As would be expected, the United States leads all the rest of the world in its use of mechanical energy, and those who have most closely studied the situation tell us that this use of energy is more responsible than any other one single factor for our having obtained the highest standard of living ever enjoyed by any people in the history of civilization and for our present immense food surpluses in a world of want.[12]

If time permitted it would be appropriate to trace the greatly increased output of food, consumer goods, and services in this Nation over the past 50 years coincident with the increased use of energy, and also to analyze the changing sources of energy supply.[12] However, since brevity is essential it is more pertinent to consider the present principal sources of energy in this Nation and to analyze their probable role in this Nation and in the world in the immediate future.

My assigned subject presumably covers all energy sources and I would not intend to neglect any. It is well for us to be fascinated with the exotic energy sources of the long range future because it is probable that civilization ultimately will depend largely upon solar and nuclear energy and that those very nuclear discoveries which now threaten to destroy all of civilization may ultimately be the means of saving it.[13] But at the present time, over 95 percent of this Nation's energy comes from fossil fuels—oil, gas, and coal—which therefore need to receive much of Government's immediate attention.

Coal will play an important role in the future of this Nation and we are fortunately endowed with many hundreds of years of supply. Since coal industry experts will appear before this committee, and their testimony will presumably contain suggestions regarding the appropriate role of Government for this industry, I will not be so presumptuous as to comment myself.

The other two fossil fuels, oil and natural gas, collectively referred to as petroleum, presently furnish 69 percent of all the energy used in this Nation.[10] It seems difficult for the public to grasp the significance of this figure. They are impressed, and properly so, by the

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[7] "The Next Hundred Years," a scientific symposium sponsored by Joseph E. Seagram & Sons, Inc., on the occasion of its centennial, New York, Nov. 22, 1957.

[8] "The Next 100 Years," University of Houston symposium, Houston, August 1959.

[9] President's Materials Policy Commission (vol. III), "The Outlook for Energy Sources," Washington, 1952.

[10] "Future Growth of the World Petroleum Industry," the Chase Manhattan Bank, New York, 1958.

[11] Weeks, Lewis G. Special issue of the Petroleum Engineer, Century Ahead, August 1959: "Where Will Energy Come From in 2059." "Population increase and an acceleration in per capita demand for energy—particularly in large areas of the world where use today is comparatively limited—will produce a total demand for energy in the year 2059 of at least 40 and probably as much as 50 or more times that of 1959."

[12] National Resources Conference Bulletin, Industrial College of Armed Forces, Washington, D.C., 1955.

[13] Weeks, Lewis G. Special issue of the Petroleum Engineer, "Century Ahead, August 1959: Where Will Energy Come From in 2059?" "He will find a way to harness and transmit solar energy. He will develop methods for making use of geothermal energy. He may do the same with tidal energy. He will learn how to free and utilize more and more the energy of the atom, the sources and supply of which are beyond our capacity to imagine."

contribution to the progress of this Nation made by some of our giant hydroelectric projects, such as Grand Coulee, TVA, and Niagara. Yet I doubt that they realize they are dependent upon petroleum for 30 times as much energy as is collectively produced by all the hydroelectric plants in the Nation.[14] Secondly, some of those who do recognize the present and past dependence of this Nation upon petroleum for progress and security seemingly feel that since the nuclear and space era are upon us, petroleum now belongs to the horse and buggy age.

But the nuclear experts rather consistently tell us that it will be several decades in the future before nuclear power can significantly alter our dependence upon petroleum for energy. This was apparently the general conclusion of the Second Atoms for Peace Conference and was the conclusion of several of the papers presented in June 1959 at the Fifth World Petroleum Congress in New York. Supporting references and quotations from the authorities cited are indicated by the footnotes.[15 16 17 18]

Since nuclear power will not soon supplant petroleum, most forecasters predict that pertoleum will continue to be the dominant source of supply in this Nation for several decades. Chase Manhattan predicts that by 1967 petroleum will furnish 74.5 percent of the national energy supply, and coal 22 percent. Petroleum's contribution will be equivalent to 22.3 million barrels of oil per day.[10]

As rapid as will be the increase in petroleum consumption in this Nation during the next two decades, most forecasters envision a much greater percentage rise in petroleum consumption in the rest of the world.[19 20 21] Dr. Walter G. Whitman, chairman of the Chemical

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[14] Weeks, Lewis G. Special issue of the Petroleum Engineer, "Century Ahead, August 1959: Where Will Energy Come From in 2059?" "About 70 percent of available U.S. water power is being utilized to provide less than 2 percent of our energy needs."

[15] Wilson, Robert E., member of the General Advisory Committee to the U.S. Atomic Energy Commission: "The Probable Impact of Atomic Energy on the World Petroleum Industry" (Sec. X, Paper 1), 1959 Fifth World Petroleum Congress, New York. "In view of the small amount of crude (2.5 percent in the United States) now used for central station power generation, plus the fact that atomic energy offers little promise for replacing other more important uses for petroleum products, the impact of atomic energy on the petroleum industry during the next few decades will be practically negligible."

[16] Keller, Dr. Edward, is quoted as stating at Geneva at the Atoms for Peace Conference that he did not look for economical power generation from nuclear fission during this century.

[17] "Future Growth of the World Petroleum Industry," the Chase Manhattan Bank, New York, 1958. "It is estimated * * * nuclear power, may in 10 years' time represent about 1 percent of the total energy supply."

[18] Heroy, William B., "The Impact of Atomic Energy," a paper presented at the Convention of American Association of Petroleum Geologists, Dallas, March 1959. * * * it is not to be expected that the cost of building reactors will, for some years if ever, compare favorably with that of the modern steam boiler plant." "Some recent estimates indicate that the fixed charges of the two competitive power sources may be about the same by 1980."

[19] De Ryckere, Paul R., "Les Provisions de Besoins Energetiques du Monde et L'Importance du Petrole Comme Forme D'Energie Primaire" (sec. IX, Paper 5), 1959, Fifth World Petroleum Congress, New York—"The forecast of energy requirements in the world * * * shows that they will slightly exceed the equivalent of 100 million barrels of oil per day in 1975. The growing demand will soon make oil the most important form of primary energy * * *."

"The consumption of oil and natural gas combined will reach the equivalent of nearly 37 million barrels of oil in 1965, and in 1975 a little less than 60 million barrels per day * * *."

"Recent experience has highlighted the unsuspected need for a greater supply of energy to meet a rapid expansion of economic activity and has proved that only the structural flexibility of the oil industry makes it possible to respond to such requirements."

[20] Levy, Walter J., and Lipton, Milton, "Some Major Determinants of Future Oil Requirements and Supplies" (sec. IX, Paper 3), 1959 Fifth World Petroleum Congress, New York—"It is believed that oil production can be increased to provide the major part of expanding energy requirements. * * *"

[21] Guyol, Nathaniel B., "The Role of Petroleum in World Energy Supplies" (sec. IX, Paper 4), 1959 Fifth World Petroleum Congress, New York.

Engineering Department of M.I.T., and a representative of the United States in organizing the Second World Atoms for Peace Conference, recently made this statement: "Oil and natural gas will furnish the bulk of the world's energy 50 years from now." [22]

Probably because of my lesser vision, I personally would not forecast that petroleum would be so important in the world energy picture this long in the future. I would concur, however, with the prediction that in 1975, 61 percent of the free world's energy supply will be furnished by petroleum, at which time the free world will then be consuming 50 million barrels of oil per day. This figure does not seem so large if we consider the fact that if the rest of the world were consuming as much oil per capita today as in the United States, it would presently be using 135 million barrels daily.

Since most authoritative sources agree that petroleum is and will continue for a lengthy period in the future to be the dominant single source of energy in this Nation, and since it is rapidly becoming the dominant source of energy for the entire world, it would appear that the appropriate role of government in insuring an adequate energy supply must largely involve an intelligent, farsighted petroleum policy. If I can emphasize this one point, my primary objective will have been fulfilled, but I would like to use my remaining time to comment briefly on suggested appropriate roles of State and Federal Government in regard to petroleum.

The relation of government to petroleum is the field in which I have had the greatest experience, since I have worked for both State and Federal petroleum agencies, and it is one in which I might be presumed to speak with authority. However, since I am presently a member of the petroleum conservation regulatory body for the largest and most publicized of the oil-producing States, I fear that my recommendations might be considered to be prejudiced and therefore ignored. Consequently, in my prepared text I have endeavored to support these conclusions with footnotes giving references and quotations from important, high-level Federal committees, commissions, or officials.

First, in regard to the appropriate role of State government, it is believed that each oil-producing State should exclusively administer wise conservation regulations for exploration, development, and production of petroleum, and that these States should continue to be permitted and encouraged to exchange information on conservation regulation techniques in a forum such as furnished by the Interstate Oil Compact Commission. The States have done a creditable job of conservation regulation and are making rapid progress with the exciting new conservation techniques which have recently been discovered in the research laboratories and are quickly being put to field practice. State conservation regulation is essential both to the future of the industry and to the principles of our democratic system of government. The Interstate Oil Compact Commission is not essential to such conservation regulations, but it has served a very useful purpose, and the attacks which have frequently been made on it, even by Mem-

[22] Whitman, Walter G., chairman, Department of Chemical Engineering, M.I.T., "The Next 100 Years," a paper presented to the University of Houston Symposium, Houston, August 1959.

bers of the Congress, are undeserved not only because the compact has not done the things of which it has been accused but, more importantly, because it has absolutely no power or opportunity to accomplish these alleged evils. Investigation of the compact by the Department of Justice has clearly demonstrated this fact, as is evidenced by the quotations in the footnotes.[23]

There should be no interference with the exercise of the State's conservation responsibility to restrict production to market demand. The essentiality of market demand proration to the security of the Nation and to the welfare of the consumers of the Nation needs to be fully developed, possibly at a separate hearing or as an assignment of your staff. It is one of the most important but misunderstod of all the conservation functions of the State regulatory bodies. Without market demand proration, it is impossible to prevent above-ground and below-ground physical waste; it is impossible to develop the reserve producing capacity so essential to national security; it is impossible to obtain ratable take and equity for all producers; and it is impossible to protect the independent producer from the integrated company with its own transportation and market outlets. The Attorney General not only found no evidence of antitrust violation resulting from the practice of market demand proration, but reached substantially these same conclusions as to the benefits derived from this practice.[24] The President's Material Policy Commission report in 1952 recognized the importance of market demand proration.[25] Although the Railroad Commission of Texas has been accused of abusing its market demand proration responsibility by making oil scarce and setting allowables at less than true demand, the Attorney General's Report [23] reveals that for 7 of 11 years under study, Texas' annual production was never as much as 1 percent above or below actual demand, and for the 5-year period from 1952 through 1956, the weighted average for Texas

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[23] Second report of the Attorney General, Washington, Sept. 1, 1957. "The Bureau of July 28, 1955, consenting to an Interstate Oil Compact To Conserve Oil and Gas, Washington, Sept. 1, 1957—"The Interstate Oil Compact Commission is a voluntary association of States with common interests in oil conservation. It conducts studies on conservation problems, disseminates valuable information and makes recommendations to be followed only voluntarily. That a certain amount of general uniformity has developed in the States on conservation laws, rules, and regulations is a tribute to its reputation and influence, not its power."

"On the whole, the activity of the Commission appears to have been worth while. It seems justifiable to ascribe a good deal of the improvement in industry operations over the past quarter century—the elimination of gushing wells and flaring gas, the better use of reservoir energy, the rise in production of oil from about 20 to 40 percent to 80 percent of the potential of the well through utilization of advanced recovery practices—to the promotional activities of the Compact Commission. Above all, the compact and its commission are unique examples of effective interstate cooperation on a wholly voluntary basis."

[24] Second report of the Attorney General, Washington, Sept. 1, 1957. "However, it seems equally apparent that, but for the operation of the regulatory systems of those States, this decline in markets might have had more serious consequences to the independent segment of the production level of this industry. * * *

"The effect of the prorationing techniques used by the State agencies, however, has spread the available market over all of the fields of the State. Thus, allocation of a share of the State's total production to newly developed fields is a powerful pressure compelling the establishment of purchasing facilities by the principal purchasers.

"At the same time, these proration rules provide for limitation of each well to an allowable production determined by market availability. Coupled with the rules relating to the ratable taking of production in any field by the common purchasers there operating, this effectively forestalls the otherwise reasonable possibility that a refining company might take all of its requirements from particular wells in a field, thus draining the oil beneath the wells of any independent producers who have no other market outlet."

[25] The President's Materials Policy Commission report (vol. III), Washington, June 1952. The Outlook for Energy Sources: "Great advances have been made in the oil producing States toward the conservation of oil through use of more efficient methods of production. The adoption of these methods has been closely associated with State regulation of production directed primarily at adjusting production to demand."

missed the actual demand by only 0.11 of 1 percent. Thus, Texas was about as close to hitting true market demand as Ivory Soap is pure.

In regard to the appropriate role of Federal Government, it is nearly as important to suggest what should not be done as to suggest what should be done. First, it is recommended that the Bureau of Mines continue their important statistical service to the industry. Their weekly crude oil stock reports assist the State regulatory bodies in establishing producing rates which will allow every demand to be met but which will not be so high as to result in wastefully excessive aboveground storage. The Bureau of Mines has been subject to attack, again occasionally by Members of the Congress, for their forecasts of market demand on the assumption that these forecasts are actually allocation quotas to the various States. The Attorney General's report effectively refutes this misconception.[26]

The Federal Government should continue to give assistance to the State petroleum regulatory bodies through the Federal Tender Board and its administration of the Connally "Hot Oil" Act.[27] The Federal Government should continue its regulation of the interstate movement of oil and natural gas, but it should not interfere with the conservation regulation by the States of the production of petroleum regardless of whether such petroleum ultimately enters interstate commerce.

It is this witness' conviction that so long as this Nation remains a democracy and adheres to its belief in the private enterprise system, then government, neither Federal nor State, should attempt to fix price ceilings or floors on any competitively produced commodity, petroleum or other. If this philosophy is unacceptable to the Congress, then I suggest that if price regulation is to be attempted, however contrary to American principles it may be, that an understandable, administrable, practicable method of price fixing should be adopted to replace the present completely confusing, ultimately chaotic system of utility-type regulation which has been thrust upon the Federal Power Commission for gas, and would of necessity, if any consistency is to be followed, ultimately have to be adopted for oil and coal. Any statement that a Texan might make on this subject presumably would be discounted, so I quote from a member of the Federal Power Commission who will testify next before this committee and can amplify or correct any unintended inaccuracy. Judge Arthur Kline recently stated, "I wish that I could tell you that we are making good progress, that we are near to evolving standards under which producers can be effectively regulated with a minimum of supervision on our part. I am sorry that I cannot give you any such rosy report. We are making some progress, but it is woefully slow progress, and the outlook for improvement in the immediate future is not promising. There are many reasons why

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[26] Second report of the Attorney General, Washington, Sept. 1, 1957. "The Bureau of Mines, Department of the Interior, has been collecting information and compiling statistics on the petroleum industry for many years. Its monthly statistical coverage of the industry is quite comprehensive. * * * It is generally agreed that State prorationing would have been difficult, if not impossible, to administer without a comprehensive body of statistical data comparable to that furnished by the Bureau.

"Much of the criticism of the Bureau of Mines' monthly demand forecasts has centered on the charge that they influence the policies of State regulatory agencies so as to produce a concerted plan of coordinated production control.

"The idea, persisting from the old NRA days, that these forecasts are State production quotas, does not stand up in the light of these statistics."

[27] Second report of the Attorney General, Washington, Sept. 1, 1957. "* * * the Connally 'Hot Oil' Act * * * prohibits the transportation in interstate commerce of oil produced contrary to the conservation statutes of the States involved in that commerce. In this, the Connally Act is an integral part of the conservation system."

this is so, but the principal reason, of course, is that of the Natural Gas Act affords little guidance as to how we should regulate producers and the Commission's attempt to arrive at a practical workable solution have been thwarted by court decisions, narrowly circumscribing our authority to evolve standards. The cost-of-service method may very well work in such a case (for a large company), but in the case of a small producer use the cost-of-service method in which a test year is used to determine the producer's rates for future years will often either justify a far higher price than he can obtain for his gas or will allow him such a ridiculously low price as to discourage future drilling. In my view, the only hope we have of establishing an effective clear-cut means of regulating producers in the near future is by means of legislation. Unless some constructive legislation is adopted, the entire gas industry will suffer, particularly the consuming public and the producers."[28]

Finally, the Federal Government has a very important responsibility in the field of regulating imports of petroleum so as to avoid serious impairment of national security. Again, it is not necessary to accept any conclusions from a Texas railroad commissioner, but instead these conclusions are clearly stated in the July 29, 1957, report of the President's Special Cabinet Level Committee under the chairmanship of the Secretary of Commerce and including the Secretaries of State, Defense, Interior, and Labor.

Ultimately the Special Committee recommended limitations on the importation of oil, and rejected all the other proposals. It believed that storing imported oil in depleted domestic fields presented serious financial problems, both of finding and equipping suitable fields and in the amount of capital investment tied up in the stored oil. Moreover, this novel procedure presented serious engineering problems, including that of economical recovery of the oil from the formations that might be available for such storage. Government participation in exploration was rejected not only as excessively costly to the Government but also as contrary to the traditional principles of a free-enterprise economy. As a practical matter, a large part of the effective search for oil is carried out by small independent drillers. It would be difficult to make provision for a system of Government incentives, in the absence of an immediate market for the oil discovered, which would maintain these efforts. Finally, the third proposal, increasing imports to reduce the drain on our own natural resources, was discarded as involving too substantial a curtailment of domestic petroleum industry activity. Without market incentives, exploratory activities would decline substantially and the necessary renewal of depleting supplies through discovery would halt. Accordingly, possible domestic reserves of crude oil, remaining undiscovered and undeveloped, would be of little use in an emergency. In districts I through IV (all of the Nation other than the west coast), however, the committee found the degree of imports excessive for national security. It proposed that imports exceeding 12 percent of such domestic production should be regarded as a peril to security.

In summary, the domestic petroleum industry has served this Nation well during two wars and a police action. Our military have affirmed that it was reserve producing capacity obtained from the States which had wise conservation regulations at the State level and which practiced market demand proration that was so important to our victory in World War II. More recently, it was such reserve producing capacity which prevented the crippling of our allies in Western Europe during the Suez crisis. It has been the domestic petroleum

[28] Kline, Judge Arthur, Federal Power Commission, "Regulatory Outlook for the Small Producer," address before Texas Independent Producers & Royalty Owners Association. Dallas, April 1959.

industry that has contributed a large portion of the energy supply which in turn has accounted in considerable measure for the progress and prosperity of this Nation. Of greater significance, we will be even more dependent upon the domestic industry for future security and for future energy supplies. Consequently, this domestic industry needs an intelligent understanding by the American public and its elected governmental representatives. Government should carry out those policies which long ago were recommended by high level committees and should refrain from changing those taxation and regulatory policies which have worked so successfully in the past simply because there presently appears to exist a misunderstanding of, and prejudice against, the domestic industry.

Finally, I would like to raise questions for possible investigation by this committee, the answers to which I must acknowledge are completely out of my field. This testimony began with a statement on the peril to the future of civilization found in the rapid population growth and the importance of abundant world energy supplies if any solution to this peril is to be found. The Cabinet Level Committee report that excessive imports of foreign petroleum jeopardize our domestic industry and imperil our national security has been quoted. The question I would raise is whether our Federal Government may not have a broader role than just to prevent ruinously high levels of foreign imports. Since this Government has attempted, through many billions of dollars of foreign aid, to strengthen the economic structure of friendly foreign nations and to raise the standards of living of underprivileged people of the world, might not we somehow intelligently and practically embark upon a policy of helping to make available to the energy-starved, overpopulated areas of Europe and Asia greater quantities of petroleum, particularly from the fabulously rich reserves of the Middle East. Machinery for agriculture, for industry, and for transportation, and petroleum to power this machinery, could do much to lift the standard of living of the people of the world, to make peace possible, and give the scientists time to harness the atom for practical, peaceful purposes and thus prepare us for the next century.

Adequate world petroleum reserves are believed available to accomplish this purpose, but only if there remains an incentive for continued exploration and development, only if these reserves are efficiently produced, and only if they are widely distributed and made available to meet the needs of all people.

Let us keep our domestic industry strong, virile, and aggressive, so that it may continue, as long as possible, to meet our peacetime demand and preserve our national security; and let us request our ablest statesmen to tackle the problem of transporting surplus foreign oil through surplus foreign tankers to areas of crucial energy shortage. If we could do this, we might save a lot of the world from communism.

Representative PATMAN. Thank you very much, Chairman Murray.

Although I will not avail myself of the opportunity to ask questions, since you have covered the subject so thoroughly and we have a crowded schedule this morning, I think one of your observations should be emphasized and underscored:

> This use of energy is more responsible than any other one single factor for our having obtained the highest standard of living ever enjoyed by any people in the history of civilization and for our present immense food surpluses—

and so forth.

I wanted to emphasize that statement as I think it is important, and also your statement on page 5 about price fixing. I hope the time never comes when we will be compelled or forced to have price fixing in our country again. But these observations are certainly timely and should be given consideration by the Congress in the event we should feel compelled to enter into such a course in the future.

Your testimony is very much appreciated, Mr. Murray, and we appreciate, too, the suggestions you have made to the committee staff and to the chairman in the preparation of these hearings. They have been very helpful to us. Thank you, sir.

Mr. MURRAY. Thank you, Mr. Chairman.

Representative PATMAN. If you desire to add anything to your testimony when you get the transcript, you may do so.

Mr. MURRAY. Thank you, sir.

Representative PATMAN. We have Judge Arthur Kline, Commissioner of the Federal Power Commission, as our next witness.

Judge Kline will speak on the problems and prospects of the natural gas industry.

You may proceed, Judge Kline.

STATEMENT OF ARTHUR KLINE, COMMISSIONER, FEDERAL POWER COMMISSION

Mr. KLINE. Mr. Chairman and members of the committee, you have asked me to appear before this committee and discuss the problems, prospects, and regulation of the natural gas industry. This covers a very broad field and I shall only discuss such matters as I believe have some bearing on the purposes of these hearings, which I understand is to determine the direction of growth in the Nation's energy industries, and to inquire into the various factors affecting that growth.

Natural gas is the only form of energy that is under comprehensive Federal regulation, with the exception of nuclear fuels, and these are not in wide use today. The Federal Power Commission is encountering many difficulties in its regulation of the industry, particularly insofar as regulation of independent producers is concerned, and there have been many long delays in the disposition of matters pending before us.

Charges have been made that these delays are leading to chaos in the industry and are affecting its growth and, accordingly, the regulation of the industry and its problems are a matter of concern to this committee.

Do these delays occur in all phases of our regulatory work? What is their cause? Will they affect the growth of the industry? Why has the Federal Power Commission not arrived at some solution of the problem of determining just and reasonable rates for producers?

A brief description of the nature of the natural gas industry and of the duties and scope of jurisdiction of the Federal Power Commission will assist in a better understanding of the answers to these questions.

Generally speaking, the interstate natural gas business consists of three segments, the producers who search for and produce the gas, the pipelines which transport the gas interstate from the point of production to the point of consumption, and the local distributors who market the gas.

The Federal Power Commission has jurisdiction over sales of gas made by producers in interstate commerce. It has no jurisdiction over sales of gas made by the producers for consumption within the States in which the gas is produced. We have complete jurisdiction over the transportation of the gas in interstate commerce.

We have no jurisdiction over the distribution or sale of the gas to the ultimate consumer by the distribution company. Jurisdiction over the pipelines who transport the gas in interstate commerce has been exercised continuously by this Commission since passage of the Natural Gas Act in 1938. Jurisdiction over the producers who made sales of gas to the pipelines was not undertaken by this Commission until after the Phillips decision—*State of Wisconsin* v. *Phillips Petroleum Company*, 347 U.S. 672—in 1954.

In the regulation of both producers and pipelines most of our work falls into two general classifications. One of these is the issuance of certificates of public convenience and necessity authorizing the natural gas company to make the sale or to transport the gas in interstate commerce, and authorizing the construction of the facilities necessary to accomplish this. The other is the fixing of just and reasonable rates for both the production and interstate transportation of natural gas.

It is apparent that failure to act promptly upon applications for certificates of public convenience and necessity would impede expansion of the natural gas industry to a much greater extent than failure to act promptly upon rate matters. Failure to dispose of rate cases promptly does, of course, have some effect upon expansion of the natural gas industry.

A company which has been collecting rates for 2 or 3 years without a final determination as to whether it will be able to retain all of the amounts collected or must refund an undetermined amount will have more difficulty in financing expansion than a company whose revenues are certain and which is not faced with the possibility of the refund of an unknown amount.

In the issuance of certificates of public convenience and necessity, whether the certificate be one authorizing a pipeline to engage in the interstate transportation of gas or one authorizing a producer to sell its gas in interstate commerce, there can be little valid criticism of undue delay on the part of the Commission.

Rather, the Commission is entitled to credit for the expeditious manner in which it has handled this type of proceeding. For example, between July 17 and July 28, four major pipeline certificate cases and the related producer applications were argued orally before the Commission. Each of the pipeline applications involved an expenditure for construction of $40 million or more and in each case there were 30 or more parties and each case involved at least several contested issues. Each of these cases was decided by the Commission and a final decision issued on or prior to August 10.

I have annexed an exhibit marked "Exhibit A" to this statement showing the time schedule of these four hearings.

(The document referred to follows:)

EXHIBIT A

	Southern Natural Gas Co.[1]	Northern Natural Gas Co.[2]	Texas Gas Transmission Co.[3]	Transwestern Pipeline Co.[4]
Date of filing of original application	Mar. 3, 1958	Jan. 12, 1959	Dec. 24, 1958	Apr. 15, 1958.
Amount involved in pipeline application.	$52,200,000	$121,500,000	$41,800,000	$191,700,000.
Number of independent producer applications consolidated in case.	10	1	21	15.
Total number of parties	60, including staff.	56, including staff.	30, including staff.	30, including staff.
Date hearing started	Jan. 20, 1959	Apr. 20, 1959	June 10, 1959	Dec. 15, 1958.
Date hearing ended	Feb. 18, 1959	June 18, 1959	June 25, 1959	Apr. 2, 1959.
Date of examiner's decision	June 11, 1959	None	None	July 1, 1959.
Date of oral argument before Commission.		July 17, 1959	July 21, 1959	July 23, 1959.
Date decided by Commission	Aug. 7, 1959	July 31, 1959	Aug. 10, 1959	Aug. 10, 1959.

[1] Southern Natural Gas Co., docket No. G-14587, opinion No. 325, issued Aug. 7, 1959.
[2] Northern Natural Gas Co., docket No. G-17485, opinion No. 324, issued July 31, 1959.
[3] Texas Gas Transmission Co., docket No. G-17335, opinion No. 327, issued Aug. 10, 1959.
[4] Transwestern Pipeline Co., docket No. G-14871, opinion No. 328, issued Aug. 10, 1959.

Mr. KLINE. It is true that certificate cases have not always been disposed of so expeditiously, but there were generally good reasons for failure to act with more celerity. For example, a number of independent producer certificate applications were held up earlier this year while the Commission was wrestling with the problem of how best to deal with initial prices proposed in contracts entered into between the producer and pipeline.

Also, you are aware, I am sure, that there was a delay of several years in making gas available to the Chicago and midwestern markets. In that instance, the Commission had several competing applications from different pipeline companies all desirous of serving the same market, and the coal interests had intervened to protect their interest in the Chicago market.

The Commission, under the law, is required to permit each of the applicants for a certificate a comparative hearing and must permit intervention by all interested parties. The first time these applications came before the Commission the various applications were consolidated and set for hearing. There were 151 parties represented by counsel at this hearing which was in session for 143 days, during which time approximately 20,000 pages of testimony were taken and exhibits introduced which made the total record approximately 100,000 pages in length.

At the conclusion of the hearing, the Commission found it necessary to dismiss all of the applications, either because the applicants had failed to show a sufficient gas supply or had a project which was economically unfeasible (*American Lousiana Pipeline Company, et al*,. 20 F.P.C. 575).

Following the dismissal of these applications on October 31, 1958, a new and materially different application to serve the Chicago market was filed by one of the competing applicants. A hearing was held, and on May 12, 1959, barely over 6 months after the application was filed, and after a hearing contested by the coal intervenors and the

Commission staff, the Commission entered an order authorizing the construction of the pipeline and the rendition of service to the Chicago area (*Midwestern Gas Transmission Company, et al.*, 21 F.P.C. 653).

Other examples could be cited, but in almost every instance, the principal cause of delay in acting upon the certificate applications has been the failure of the company making the application to furnish promptly all of the necessary information for the processing of its application, or else the company made last minute revisions or amendments to its application which necessitated a delay to permit further study by the staff of the Federal Power Commission.

A very different situation exists with respect to rate cases. Cases involving the justness and reasonableness of rates charged by a natural gas company arise in one of two ways. The Commission may, either upon its own motion or upon complaint, institute an investigation into the justness and reasonableness of rates charged by a natural gas company. This proceeding is authorized by section 5(a) of the Natural Gas Act and is generally referred to as a 5(a) proceeding.

Since 1954, the Commission has instituted investigations into the rates of almost all of the major independent producers and we have 37 such rate investigations pending. None of these 5(a) cases against independent producers has been completed as yet.

An oral argument was held before the Commission on October 1 and 2 of this year in the 5(a) proceeding brought against Phillips Petroleum Co. This is the first of these cases to come before us and a decision should be forthcoming in a few months.

The other type of a rate case arises as a result of an increase in rates requested by the natural gas company. Section 4(e) of the act permits natural gas companies to file for rate increases. If the Commission is not satisfied that the proposed rate is just and reasonable, it may suspend the proposed rate for a period of 5 months and institute an investigation

We had pending as of August 31, 1959, a total of 90 pipeline cases seeking rate increases aggregating a total of $339,630,400 annually. We also had pending 2,361 independent producer rate cases seeking total annual increases of $111,756,938. The 2,361 suspended filings does not mean there will be that number of separate rate cases, as each of the larger independent producers has dozens of rate filings suspended and all of the suspended rate filings made by any one independent producer will undoubtedly be consolidated for trial.

Since it undertook regulation of independent producers, the Commission has finally acted upon 231 independent producer rate increase suspensions. The aggregate annual amount involved was $9,178,167, of which $5,973,309 was allowed and $3,204,858 was disallowed.

In addition, the Commission had disposed of 22 other rate suspensions involving an annual amount of $5,705,217, which cases were appealed to the courts and subsequently remanded to us and which are included in our present total of pending cases.

The failure of the Commission to arrive at a solution to the problem of determining just and reasonable rates and the delay in disposing of rate cases is not due to any one single factor. A myriad of factors are responsible.

Perhaps the principal reason is the nature of the producing business and the business practices which have developed in it throughout the years. The regulation of any phase of the natural gas business is exceedingly difficult and presents many problems. Justice Brandeis once remarked, in *Pennsylvania* v. *West Virginia* (262 U.S. 553, 621):

> In no other field of public service is the controlling body confronted with factors so baffling as in the natural gas industry; and in none is continuous supervision and control required in so high a degree.

This remark was made some 35 years before there was any regulation of the producers of natural gas. The problems which have arisen in connection with the regulation of the independent producers are incomparably more baffling and perplexing than those which exist in any other segment of the industry. The following are a few of the reasons for the difficulties the Commission has encountered in regulating the producing industry:

1. The cost of natural gas has no consistent relationship to the value of the product

Some gas is obtained from sands a few hundred feet under the surface of the earth; other gas comes from formations many thousands of feet in depth or from regions such as the Gulf of Mexico, where drilling costs are much higher than on dry land. One producer may drill a much higher proportion of dry wells than another. Gas leases may vary greatly in cost, depending upon factors which have very little relationship to value.

The West Edmond field in Oklahoma, discussed by us in opinion No. 310, *Pan American Petroleum Corporation* (19 F.P.C. 463), is an illustration of this principle.

This field was discovered in 1943 and by 1945 the limits of the field had been clearly defined and a well drilled on each 40-acre tract in the field. There were 754 wells drilled—exclusive of dry holes which may have been drilled off the structure in determining its boundaries. The actual cost of drilling these wells was reasonably uniform, within 20 percent of $90,000, one way or the other.

These wells were drilled by 143 producers, both large and small. Some paid very little for their leases, having obtained them before the original discovery well. Others had high lease costs. Gas was obtained from a formation known as the Hunton lime, which varied in thickness from 300 feet on one side of the field to zero feet on the other.

After the field was fully drilled, it was unitized for purposes of conservation and was operated as a unit by one producer. Each of the 754 tracts was assigned a different percentage participation in the production from the field, the amount of participation depending upon the amount of gas and oil estimated to underlie each tract.

These percentages varied greatly, some tracts receiving 27 times as much as other tracts. Since drilling costs were relatively constant, a producer from one tract would need to receive 27 times as much for his gas as a producer on another tract in order to obtain a like return on his investment, assuming their lease costs were likewise the same.

In this respect, I might say that the lease cost of the outlying wells were usually much higher than the lease cost of the wells where the gas was first discovered, and as a result the total costs of a producer receiving a small portion of the production were generally higher than the total costs of a producer receiving a greater amount of the production.

Recognizing the fact that the cost of gas bears little relationship to its price or value, this Commission has attempted to regulate the price of gas on the basis of prevailing field prices, but in the *City of Detroit* case—*City of Detroit* v. *FPC*, 230 Fed 2d 810 (CADC), certiorari denied 352 U.S. 829—was reversed in its attempts to do so, the court holding that the Commission must use the cost-of-service approach at least as a point of departure.

2. The industry produces a joint product

Unlike some extractive industries, such as the coal industry, the independent companies produce both gas and oil, and many are engaged in other phases of the petroleum business. Only 6 percent of the revenues of the Phillips Petroleum Co., the largest gas producer in the country, are derived from natural gas, and other large producers obtain a similarly small proportion of their revenues from gas.

A very difficult regulatory problem is posed by the fact that the companies have made no attempt to assign costs to gas in their general record systems. Many of the companies own and operate producing facilities in a number of fields. They may have dry gas wells, casinghead gas wells—that is, gas produced with oil—and condensate gas wells—that is, gas left after liquid hydrocarbons have been removed upon reduction of the natural well pressure.

But very few companies even break down their costs by field, although there is a present trend to maintain separate costs for the larger fields.

To arrive at a cost of service, it is necessary to assign costs of production either to gas or oil. The problem of allocation is directly posed where a well produces both gas and oil, where exploration is directed, as it generally is, to the discovery of either gas or oil, and where there are administrative expenses and other overhead which pertain to both oil and gas.

On the books of the producers there are ordinarily large amounts of administrative and supervisory expenditures which are not allocated to lease or field operations. The basis of making these allocations have led to great controversy in some of the proceedings now before us.

I cannot overemphasize the importance of this allocation question and the difficulties it has caused. To illustrate the difficulties, assume a member of this committee entered the drilling business and drilled a well, the total cost of which was $100,000, and which produced 20 barrels of oil and 1,000 M c.f. of gas daily. How much of the $100,000 cost should be recovered from sales of gas to assure the member a fair return on the money he has invested?

Various methods of allocation have been suggested to us. Some are based upon the relative B.t.u. content of the oil and gas. Thus, assuming the 20 barrels of oil produced the same number of B.t.u.'s as 1,000 M c.f. of gas, one-half of the cost, or $50,000, would be assigned to gas. A principal disadvantage of use of the B.t.u. method is that it would result in greatly increased costs of gas.

Other methods of allocation are largely based upon existing prices. Gas discovered near several large existing pipelines has in the past brought far higher prices than gas discovered in remote areas and use of these methods of allocation tends to promote existing price inequities and is to some extent a departure from the cost method.

3. The Commission regulates only interstate rates

Forty-one percent of the gas marketed in this country is sold within the State where it is produced—Mineral Market Report No. 2972, issued by the Bureau of Mines on September 10, 1959—and we have no jurisdiction over such sales. Neither do we have jurisdiction over sales which are not for resale.

It is difficult, if not impossible to regulate and hold down prices of gas where we have no jurisdiction over such a large portion of the market. Numerous examples could be cited as to how regulation on a cost basis will tend to operate to the advantage of the intrastate market.

Let us use as an illustration the West Edmond field which I have cited, and assume a similar field was discovered in the future. With such a large portion of the market unregulated, those producers who obtain production from the thick sands at a cheap unit cost would tend to sell their product in the intrastate market since they would be entitled to only a low price per M c.f. in the intrastate market.

On the other hand, those producers who had high unit costs would sell to the interstate market as they would be unable to compete in the intrastate market. Thus, regulation on a cost basis of only a portion of the gas production is ineffective since it tends to drive gas which is cheap in cost to the intrastate market, and expensive gas to the interstate market.

(Another example of how the existence of the intrastate market renders ineffective action taken by the Commission to hold down prices can be found from an examination of our order issued Sept. 18, 1959, in *Phillips Petroleum Co.*, docket No. G–17897, and the examiner's decision and the proceedings therein.)

The fact that we have jurisdiction only over sales made by producers in interstate commerce for resale has led to many attempts to avoid our jurisdiction either by purchase of the gas in the field by the ultimate user—see, for example, *Transcontinental Gas Pipeline Corporation*, 21 FPC 138—or by acquisition of an entire gasfield by a pipeline company rather than a purchase of the gas production only—see our opinion No. 322, *Texas Eastern Transmission Corporation*, docket No. G–12440, issued June 23, 1959. In summary, lack of jurisdiction over a substantial portion of the market for gas complicates and sometimes thwarts regulation.

4. The great numbers of independent producers

The very number of the independent producers has added greatly to the difficulties and delays in regulation. As of January 1, 1959, there were some 3,000 such producers, having 10,000 basic contracts for the sale of gas and 27,000 supplements thereto.

5. Diversity in recordkeeping

The independent producers have no uniform method of keeping accounting and other records. This causes delay to the Commission's staff in examining the records, particularly the books of account. As we pointed out earlier, the companies make no attempt to assign costs to gas in their general record systems.

Some of the companies separate their records by fields, but some do not. On their books, most companies capitalize their intangible well-drilling costs, while other companies expense these costs just as they do on their income tax returns, or handle them in still other ways. Most companies record depletion, amortization, or depreciation on a unit of production basis; others amortize them over a fixed period.

Another problem in connection with company records is that the records are maintained in a number of different offices, sometimes scattered widely. This, of course, leads to delays in the work of the Commission's staff and delays in scheduling rate cases for hearing.

6. Diverse size of the producers

Because there are such differences in the size and financial standing of the producers, regulation is further complicated. The risks involved are so different between the large producers, like Phillips with many wells, and the small producers with few wells, that a complete regulatory scheme will have to take this into account.

7. Irregularity of price patterns

Producer prices vary widely from one field to another and one part of the country to another. This pattern had developed prior to the time we assumed jurisdiction over producers in 1954. Where a number of pipelines compete for the gas, the price level tends to be high. Where there is only one pipeline in the area to which producers must sell their gas, the price level is much lower. An example of a high-priced competitive area is the gulf coast, while an example of a low-priced area, where the sales are largely made to one pipeline, is the Permian Basin in New Mexico.

These are a few of the problems we have encountered in regulating producers and a few of the causes for delay in regulating them more effectively.

Another important factor contributing to the delays we have encountered is the nature of the administrative process itself. These delays are common to all administrative agencies regulating industry. Mr. Louis J. Hector, who recently resigned from the Civil Aeronautics Board, set forth in detail many of the defects in the administrative process. (See memorandum to the President, "Problems of the CAB and the Independent Regulatory Commissions," dated September 10, 1959.)

His statement dealt primarily with the CAB, but virtually every criticism he had as to the handling of matters before the CAB applies to a greater or lesser extent to proceedings before the Federal Power Commission.

Our procedure has the same flaws and the same shortcomings mentioned by him in discussing CAB procedures. In subscribing to his analysis of the flaws in the administrative system, I wish it clearly understood that I do not generally agree with his suggested solution of these problems. The subject of improvement of the administrative process is being considered by other congressional committees and I shall limit my discussion of procedure to two matters.

Criticism has been directed at the Federal Power Commission for failure to evolve standards for determining the justness and reasonableness of producers' rates. We were directed by the Supreme Court in the *Phillips* case on June 7, 1954, to regulate independent producers, and that case was remanded to us on November 22, 1954, with instructions to investigate Phillips' rates.

The only way we could proceed with the *Phillips* case was to have the matter set for hearing before an examiner and to permit all parties to present fully their evidence in the case. This was done and our staff immediately undertook an investigation of Phillips' books and accounts in order to produce testimony, since the burden of going forward with the evidence in a 5(a) proceeding is on the staff.

The hearing commenced on June 26, 1956, and closed on December 18, 1957. The examiner called for the filing of briefs by the various parties, and on April 6, 1959, more than 15 months after the close of the evidence, filed a 317-page decision. Under the rules of the Commission, each of the various parties had a prescribed time within which to file exceptions, which time was extended because of the importance of the case and the length of the record.

It was not until October 1 and 2, 1959, that we heard oral argument in this proceeding, and the matter was formally before us for the first time. The provisions of the Administrative Procedure Act, under which the Federal Power Commission operates, in effect prevents the Commission from taking any action to affect the course of the proceeding while it is in the hands of the examiner.

Many important matters, such as how to allocate costs between oil and gas, and the rate of return to be allowed independent producers, were determined by the examiner on the basis of the facts appearing in the record and are now before the Commission for the first time.

Such issues are present in other proceedings now pending before the Commission, and an earlier decision would have greatly expedited all such proceedings. Yet the administrative procedure is such that this Commission has been unable to consider and decide these matters until presented to us for the first time in a specific case.

If there is valid criticism of the delay in arriving at a solution of the independent producer rate problem, the fault is one of the administrative system and not of the Commission, which must operate under laws passed by the Congress.

It is true that the Commission could have proceeded under its rulemaking powers to determine general principles in the regulation of independent producers and the Commission attempted to do so by issuing a notice of proposed rulemaking in docket R-142 on November 17, 1954.

However, the Commission found that the producing industry varied so much from any other regulated industry, and the issues involved were so complicated, that it would not be wise to determine them in such a proceeding, and, accordingly, on November 30, 1955, entered an order terminating the proposed rulemaking proceeding.

Although I was not a member of the Commission at the time this proceeding was terminated, I cannot see how it could have done otherwise unless it ordered an industrywide hearing before an examiner, a process which would have taken far longer that the *Phillips* case.

Before leaving the question of administrative procedure, I wish to mention the subject of interventions. We have requested Congress to limit by legislation the number of interventions in natural gas cases. Exhibit A attached hereto illustrates the number of parties appearing in proceedings before us. It shows that the number of parties in each of the four proceedings described therein varied from a minimum of 30 to a maximum of 60. In the first *Midwestern* case, to provide gas to the Chicago market, there were 151 parties represented by counsel who appeared in the case. It is obvious that the presence of so many parties is bound to complicate and confuse the issues in any case.

The Commission has been reversed several times by the courts in its attempts to limit the number of parties intervening, the courts holding that under the provisions of the Administrative Procedure Act the parties had a right to appear. It is a matter for the Congress to determine whether it is more desirable to limit the interventions in these proceedings in order to attain a more speedy determination of the case or to permit almost unlimited interventions as is now the case in order that the requirements of due process afforded by the Administrative Procedure Act will not be violated and that every possible interested party will have an opportunity to be heard.

I stated earlier that there were many factors contributing to the delay in cases before the Federal Power Commission and have discussed in some detail causes for delay brought about by the nature of the business we are regulating and by the nature of the administrative process.

I shall mention only two other causes of delay. First, we do not have a sufficient staff to regulate adequately the industry. Our annual reports to Congress show that the average number of employees of the Commission for the fiscal year ending June 30, 1950, was 751. In fiscal year 1957, my first full year with the Commission, the average number was 714; in fiscal 1958, 715; and in fiscal 1959, 796.

The situation is improving and we have been given increased appropriations by Congress for fiscal 1960, but even greater appropriations must be made and a larger staff maintained if we are to regulate adequately the natural gas industry.

The other factor contributing to the delay which I shall mention has been the attitude of the producers themselves. There has been a stubborn reluctance on the part of the production industry to submit to regulation. The industry as a whole has not cooperated. Requested information has not been furnished readily and every possible issue has been litigated through the courts, thus placing a heavy burden on our limited staff.

In fairness, I should state that the attitude of the industry has continually improved, and that we are obtaining far better cooperation now than at any previous time since I was appointed to the Commission.

Earlier I mentioned that the great diversity in size and financial standing of the various producers was a complicating factor in regulation. There is no question but that the cost problem and how to handle it raises a much more serious issue insofar as small producers are concerned than it does with respect to large producers, for the large producer has many wells and his costs will usually average out, while a small producer may have only a few high-cost wells.

This raises the question of whether or not small producers should be exempted from regulation. Whether the task of the Federal Power Commission would be eased if these small producers were exempted is questionable. Much of the gas production has developed in the manner of the West Edmond field previously described.

There are many fields throughout the country in which both large and small producers operate. Many of these have been unitized and are operated by one producer for the benefit of all. If small producers were exempted, we would have part of the gas produced in these fields subject to regulation and part free from regulation, even though it was all produced by one operator.

Undoubtedly, exemption would lead to different prices being paid to different producers in the same field. This would complicate the accounting of the operator and might lead to other difficulties, such as the triggering of favored-nation clauses and price redetermination clauses in contracts of the regulated producers in event the unregulated gas was sold at a higher price than the regulated gas.

On the other hand, there is no doubt but that exemption from regulation would, in many respects, lessen the work of the Federal Power Commission in that it would greatly reduce the number of producer rate and certificate filings.

PROSPECTS

The natural gas industry should enjoy a steady period of growth in the years ahead. This growth will probably not be as rapid as during the past decade, when natural gas was being brought for the first time into many metropolitan areas. Our rapidly expanding population, coupled with the fact that natural gas is the cleanest and most convenient of fuels and enjoys a price advantage in most areas over other competitive fuels, are sufficient to insure its future growth. However, there are several factors which may limit this growth.

The first possible limiting factor is that of supply. Most of the natural gas requirements of this country will probably need to be supplied from gas found within the continental limits of the United States. It is true that recent developments in shipment of liquefied methane have proven most promising and it may be that the cost of such shipment may ultimately be reduced to a point where natural gas can be brought into this country from Venezuela and other foreign countries in this manner.

However, at the present time, liquefied methane shipments from abroad cannot compete competitively with natural gas produced in this country. Canadian gas will supply some of the gas requirements of our west coast and upper Midwest regions, but most experts agree, for reasons I shall not detail here, that we cannot, on the basis of our present knowledge, expect Canada to furnish any substantial portion of our future gas requirements.

In this country most of our proven reserves, estimated to total 254 trillion cubic feet at the close of 1958, are dedicated to meet the requirements of existing pipelines. Any substantial future expansion of the industry must be based upon reserves which have not as yet been discovered.

While most authorities seem to feel that there is but little question that we shall be able to find these reserves, and estimate the ultimate recoverable reserves of this country at figures varying from 1,100 trillion to 1,700 trillion feet, there are other eminent authorities who seriously question these estimates, and the manner in which they are made, and express doubt that this country will discover as much gas in the next 15 years as in the past 15 years. (See, e.g., paper entitled "The Natural Gas Industry, 1959," given by Ralph E. Davis, on April 23, 1959, before American Petroleum Institute, Division of Production, at Dallas, Tex.)

The factor most likely to retard future growth of the natural gas market will be the inability of gas to compete in price with coal and fuel oil, its chief competitors. Until recently, gas has enjoyed a distinct price advantage, but in the last few years this advantage has diminished and even disappeared in certain areas insofar as the industrial markets are concerned.

Fuel oil and coal are still unable in most areas to compete with gas for domestic and commercial uses, but since the industrial load comprises more than one-half of the total gas consumption, any substantial loss in this area will seriously affect the growth of the natural gas industry.

The *Midwestern Gas Transmission Company* case, docket No. G-16841 (21 F.P.C. 653), decided by us on May 12, 1959, illustrates the seriousness of this threat. The evidence in this case showed that the gas purchased by Tennessee Gas Transmission Co. in the Gulf of Mexico in order to supply the Chicago market to be served by Midwestern cost 21.4 cents per M c.f. plus taxes of approximately 20 cents per M c.m. When the price of this gas was rolled in with the cost of Tennessee's other gas, the average purchased gas cost to Tennessee for all its gas became 15.74 cents per M c.f.

The estimated cost of transporting this gas to the Chicago market by Tennessee and Midwestern was 21.5 cents per M c.f., making a total average cost in Chicago of 37.2 cents per M c.f. to the distributing companies for pipeline delivered gas.

The evidence clearly showed that the cost of coal in the Chicago market was so low that only gas priced at 25 cents per M c.f. delivered to the industrial customer could compete, and that the pipeline delivered price of gas to the distributor selling to these industrial concerns could not exceed 22 cents per M c.f. in order to make provision for distributing company costs and profits.

The Federal Power Commission has recognized that gas sold industrial customers on an interruptible basis should not bear as high a portion of the fixed costs as gas sold firm domestic customers. Under the allocation methods ordinarily used, these costs would have been so allocated as to require a commodity charge of 26.7 cents per M c.f. under a demand-commodity form of rate for gas sold by Midwestern to its Chicago distribution company customers.

However, in order that Midwestern might sell to distributors at a a price at which they could compete in the industrial market, the Commission authorized the sale under a rate, the commodity component of which was 22 cents. Since the commodity component of Tennessee's rate at Portland, Tenn., where it delivered the gas to Midwestern was 22.16 cents, I dissented, pointing out that the effect of our decision was to require the domestic and commercial users in the Chicago area not only to bear all of the costs of construction and operation of Midwestern's pipeline, but to contribute to the cost of the gas supplied the industrial user.

When gas purchased in the Gulf of Mexico at 23.4 cents per M c.f. must be sold in Chicago by the pipeline at 22 cents per M c.f. to retain the industrial market, gas is not competitive with coal in that area.

The Chicago situation is typical of that existing in many other sections of the country. One of the difficult issues in many of our pending pipeline rate cases is whether, in order to permit continuance of industrial sales, we must change our allocation formulas and allocate less costs to the commodity component of the rate and, in effect, reduce the rates charged industrial users and increase the rates charged domestic users.

The prospects are that gas will have even more difficulty in the future in competing with other fuels. Coal prices have increased but slightly since 1948, due to improvements in technology. In fact, the testimony in the *Midwestern* case was to the effect that coal prices in the Chicago area were coming down. Fuel oil prices have firmed somewhat since import restrictions were imposed, but the world oversupply of oil indicates there will be no immediate upward trend in these prices.

On the other hand, the prospects of higher gas prices seems inevitable. Producer costs are increasing. Not only does the producer face the same inflationary trends with respect to wages and supplies as other industries, but the producing industry is being compelled to drill ever deeper and in more remote areas in its search for gas.

Industry figures show that the cost of drilling rises in geometric proportion as the depth of drilling increases.

The American Petroleum Institute, the Mid-Continent Oil & Gas Association, and the Independent Petroleum Association of America recently published a "Joint Association Survey of Drilling Costs." This survey showed that in 1956 the average cost of drilling a well in the depth range of 2,501 to 3,750 feet was $8.58 per foot and $26,500 per well; in the depth range of 7,501 to 10,000 feet was $14.41 per foot and $125,000 per well, and in the over-15,000-foot-depth range was $47 per foot and $761,700 per well. It also showed costs of offshore to be several times the cost of onshore drilling.

As for pipeline costs, two of the most important items are the price of steel and the cost of money. This committee is well aware of recent developments in both these fields, and can draw its own conclusions as to what the future holds.

Finally, delays in administration of the Natural Gas Act may have some retarding influence in the future. Up to now, such delays have had little such effect.

We are proceeding on a case-by-case method and future progress will be slow and tedious. The *Phillips* case, when decided, may supply some of the answers, but it will not supply all of them and may also raise as many questions as it settles.

This is usually the case where, as here, we are venturing into a comparatively new field. The best hope for a speedy determination of many of these issues is action by Congress clearly defining how we should regulate producers, or exempting them, but I recognize that as a practical matter there is little prospect of this during the present session of Congress.

I recognize that my subject has been a broad one and there are many phases of it which I have not covered. I shall be glad to answer any questions or supply any additional information desired by the committee.

Representative PATMAN. Thank you, Judge Kline.

We will not ask you questions this morning because of our crowded schedule, but it is possible that members of the committee who are not here would like to avail themselves of the opportunity of asking you questions which you can answer along with the correction of your transcript.

Mr. KLINE. Yes, sir. Thank you.

Representative PATMAN. Thank you very much.

Our next witness is Mr. Russell J. Cameron, president, Cameron & Jones, Inc., Denver, Colo., and Rio de Janeiro, Brazil.

Mr. Cameron was born in Austin, Tex. He was educated at elementary and high schools in Dallas and Linden, Tex., and the University of Texas. From 1942–48, he held various positions in the synthetic rubber program; 1948–55, various positions in the U.S. Bureau of Mines oil shale development program at Rifle, Colo. His last position was supervisor, process development. Since 1955 he has been a consulting engineer specializing in oil shale and synthetic fuels.

Mr. Cameron, we are glad to have you, sir. You may proceed in your own way.

STATEMENT OF RUSSELL J. CAMERON, CAMERON & JONES, INC., DENVER, COLO., AND RIO DE JANEIRO

Mr. CAMERON. Thank you, Mr. Chairman. It is a privilege to present some information on oil shale to this committee. As I understood, the interest of the committee in this subject was in connection with the long-range aspects of the energy supply, related to an automated economy. Therefore, the remarks are along the long range aspects of this future source of energy.

Without hesitation, I can assure this committee that the United States need not fear shortages of oil or natural gas for generations to come. Oil shale is a practical supplement for both.

Reserves of oil shale are measured in trillions of tons. This vast mineral fuel accumulation will yield hundreds of billions of barrels of high-quality petroleum products, and volumes of fuel gas exceeding present natural gas reserves many times over.

Efficient, economical processes have been developed to manufacture shale oil fuels. Products equivalent to the best of those from petroleum can be made from oil shale at competitive costs.

Research work during the past year has shown the possibility of making a natural gas substitute from oil shale. Process development work on this new approach to shale utilization is underway. Chemical products, also, can be made from oil shale when needed.

Low cost energy in the form of coal, petroleum, and natural gas has in large measure made possible our high standard of living. We will continue to rely on these conventional sources of energy for most of our needs for many years to come; however, the real cost of these fuels increases as the more accessible reserves are utilized. We already are facing this problem with coal and petroleum, and in the case of the latter, we have had to resort to oversea imports to maintain the oil industry's economic health.

It is of utmost importance for the responsible officials in our Government to appreciate that in oil shale, we have the means to sustain our energy supplies at real costs which are little, if any, higher than present levels, without the necessity to rely on oversea imports of any kind.

The Status and Prospects of Oil Shale Technology

OIL SHALE RESOURCES

Any statement bearing on the significance of oil shale in our future energy picture should begin with a restatement of what we know about its resources. The measured quantities of oil shale are staggering in size but they grow larger as more information becomes available. Actually, we have resources several times the amount given in published figures.

Geologists now estimate that the oil shales of the Green River formation of western Colorado could yield 1.5 trillion barrels. This is almost a threefold increase over figures quoted 10 years ago. For the most part, these new quantities were discovered by drilling into formations below the known oil-shale horizons. Oil shale measures hundreds of feet thick were encountered; and although they lie two or three thousand feet below the surface, they can be utilized when needed.

Although our most important shale resources are in Colorado, they are by no means our only large western deposits. Colorado contains only 2,592 square miles of Green River formation, while east central Utah has 4,680, and southwestern Wyoming, 9,192 (1). Because much of the Utah and Wyoming oil shale does not outcrop and has not been sampled extensively, the published figures are very small. The most recent resource estimate (2) gives Utah 42.8 billion barrels, and Wyoming only 3 billion.

In the last few years, additional information has been obtained from oil well cuttings and from core holes drilled specifically for the purpose of sampling the oil shale sections. When new estimates are made, it is certain the resources will be increased. It would not be surprising in view of the large shale-bearing area, to see the figures for Utah and Wyoming reach hundred-billion-barrel proportions.

Oil shale also occurs in many other States, and the total quantities are fantastic. Almost 47,000 square miles of the State of Illinois are underlain with oil shales. A. C. Rubel (3) has compiled information which indicates the existence of at least 500 billion barrels of shale oil in areas east of the Mississippi River in shales averaging 10 gallons per ton. The States of Tennessee, Iowa, Kentucky, Ohio, and Illinois apparently have the largest resources. Without doubt, these are ultraconservative figures and will be increased manyfold when more accurately sampled.

Although 10-gallon-per-ton shale would not be considered economic under present day conditions (nor would such low-grade shales necessarily be needed for years to come) it is technically feasible to recover oil from shales of this quality. As an example, one of Brazil's principal oil-shale deposits yields only 12–15 gallons of oil per ton and, in addition, contains about 35 percent free moisture. Yet, within the past 2 years, methods have been developed for the practical recovery of oil from this shale.

Oil shale is a worldwide energy resource of first-order magnitude. The Swedish Oil Shale Co. recently estimated world amounts at 1.2 trillion barrels (4). These figures, like other published estimates, are based on incomplete information and are certain to be increased. We suggest that resources worldwide, ultimately will prove to be more than 4 trillion barrels.

The tabulation below gives our estimate of the minimum shale-oil quantities which we believe will be ultimately estalished as recoverable reserves. The tabulation also gives comparative estimates by Pratt (5) of ultimate petroleum discoveries.

Estimates of total economically recoverable petroleum and oil-shale resources of the United States and the free world

[Billions of barrels]

	Liquid hydrocarbons	Shale oil
United States	170	2,000+
Rest of free world	730	2,000+
Total	900	4,000+

Currently the United States consumes about 3.6 billion barrels of petroleum annually, and the rest of the free world about 2 billion. Even with demands doubling each few years, as has been the pattern, we can see no possibility of long-term liquid-fuel shortages on account of inadequate resources for hundreds of years to come.

STATUS

Historical sketch

It is a matter of record that "oyl from a kind of stone" was produced in Great Britain as early as the 15th century. During the Revolutionary War, small quantities of oil were distilled from cannel coal and oil shale in the Appalachian Region for use as foundry fuel. About the same time, shales in the maritime Provinces of Canada also were being dug to produce fuels.

Well-established industries were in existence in France and Scotland prior to 1850 and in many other countries by the turn of the century. However, for the past 50 years or so, owing to the abundance of low-cost petroleum, shale oil has been relatively unimportant except in special circumstances.

During World War II, shale oil supplied critically needed fuels for Japan, Sweden, Australia, and other countries cut off from their normal sources of oil. In our own country, extensive development work by both the Federal Government and the petroleum industry was conducted, but large-scale production of shale fuels was not necessary.

Since 1945 research on all facets of oil-shale technology has continued. Today, although no commercial shale oil plants are in operation in the United States, we have processes ready for application whenever the need arises.

World picture

The shale-oil industries of the world are resurgent. Sweden, which the established oil-shale industries of the world and that required for dernize its facilities and has recently expanded output 80 percent. Oil shale is the principal source of Sweden's sulfur and ammonia, as well as its only domestic source of oil.

Spain has a new oil-shale operation geared principally to the production of lubricants and chemicals. Spain is another country which has no domestic petroleum production.

Russia has a well-established oil-shale industry in satellite Estonia, producing both shale oil and shale gas. A new 10,000-barrel-per-day plant has been announced recently, and Russian technical journals for several years have reported on research activities in the field. Communist China also operates what probably is the world's largest shale-oil facility in Manchuria. The Manchurian plant was originally developed and operated by the Japanese.

For about 10 years, Brazil has conducted research and development work leading toward utilization of its extensive oil-shale resources. Brazil's shale reserves are such that, if developed, this flourishing South American country need not be concerned with the presence or absence of petroleum.

Elsewhere, other new oil-shale projects have been announced or investigations are in progress—Thailand, Australia, Belgium Congo, Yugoslavia—almost everywhere that oil shale is known to exist.

U.S. oil-shale technology

It is important to distinguish between the technology being used by the established oil-shale industries of the world and that required for successful application in the United States. For several reasons, discussed below, a new technology specifically adapted to our own needs has had to be developed.

The first difference in requirement is that of size. To be of significance for our energy needs, shale-oil production must attain levels of hundreds of thousands of barrels daily. Whole industries in Europe produce only a few hundred barrels per day and the methods used are totally inadequate for large-scale production.

There also are differences in the chemical and physical properties of oil shales that preclude the use of certain processing concepts practiced elsewhere.

Finally, shale oil in this country must be competitive with petroleum. Most existing shale industries cannot compete successfully with petroleum and require subsidies in one form or another. One of the main reasons for this situation is the use of antiquated, uneconomic production methods.

Oil-shale technology, as we now know it, is straightforward. The shale first must be mined, then subjected to a heating process (retorting) to distill from it a crude oil; and finally, the oil must be refined to usable products. The methods which have been worked out for our Colorado oil-shale deposits are described below.

Mining.—A low-cost mining method adapted to certain favorable characteristics of the Colorado oil-shale deposits has been developed and demonstrated in two large-scale experimental mines. A large international mining concern is conducting additional experimental work.

The mining method utilizes the concepts of a rock quarry operation in an underground mine. Large mechanized equipment is used including 22-ton trucks, 3½-cubic-yard electric power shovels, and instrument-controlled drilling machines. All equipment is mobile and in production tests up to 150 tons of oil shale for each man-shift of underground labor has been achieved. By comparison, 25 tons per man-shift is considered a high production rate in most mechanized underground mines.

Mining costs below $0.50 per ton can be realized. It is noteworthy that a large limestone company, with rock conditions similar to the Colorado oil shale beds, has converted its mining practice to the method developed for oil shale.

Retorting.—Two outstanding new retorting (distillation) processes have been demonstrated on a pilot plant scale (6) (7) (8). One of these processes is in an advanced stage of development, having been successfully operated at a capacity approaching that of a commercial-sized retort (1,000 tons per day); however, neither process has been applied commercially.

Both retorting methods are similar in principal. Each derives all process fuel from the shale itself and neither requires water for condensing and cooling the product oil. The latter consideration is important in the arid west.

Each process seems capable of scale-up to very large-capacity unit sizes, a prerequisite of low-cost operation. Three-thousand-ton-per-day units have been designed for each process. One widely used European retort has a 16-ton-per-day capacity.

Refining.—Shale oil refining research has been aided greatly by new processes developed to refine high sulfur crude oils. Refining methods are commercially available to convert crude shale oil to gasoline, jet fuel, diesel, and other fuels equivalent to the highest quality products manufactured from petroleum.

A commercial refinery is now in operation in western Colorado producing liquid fuels from a solid, naturally occurring hydrocarbon called Gilsonite (9). The chemical properties of Gilsonite are almost identical with those of shale oil and the refining methods in use are the same as would be specified for shale oil.

Summation of present technology

Each step in a practical mining and processing sequence for Colorado oil shale is ready for commercial application. No further development work is required before building the pioneer plant. For the mining and refining steps, related commercial experience is directly applicable. Retorting will employ new techniques without prior industrial counterpart.

Economics

Careful engineering and economic studies of the large-scale application of the new methods developed for oil shale utilization indicate that Colorado shale oil may cost no more, and perhaps less, than new domestic petroleum (10) (11). It is estimated that crude shale oil could be produced and sold profitably for a "wellhead" price of no more than $2.50 per barrel. The owners of one particularly attractive oil shale tract are attempting at the present time to find a market, at $1.75 per barrel, for 25,000 barrels per day of crude shale oil. If successful in locating a market, the backers would then build a production facility.

The investment for a shale oil production facility of significant output is sizable. A 25,000-barrel-per-day plant may cost between $30 and $50 million, depending on location, retorting process used, and the degree of refining conducted at the production site. In addition, pipelines must be provided to move the oil either to existing trunk pipelines, or to a market area.

Although this investment seems high, the unit investment per barrel of daily production seems reasonable compared with current exploration and development costs for petroleum. However, it is this high initial investment which has been a deterrent to shale oil production to date.

It is probable that a change in market conditions must take place before shale oil will be produced in quantity. As long as there is shut-in petroleum production capacity which can be made available at no additional investment, there would seem to be little incentive in bringing in new oil supplies that require substantial investment.

PROSPECTS

Atomic explosions in oil shale

A great deal of publicity has been given the proposed use of an underground atomic explosion to free shale oil such that it can be produced without conventional mining and retorting (12). An experiment to be financed jointly by the petroleum industry and the Federal Government is scheduled to take place within the next year or so. If successful, this means of shale oil production might immediately make attractive the production of oil from the deep-lying shale formations which otherwise would not be utilized for many years to come. It seems essential, both for reasons of safety and economics, that atomic explosions in oil shale be deeply implanted in the earth.

In the method now envisioned, a hydrogen fusion device would be used to break up several million tons of oil shale in place. The only purpose of the explosion would be to create a permeable matrix. The shale then would be ignited and a portion of its organic matter burned. This heat of combustion would release the oil and allow it to be pumped to the surface in a manner analogous to petroleum production.

There is no certainty that oil produced in this manner will cost any less than that produced from favorable locations by conventional methods. There is no assurance yet that the method will even work; but if found feasible the most likely application will be deep-lying oil shale strata and perhaps some of the leaner shale deposits.

Successful development of the method will be dependent on the solution of a number of formidable technical problems requiring multimillion dollar expenditures. Even if found practical, several years of development work are in the offing.

Pipeline gas from oil shale

From a long-range standpoint, perhaps the most interesting development in recent years is research work by the Institute of Gas Technology, which has shown that oil shale is a good raw material for the production of a high B.t.u. fuel gas (13). The process of conversion is called hydrogasification because it uses hydrogen as a reagent to gasify the organic matter in oil shale. The product is principally methane and ethane, which also are the principal constituents of natural gas.

This work is the result of an extension of investigations made by the institute for a number of years on the gasification of coal and oil. Experiments using Colorado oil shale showed it to have superior gasification properties to other materials tested. Engineering studies are now in progress on the commercial application of the process.

It does not seem likely that hydrogasification of oil shale will be in general use for some time to come because ample supplies of natural gas are assured for many years. However, with oil shale a potential raw material, gas will be available to us as a fuel for as long as we will care to use it.

Elliott (14) has estimated that if the Colorado oil shale deposits were used for gas production instead of oil, 6,000 trillion cubic feet could be produced therefrom. This compares with present proven reserves of 250 trillion, and ultimate reserves estimated by Pratt (15) of 3,000 trillion cubic feet.

An even more interesting aspect of oil shale hydrogasification is the fact that many eastern shales seem better suited for gas production than for the production of oil. For instance, a Tennessee shale subjected to hydrogasification gave more gas than would be indicated by its oil yield. This phenomenon can be explained by the chemical nature of the organic material in the particular shale.

Gas will be produced from shale when demand exceeds our ability to produce gas economically from natural reservoirs. The oil shales of the West and probably those of the East, because of their proximity to the large population centers, will become an important fuel gas supply for our cities and towns as well as raw material for the petrochemicals industry.

Uranium from oil shale

Some of the world's oil shales have uranium associated with the organic matter. In Sweden, for instance, the uranium content is such that it is practical to process certain shales for recovery of fissionable materials.

In this country, some shales in the Eastern United States have a small uranium content, about 0.004 percent. The recovery of uranium from Tennessee oil shales has been studied, but is not presently economical; however, when low-grade uranium sources become needed, there seems no reason why uranium from oil shale should not be considered one of our larger potential energy resources.

Unfortunately, uranium does not occur in our richer Colorado, Utah, and Wyoming oil shales.

Future technological objectives

With modern oil shale technology in its infancy, we can expect rapid improvements in methods merely through learning more about what we are doing. But entirely different approaches will be used to effect major changes.

The desirability of retorting the shale in place is one of the more attractive objectives we would like to attain. This would eliminate mines and retorts as we now know them and neatly solve the problem of spent shale disposal.

Atomic explosions are only one possibility for accomplishing in situ shale oil production. Several patents have been issued and some experimentation has been conducted on other ideas. We can be cautiously optimistic that this desirable objective may one day become a reality.

One of the apparent shortcomings of shale oil is its relatively poor quality compared with the best crude oils. Some of its impurities are present in larger amounts than in most petroleum. Although our newer refining processes can handle feed stocks, such as present-day shale oil, it would be desirable to improve its quality. Some extraction method of the future may do this.

Another worthwhile objective is better utilization of the resource. We now leave 25 percent of the shale in the mine as roof support pillars; we recover only about 60 percent of the organic matter of the shale as oil; and present retorts cannot efficiently utilize the fines and dust produced by crushing and sizing the shale prior to retorting. The marginal or low-grade shales which give shale oil resources its remarkable dimension are not now economical to use. Entirely new methods may be required for significant progress toward the goal of better oil shale utilization.

New developments, along the lines discussed above, are certain to come as the industry matures. They are the things which will make oil shale a primary, rather than a supplementary energy source of the future. We do not need "black magic" or assistance from outer space to accomplish these objectives; but we must devote well-financed scientific manpower to the task.

The best way to gain these new horizons is for the shale industry itself to finance and conduct the necessary research. For this, we must have an industry in being. The most important problem facing the Government today, with respect to oil shale, is how to provide an atmosphere under which this industry can be established.

CONCLUSIONS

1. Oil shale reserves, both within the United States and worldwide, are sufficient that future needs of oil and gas for hundreds of years are assured.
2. Although there is no commercial production of shale oil in the United States, processes have been developed and are ready for application that can make high quality shale oil products at costs little, if any, higher than we pay today.
3. Our marginal and low-grade oil shale deposits are usable and should be considered a part of our long-range energy reserve in the future.
4. New ideas already are being explored for oil shale utilization. The use of atomic explosions to extract oil from shale deposits far underground and a process to produce high quality fuel gas and chemicals from oil shale are examples. It is certain that with the continued application of technological effort, other new concepts will come forth and some ultimately will be used.
5. Uranium as a byproduct of oil shale processing is of the greatest significance in considering long-term future resources of energy.

BIBLIOGRAPHY

(1) BELSER, CARL, "Oil Shale Resources of Colorado, Utah and Wyoming", American Institute of Mining and Metallurgical Engineers Technical Publication No. 2358 (1947).

(2) Ibid.

(3) RUBEL, A. C., "Shale Oil as a Future Energy Resource," Interstate Oil Compact Commission, Denver, Colo. (1955)

(4) SVENSKA SKIFFEBOLJE AKTIEBOLAGET, Brochure of 1958 from Swedish Oil Shale Co., page 9.

(5) PRATT, WALLACE E., "The Impact of the Peaceful Uses of Atomic Energy on the Petroleum Industry, January 17, 1956", Panel on the Impact of the Peaceful Uses of Atomic Energy to the Joint Committee on Atomic Energy, 1956.
(6) HARTLEY, FRED L., BRINEGAR, CLAUDE S., "Oil Shale—Energy for the Future", a paper presented at the 1959 Fifth World Petroleum Congress.
(7) MATZICK, A., ET AL., "Development and Preliminary Operation of the Gas-Combustion Oil Shale Pilot Retort", Bureau of Mines Report of Investigation 5145 (November 1955).
(8) CAMERON, RUSSELL J., GUTHRIE, BOYD, "Oil from Shale", Chemical Engineering Progress (July 1954).
(9) MORRIS, L. P., "The Gilsonite Refinery", presented at Salt Lake City meeting of American Institute of Chemical Engineers (Sept. 1958).
(10) MILLER, E. P. CAMERON, R. J., "Shale Oil Nears Competitive Level with Domestic Petroleum", Journal of Petroleum Technology (August 1958).
(11) HARTLEY, FRED L., BRINEGAR, CLAUDE S., see reference 6.
(12) BUREAU OF MINES, Laramie Petroleum Research Center, "Application of Nuclear Explosions to Oil Shale Utilization" (January 1959).
(13) ELLIOTT, M. A., CHANDLER, "Today's Frontiers of Science Point to Bright Future for the Gas Industry", a paper presented before the A.G.A., General Management Section, March 31, April 1–2, 1958.
(14) Ibid., ELLIOTT, M. A.
(15) PRATT, WALLACE E., ibid., see reference 5.

Thank you, Mr. Chairman.

(Mr. Cameron later submitted the following for the record:)

SELECTED BIBLIOGRAPHY OF OIL SHALE PUBLICATIONS

(1) ——— "Synthetic Liquid Fuels," Annual Report of the Secretary of the Interior for 1948, U.S. Bureau of Mines Report of Investigations 4457 (January 1949).
(2) ——— "Synthetic Liquid Fuels," Annual Report of the Secretary of the Interior for 1949, U.S. Bureau of Mines Report of Investigations 4652 (February 1950).
(3) ——— "Synthetic Liquid Fuels," Annual Report of the Secretary of the Interior for 1950, U.S. Bureau of Mines Report of Investigations 4771 (February 1951).
(4) BELSER, Carl, "Green River Oil Shale Reserves of Northwestern Colorado," U.S. Bureau of Mines Report of Investigations 4769 (1951).
(5) ——— "Synthetic Liquid Fuels," Annual Report of the Secretary of the Interior for 1951, U.S. Bureau of Mines Report of Investigations 4866 (July 1952).
(6) ——— "Synthetic Liquid Fuels," Annual Report of the Secretary of the Interior for 1952, U.S. Bureau of Mines Report of Investigations 4943 (January 1953).
(7) ——— "Synthetic Liquid Fuels," Annual Report of the Secretary of the Interior for 1953, U.S. Bureau of Mines Report of Investigations 5044 (April 1954).
(8) ——— "Synthetic Liquid Fuels," Annual Report of the Secretary of the Interior for 1954, U.S. Bureau of Mines Report of Investigations 5119 (March 1955).
(9) GUTHRIE, Boyd, "Technological Developments in Retorting Colorado Oil Shale, 1944–54," Proceedings, Fourth World Petroleum Congress, Section III/H (1955).
(10) PRIEN, C. H., SAVAGE, J. W., "A Shale Oil Industry Is on the Way," Chemical Engineering Progress, 52, 16J–26J (January 1959).
(11) CAMERON, R. J., "Where Oil Shale Stands Today," World Petroleum, 27, 58–61 (February 1956).
(12) ——— "Synthetic Liquid Fuels," Annual Report of the Secretary of the Interior for 1955, U.S. Bureau of Mines Report of Investigations 5237 (July 1956).
(13) FISHER, F. R., and PELZER, H. L., "Thermal Process for In-Situ Decomposition of Oil Shale," U.S. Patent 2,780,449 (Feb. 5, 1957).
(14) MILLER, Captain A. S., U.S.N., "The Navy and Oil Shale," preprint, paper delivered at the Oil Shale Session of the Colorado Mining Association, Denver, Colo. (Feb. 7, 1957).

(15) HARTLEY, F. L., "Union Oil's Shale Program—Progress Report," preprint, paper delivered at the Oil Shale Session of the Colorado Mining Association, Denver, Colo. (Feb. 7, 1957).

(16) DONNELL, John R., "Preliminary Report on Oil Shale Resources of Piceance Creek Basin Northwestern Colorado," Geological Survey Bulletin 1042–H (1957).

(17) HARTLEY, F. L., BRINEGAR, C. S., "Oil Shale and Bituminous Sand," Science Monthly 84, 275–89 (1957).

(18) STANFIELD, K. E., et al., "Oil Yields of Sections of Green River Oil Shale in Colorado, 1952–54," Bureau of Mines Report of Investigations 5321 (April 1957).

(19) CAMERON, R. J., MATZICK, Arthur, "Recent Developments in Oil Shale," World Petroleum, 28 (September 1957).

(20) MILLER, E. P., CAMERON, R. J., "Oil Shale Economics," Fourth Annual Joint Meeting, Rocky Mountain sections, AIME, Denver, Colo. (Also for later publication in Journal of Petroleum Technology.) (Mar. 4, 1958.)

(21) PRIEN, C. H., NEVENS, Thomas D., Denver Research Institute, "Summary Economic Report—Aspeco Process of Oil Shale Retorting" (May 12, 1958).

(22) OBERT, Leonard, MERRILL, Robert H., "Oil Shale Mine, Rifle, Colo.: A Review of Design Factors," U.S. Bureau of Mines, R. I. 5429 (1958).

(23) CAMERON, R. J., GUSTAFSON, R. E., "Shale Oil Activities," World Petroleum (March 1959).

(24) ANDERSON, Carl C., "Application of Atomic Energy to Petroleum Reservoirs and Oil Shale Deposits," a talk before the annual meeting of the North Texas Oil and Gas Association, Wichita Falls, Tex. (Mar. 21, 1959).

(25) SHULTZ, E. B., LINDEN, H. R., ELLIOTT, M. A., "Hydrogasification of Bituminous Sand to Ethane and to Pipeline Gas," Fuel 38, 250–1 (1959).

(26) CAMERON AND JONES, INC., "Water Requirements for Oil Shale 1960–75," a study for the Colorado Water Conservation Board.

SHALE OIL NEARS COMPETITIVE LEVEL WITH DOMESTIC PETROLEUM [1]

(By Ernest P. Miller and Russell J. Cameron, of Cameron & Jones, Inc., Denver Colo.)

INTRODUCTION

Advancements in oil shale technology, coupled with the sharply rising expense of finding and producing petroleum in the United States, have closed the economic gap between the two fuels. A realistic comparison of shade oil and petroleum costs presents certain problems, for the real meaning of posted crude prices is difficult to ascertain. Marginal crude-producing areas, discovered before the steep rise in exploration and producing costs of the past dozen years, are now being exploited. This report briefly reviews technical activities in oil shale and presents discussion and comparisons of shale oil production economics with crude petroleum prices.

REVIEW OF TECHNICAL ACTIVITIES

Production of oil from shale has been an art and science in various parts of the world for more than a century. In the United States, prophecies of acute domestic petroleum shortages have been made periodically throughout this century. Previous flurries of activity in shale have soon diminished because of economic facts of life. Present efforts in shale development are the most significant to date and may finally indicate serious entry into the field—again because of economic facts.

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[1] Original manuscript received in Society of Petroleum Engineers office Jan. 16, 1958. Revised manuscript received Apr. 29, 1958. Paper presented at fourth annual joint meeting of Rocky Mountain Petroleum Sections in Denver, Colo., Mar. 3–4, 1958.

Foremost among current and recent publicized oil-shale activity have been the multimillion-dollar project of the Union Oil Co. of California at Grand Valley, Colo.; the U.S. Bureau of Mines installation at Rifle, Colo., from 1944 to termination of that program in 1955; and the pilot plant retorting work being carried out by the Denver Research Institute (DRI) for the past several years. Most major oil companies hold oil shale land and represent varying degrees of interest and effort within their own organizations. Brazil has vast shale deposits and produces only 30 to 40,000 B/D of petroleum within her own borders—about 20 percent of present controlled requirements.

Most current development work is directed toward the retorting phase of oil shale processing. USBM's mining work at Rifle is generally accepted as having adequately demonstrated that step to furnish basic information. Modern refining technology is such that shale oil can be processed to desired end products using processes with results and costs that are reasonably predictable.

Retorting, on the other hand, has not yet been demonstrated to the extent that any one process has received general acceptance. Three processes at various stages of development are Union Oil's retort, USBM's gas combustion retort, and the Aspeco retort being piloted by DRI.

Union Oil retort

Union Oil's retort is an underfed countercurrent type, the shale rammed upward through the retort vessel being contacted with hot gases drawn downward by blowers. The unit at Grand Valley is a circular vessel with a rated capacity in excess of 300 ton/D, and is based on a design operated at a 30-ton/D pilot-plant level. Commercial installations have been visualized as being composed of nests of these retorts.

Gas combustion retort

The gas combustion retort developed at Rifle consists of countercurrent flow of oil shale and hot recycle gas. Sized shale flows downward by gravity in a round or rectangular vessel. The gases are drawn upward. The retort now idle at Rifle is a 200- to 300-ton/D unit. Commercial units of 2,000 ton/D or even larger are envisioned for this process. At present, construction and operation of a large unit is being considered for the next phase of the Brazilian shale program.

Aspeco process

The Aspeco process, being investigated at a pilot plant by DRI, consists of two rotating kilns. One kiln acts as a retort for heating raw shale to pyrolysis temperature, the other as a combustion furnace for burning off carbon from spent shale. In each kiln, crushed shale flows counter to closely sized balls. Heat transfer occurs through solids-solids contact, the balls being the heat-transfer medium.

ECONOMICS

Discussion of the economics of shale processing will be limited to schemes including the Union and gas combustion retorting processes. The Aspeco process is a newcomer to Colorado shale, and little information has been published.

In 1951, at the request of the Secretary of the Interior, the petroleum industry, acting through the National petroleum Council (NPC), cooperated in making a comprehensive study of the economics of producing liquid fuels from Colorado oil shale. NPC based its study on mining methods developed by USBM; Union Oil's retort, then in the pilot-plant stage; and a refining sequence considered practicable for crude shale oil.

It is this study that has since been the oil shale bible. Generalized economic statements and other quoted statistics have been taken directly or indirectly from this seven-year-old evaluation.

Components of shale oil cost

The processing scheme originally presented by the NPC consisted of mining, retorting and hydrogenation in Colorado on a 250,000 B/D basis. Hydrogenated distillate is pipelined to southern California, where it is fractionated, catalytically cracked and blended to diesel fuel and gasoline. Quantities of products made are shown in table 1, and the economic summary for this case is presented in table 2. The NPC figures for 1951 are escalated to 1957 levels in the same tabulation.

TABLE 1.—*Products from processing 250,000 B/D crude shale oil (NPC study, 1951)*[1]

California:		
Gasoline:		
Regular	B/CD	63,450
Premium	B/CD	63,450
Middle distillate (net)	B/CD	62,360
Fuel oil (net production)	B/CD	3,000
LPG	B/CD	8,925
Colorado:		
Coke	T/CD	5,900
Fuel gas	Mscf/CD	125,300
Anhydrous liquid ammonia	T/CD	460
Sulfur	T/CD	215

[1] Barrels, tons, or standard cubic feet per calendar day.

TABLE 2.—*Summary of shale oil economics (NPC study, 1951—250,000 B/D)*

	NPC, 1951	Adjusted to 1957 price levels
Total investment for mining, retorting, pipelining, refining in California	[1] $1,517,460,000	$2,000,000,000
Economics ($/CD):		
Total operating expenses	458,648	575,000
Depreciation	208,621	275,000
Subtotal	667,269	850,000
Byproduct and rental credits	−113,511	−148,000
Subtotal	553,758	702,000
Return on investment, at 6 percent per year [2]	249,446	328,000
Income tax	249,446	328,000
Total	1,052,650	1,358,000
Cost of equivalent gasoline produced, cents per gallon [3]	14.7	19
Approximate cost of gasoline from petroleum	12	14-15

[1] Includes $150,000,000 cost of housing and community facilities for labor force in Colorado.
[2] Net return after income taxes at 50-percent rate.
[3] 100 percent gasoline plus 70 percent diesel fuel made.

The 14.7 cents per gallon for shale oil gasoline is the cost often described as being within a few cents of the cost of gasoline from petroleum, which was about 12 cents per gallon in 1951. This price for petroleum gasoline reflects a depletion allowance and is based on prices for crude oil, part of which was discovered before exploration costs increased sharply. On the other hand, the petroleum gasoline price includes a profit higher than the 6 percent return assumed for shale oil. It is a simple matter to calculate that the cost of equivalent shale oil gasoline at a 12 percent instead of a 6 percent return on investment would be about 21 cents per gallon rather than 14.7 cents per gallon as in the NPC case. On this basis the cost of shale gasoline was not within a few cents of the cost of petroleum gasoline.

At today's cost levels the NPC scheme would give 19 cents per gallon (6 percent return) shale gasoline as compared with 14 to 15 cents for petroleum gasoline. On a percentage basis shale gasoline has increased about 30 percent in 7 years, whereas petroleum gasoline has gone up only about 20 percent on the average. Thus, it would appear that time has hurt, not helped, shale's position in the last 7 years.

It is interesting to note that the increase in the estimated cost of shale gasoline is totally attributable to the general inflationary trend. The engineering basis is the same as for the original estimate. The significantly smaller increase in petroleum gasoline price, despite domestic oil findings costs that are conceded to have increased even more than the general inflationary trend, shows clearly the price-cost squeeze now facing the petroleum industry. Although it is not certain that low-cost imports are totally responsible, we note that in 1951 the Pacific coast imported no oil, whereas in 1957 the average was 275,000 barrels per day, or nearly one-third of production in the area.

Please recall that the NPC study is based on a particular arbitrary set of assumptions and on shale technology as it appeared in 1951. Let us see what happens when the basis is changed somewhat and technological developments since 1951 are applied. Perhaps the comparison of shale oil and petroleum can be made clearer on the basis of crude shale oil costs rather that cost of producing gasoline. Such costs were estimated using NPC rules but excluding refining other than preparation for pipelining (by visbreaking).

Economics shown for the Union Oil retort in table 3 are based on a 1953 revision to the NPC estimate escalated to 1957 levels. The quantity of crude shale oil produced is 250,000 barrels per day.

TABLE 3.—*Economics of crude shale oil production, union retort and gas combustion retort, 250,000 B/D crude shale oil, 1957*

	Union retort	Gas-combustion retort
Capital investment: [1]		
Mining and crushing	$323,000,000.00	$323,000,000.00
Retorting	468,000,000.00	201,000,000.00
Pipeline preparation	86,000,000.00	86,000,000.00
Pipeline to California	103,000,000.00	103,000,000.00
Total	980,000,000.00	713,000,000.00
Net daily cost [2]	431,000.00	356,000.00
Cost per barrel of oil delivered in California—		
at 6-percent return on investment after taxes, no depletion allowance	3.00	2.35
at 12-percent return, no depletion allowance	4.30	3.30
at 6-percent return and 15-percent depletion allowance on crude	2.85	2.20
at 12-percent return and 15-percent depletion allowance on crude	3.95	3.00

[1] Includes housing.
[2] Includes depreciation but no depletion or return on investment.

Economics for the same scheme but substituting the gas combustion retorting process for the Union process are shown in the second column of table 3. Retorting costs for the gas combustion retort are estimated from design and operation of USBM and Brazilian pilot-plant units and our design of a commercial unit. Also included in these economics is a slight mining cost reduction resulting from improvements in techniques demonstrated at Rifle after 1951. Investment requirements include cost of housing and community facilities for the permanent Colorado labor force. The percentage oil recovered from the shale is assumed to be essentially the same for both retorting processes—about 90 percent of assay. Any change in actual recovery from this figure would, of course, vary costs proportionately.

A selling price for crude shale oil is calculated at both 6- and 12-percent return on investment, and with and without a depletion allowance. As explained previously, a 12-percent return on investment is shown as being more representative of an acceptable profit than the 6-percent return used in the NPC study.

Depletion allowance

Depletion, as now interpreted by the Treasury Department, is applicable only to the shale as mined and not to the oil produced therefrom. This is not a valid interpretation of the percentage-depletion rule; percentage depletion applies not merely on the extraction of ores or minerals from the ground but also on the ordinary treatment processes normally applied in order to obtain commercially marketable mineral products—in this case, crude shale oil. Therefore, a 15-percent depletion allowance based on crude shale oil is shown to illustrate the effect of a more reasonable depletion allowance. The choice of 15 percent has no significance other than its being the percentage now allowed based on oil shale as mined.

Comparison of costs

The cost of each new barrel of domestic oil found and produced is hard to isolate. Even if this were done, a direct comparison with shale oil would be clouded with intangibles. Therefore, current prices of crude oils should give the best available criterion for judgment of the overall economic feasibility of shale oil production. Obviously, an individual oil company's appraisal of the attractiveness of shale oil will depend on its own current crude oil position and other intangibles that vary throughout the industry.

Current prices for 21° API California and West Texas crudes, including approximate transportation costs to California area refineries, are about $3 per barrel. A comparable Venezuela crude is 20 to 30 cents per barrel less. Shale oil and West Texas or California 21° API crudes can be considered more-or-less comparable, being of similar gravities and each containing high sulfur. (Shale oil contains less.) While shale oil should be penalized a relatively small amount because it contains less lower boiling fractions and more nitrogen than the crude petroleum oils, a direct comparison of costs will be adequate to illustrate that shale oil costs are within the same range as petroleum. Moreover, shale oil can be refined to equivalent products by processes now installed and in use in the larger refineries.

Table 4 is a comparison of shale oil and West Texas crude oil costs presented on similar bases. Economics presented for shale oil using both the Union Oil and USBM retorts are included.

TABLE 4.—*Selling price per barrel of oil delivered, California, 1957*

Return (percent)	6	6	12	12	(?)
Depletion (percent)	None	15	None	15	27.5
West Texas, 21° API					$3.00
West Texas, plus 10 percent					$3.30
Shale oil (Union Oil)	$2.85	$2.65	$4.10	$3.75	
Shale oil (gas combustion)	$2.35	$2.10	$3.30	$2.95	

West Texas crude posted price would be about $3 per barrel delivered in California. However, the petroleum industry has presented convincing arguments that prices for domestic crudes are too low, having risen only about 20 percent since 1948, while total costs have risen 70 percent. Oil finding costs are up 125 percent. If we would be convinced, at least a 10-percent increase in crude oil price would appear justified in spite of the present paradoxical situation of a temporary oil glut in the domestic market. The figure of $3.30 per barrel for West Texas crude listed in table 4 is based on an assumed 10-percent increase.

Comparisons of petroleum prices with shale oil prices that include a 12-percent return on capital investment after taxes, are more realistic than comparisons with shale-oil prices based on a 6 percent return. Thus, on a comparable basis, shale oil cost is estimated to be as low as $3.30 per barrel without a depletion allowance, or about $3 per barrel with a 15-percent allowance on the crude. Even without depletion allowance, and assuming a realistic profit, the gas combustion retort case economics is estimated to be within 10 percent of present crude petroleum prices.

CONCLUSION

The data presented illustrate that significantly different shale-oil prices can be presented depending only on the basis of evaluation selected. It is also evident that shale oil cannot compete on even terms with imported crudes. Venezuelan oil of equal or superior quality could be laid down on the west coast for considerably less than $3 per barrel. Mideast oil of equal quality, if there were such a thing, could be delivered at perhaps an even lower price. However, neither can domestic crudes compete with these oils. Doubtless, the final solution of the crude-oil import problem will have significant effect on the speed with which commercial development of shale becomes fact.

A final point in stressing the competitive status of shale oil with domestic petroleum can be made by comparing capital investment requirements per barrel of oil. Exclusive of refining, investment per barrel of crude shale oil delivered in California has been shown to be $713 to $980 million for 250,000 barrels per day, or $2,800 to $3,500 per daily barrel. The cost of each daily barrel of new petroleum crude found and produced in the United States today is 50 to 100 percent higher than this.

WATER REQUIREMENTS FOR OIL SHALE, 1960–75

A Study for the Colorado Water Conservation Board

(By Cameron & Jones, Inc., engineers-consultants, Denver, Colo., July 1959)

SUMMARY

Most authorities agree that shale oil will be needed in the fairly near future to supplement domestic petroleum. The principal deposits of oil shale in the United States are in western Colorado and the water used by the industry will be taken from the Colorado River and its tributaries. It is of vital importance that the development of an adequate water-supply system for an oil-shale industry not be neglected.

The purpose of this study is to determine the water needs of a shale-oil industry in the United States from its inception through the initial period of growth. This report also attempts to establish approximately when commercial shale-oil production will begin and the rate at which it will grow, thus providing a timetable for planning adequate water supplies for the industry.

Production schedule

Shale-oil production in the United States is expected to begin during the period 1960–65 and increase steadily to about 1,250,000 barrels per day by 1975. Estimates of oil demand and the sources from which we will obtain our supply for the period 1960–75 are given in the tabulation below.

U.S. oil demand and supply

[Millions of barrels daily]

	1960	1965	1970	1975
Demand	10.0	12	14	16
Domestic production	8.3	9.2	9.4	8.8
Imports, synthetics, etc.	1.7	2.8	4.5	6
Shale oil		.025	.15	1.25

The expansion of shale oil production should continue after 1975, ultimately reaching several million barrels per day. It must not be implied that 1,250,000 barrels per day is the maximum production rate the industry will attain.

Water requirements

Water requirements for shale oil production will be small until 1970, but will reach about 250,000 acre-feet per year by 1975. The tabulation below presents estimated water usage attributable to shale oil production, including municipal use. A recommended minimum firm water supply capability for shale through 1975 also is given.

Oil shale water requirements

[Acre-feet per year]

	1960	1965	1970	1975
Diverted	(1)	1,300	27,000	252,000
Returned		550	11,000	93,000
Consumed		750	16,000	159,000
Supply capability	2,500	5,000	40,000	250,000

1 Negligible.

Development pattern

Because of the time needed to design and build the first production facility, it is doubtful that a shale industry can begin much earlier than predicted. A

delay is possible, however, in the event that petroleum continues to be available in ample supply. Even so, we believe the development pattern of the industry, once started, will be the same—first, prototype production followed by moderate expansion and, finally, significant production quantities. The time required for this sequence, in the absence of a national emergency, will be 12 to 15 years.

Location

It is anticipated that the first oil shale developments will be in the Parachute-Roan Creek area of western Colorado and along the Colorado River between Rifle and Debeque. After 1970 the oil shales in the Piceance Creek area and in Uintah County, Utah, will become important. Some development in these latter areas could begin earlier. It is estimated that of the 1,250,000 barrels per day of shale oil production predicted for 1975 over 90 percent will be in Colorado.

Population

The population serving the shale industry will be large by 1975. The tabulation below gives estimates of persons directly or indirectly related to the shale industry.

Shale industry population

	1960	1965	1970	1975
Shale employees	100	900	6,900	[1] 51,000
Construction force, average	1,200	3,000	18,000	
Service personnel	----------	360	7,100	53,500
New households	----------	630	12,500	93,000
New population	----------	2,300	45,000	340,000

[1] Includes shale related industries.

Byproducts

The principal byproducts of shale processing for outside consumption will be ammonia, sulfur, and coke. Petrochemicals will not be important during the first 15 or 20 years of the industry. Retort and refinery gases will be consumed by the industry for fuel and power generation. After 1970 the manufacture of explosives, sulfuric acid, cement, and other materials consumed by the industry and its community will begin.

Investment

The investment in mines, retorting plants, refineries, and pipelines through 1975 will exceed $6 billion. This magnitude of investment is well within the capabilities of the petroleum industry. An additional investment of undetermined magnitude will be made in housing, service facilities and other improvements. These expenditures may exceed that for production facilities.

Current status of U.S. oil shale

During the past 15 years, Government and industry have spent perhaps $50 million on research, land acquisition, and other activities preparatory to starting a shale industry. Efficient, economic processes now are available for each phase in the production and refining of shale oil. Shale products can be manufactured which are equivalent in every way to those from petroleum.

Presently, shale oil awaits a market. Both United States and foreign petroleum producing areas have excess capacity. This oil can be obtained at little or no additional investment. Shale oil, technologically and economically, is ready for development when domestic fields are being produced at maximum practical rates and there is protection from competition by imported oil.

INTRODUCTION

The first step in this study was to attempt to establish the date when commercial shale oil production will start. This was done by a study of recent petroleum supply and demand forecasts by experts in this field.

Next, a pattern of industry growth was worked out taking into account the present status of the technology, the forecasted gap between domestic production and demand for oil, the comparative economics of shale oil and petroleum, the remoteness and industrial underdevelopment of the oil shale areas, and other factors. Engineering estimates of water requirements both for municipal and industrial use were made for each investment of shale oil production.

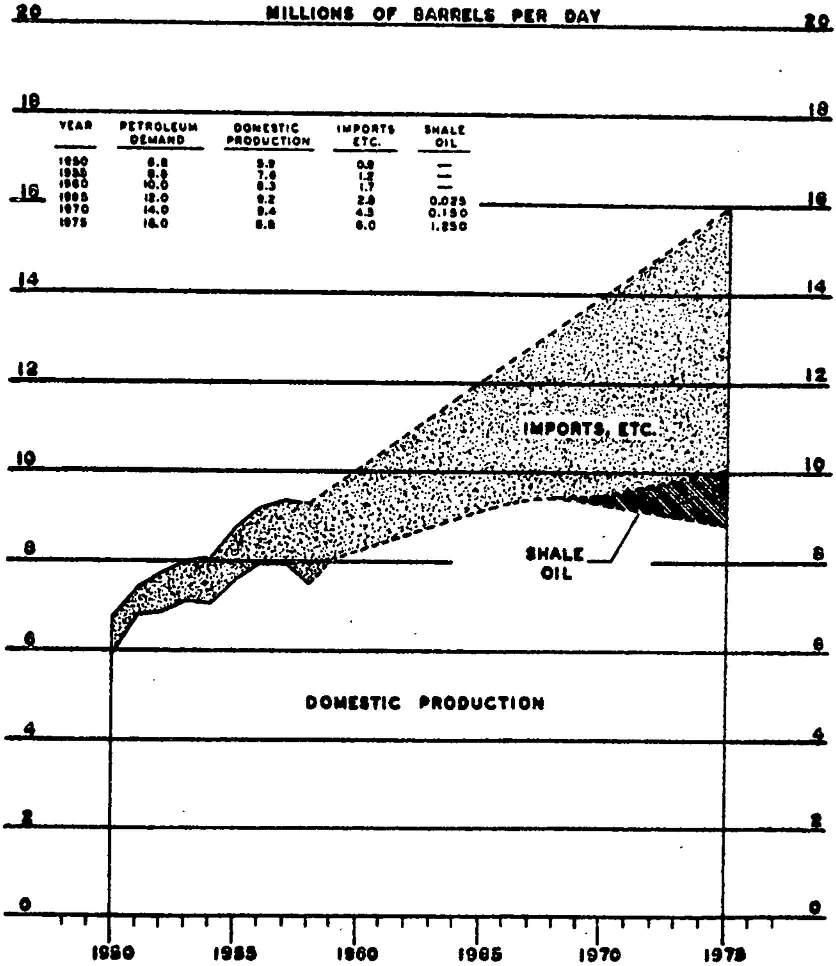
The result is a first approximation of a time schedule for water supply planning for oil shale. This study will require periodic review. Once commercial shale oil production begins and as new technology emerges it is likely that revisions will be necessary.

ESTIMATE OF PETROLEUM SUPPLY AND DEMAND THROUGH 1975

Future petroleum demand and availability is a subject of continuing study by oil company economists, Government agencies, and others (5), (11), (13), (14), (25), (26), (48). Currently, several estimates are published each year by experts in this field. From a study of the most recent estimates and consultation with the authors, we have derived a consensus prediction of petroleum demand and domestic petroleum production through the year 1975. Our demand and production estimate is presented in figure 1.

FIGURE I

USA PETROLEUM SUPPLY AND DEMAND 1950-1975



It is the conclusion of the experts that petroleum demand in the United States will continue to increase for the next 15 to 20 years. The rate of increase will be slightly less than that of the past 10 years, but will reach a level of 16 million barrels per day in 1975. Domestic petroleum demand in 1958 was 9,313,000 barrels per day (38).

Petroleum production in the United States has shown a steady increase, but has not kept pace with demand. It is predicted that production will continue to increase until the period 1965 to 1970, then begin a gradual decline. The reason for this decline will not necessarily be that the industry cannot find more oil, but that the cost of alternate sources, such as shale oil, will be less than the cost of finding new and replacement petroleum.

The gap between demand and production since 1948 has been filled by imports and this practice probably can be followed through 1965 without our becoming overly dependent on overseas oil. However, when production levels off, then begins to decline, the deficit between production and demand will increase at more than twice the present rate, reaching about 7 million barrels per day by 1975.

It seems reasonable that shale oil production to supply a part of this large deficit will begin between 1965 and 1970. A pioneer production unit to establish the technology on a commercial basis probably will be built prior to this time. Assuming a logical pattern of development for the shale industry, unaffected by war or other emergencies, shale oil production should reach about 1,250,000 barrels per day by 1975.

INFORMATION ON OIL SHALE

Oil shale reserves

Shale oil has long been looked upon in the United States and elsewhere as the logical supplement to petroleum. Oil shale reserves are large and widely distributed. The shale oil potential of the United States exceeds the combined petroleum reserves of the Middle East and Venezuela and is many times greater than the most optimistic prediction of ultimate petroleum discoveries in the United States. Without question, shale oil, when needed, can contribute significantly to our energy supply.

Svenska Skifferolje AB, the Swedish Shale Oil Co., has roughly estimated the world's oil reserves in shale (18). Table 1 gives their estimates by country in which oil shale is known to occur.

TABLE 1.—*World shale oil reserves*

[In millions]

Country	Oil content		Country	Oil content	
	Metric tons	Barrels		Metric tons	Barrels
Australia and Tasmania	30	200	Madagascar	30	200
Belgian Congo	15,000	103,000	Manchuria	30	200
Brazil	50,000	344,000	Russia	1,000	6,900
Bulgaria	30	200	Scotland	90	600
Burma and Thailand	2,500	17,200	South Africa	5	40
Canada	5,000	34,000	Spain	40	300
China	400	2,800	Sweden	410	2,800
England	200	1,400	United States	90,000	618,300
Estonia	1,500	10,300	Yugoslavia	200	1,400
France	200	1,400			
Germany	300	2,000	Total reserves	[1] 172,000	[1] 1,200,000
Italy	5,000	34,000			

[1] Approximate.

Source: Svenska Skifferolje AB.

The estimates by Svenska Skifferolje are very conservative since many of the larger deposits have been inadequately surveyed. As more information becomes available, these reserves will increase. For instance, U.S. reserves alone now are estimated at 1.5 trillion barrels or about 200 billion metric tons (19). It seems within reason that the world's recoverable shale oil reserves may ultimately prove to be in excess of 500 billion metric tons or over 4 trillion barrels.

For comparison, the table below gives recent petroleum reserve estimates for the United States and for the world as a whole.

TABLE 2.—*Petroleum reserve estimates*

[Billions of barrels]

	United States	World
Proved reserves, 1959	37	275
Ultimate future production	200-250	900

Source: Oil and Gas Journal (38), Chase Manhattan Bank (11), Wallace Pratt (41).

Historical sketch

Throughout the world, shale oil has been produced when petroleum has been scarce or expensive. In fact, shale oil predates the discovery of petroleum and shale industries have operated in Europe for more than 100 years.

For the past 50 years or so, owing to the abundance of low-cost petroleum, shale oil has been relatively unimportant except in special circumstances. However, during World War II, shale oil supplied critically needed fuels for Japan, Sweden, Australia, and other countries cut off from their normal source of oil.

Shale oil has never been of great importance in the United States, despite our large reserves. Small quantities of oil were distilled from cannel coal and oil shale in the Appalachian region early in the history of our country, but shale oil has never been produced commercially from our western shales.

Current world picture

The oil shale industries of the world are resurgent. Sweden now is expanding its output of shale oil production 80 percent. Oil shale is the principal source of Sweden's sulfur and ammonia as well as its only domestic source of oil.

Spain has a new oil shale operation geared principally to the production of lubricants. Russia reportedly is expanding shale oil and shale gas output in satellite Estonia. A new 10,000-barrel-per-day plant has been announced at Kochtla Jarwe and Russian technical journals for several years have been reporting on research in the field of oil shale.

For about 10 years, Brazil has conducted research and development work leading toward utilization of its extensive oil shale resources. A large commercial operation within the next few years seems likely.

Elsewhere, new oil shale projects have been announced or investigations are in progress—Thailand, Australia, Belgian Congo, Yugoslavia—almost everywhere that oil shale is known to exist.

Recent oil shale activities in the United States

The current era of interest in oil shale in the United States began during World War II and has continued without interruption. Activities mainly have been research and development on improved mining, retorting, and refining methods and in the acquisition of oil shale properties. Water filings also have been made by several companies.

With the exception of the naval oil shale reserves near Rifle, the most accessible oil shale lands are privately owned. A majority of the major oil companies have shale holdings. Several are increasing their reserves and some already may be measured in the billions of barrels.

During the past 15 years, the Federal Government, private companies, and individuals have spent about $50 million on oil shale. More than half these expenditures were by private companies and individuals. Research by both Government and industry on new methods of shale oil production and utilization has obtained outstanding results.

The technology is straightforward. The shale first must be mined, then subjected to a heating process (retorting) to distill from it a crude oil, and finally, the oil must be refined to usable products.

A low-cost mining method adapted to certain favorable characteristics of the Colorado oil shale deposits has been developed and demonstrated in two large-scale experimental mines, one operated privately. A large mining concern is conducting additional experimental work on the method.

Two outstanding new retorting processes have been demonstrated on a pilot plant scale, one resulting from the Government's research program, the other privately financed. The latter process is in an advanced stage of development having been successfully operated at a capacity approaching that of a commercial-sized retort (1,000 tons per day).

Shale oil refining research has been aided greatly by new processes developed to refine high-sulfur crude oils. Refining methods are commercially available to convert crude shale oil to gasoline, jet fuel, diesel, and other fuels equivalent to the highest quality products manufactured from petroleum.

Economics

Many statements have been made regarding the competitive position of shale oil products when produced commercially. All are based on estimates of cost, usually derived from pilot plant data. Since shale oil is not produced commercially in this country there is a certain degree of uncertainty in appraising its economic attractiveness.

Careful engineering studies of the large scale application of the new methods developed for oil shale utilization indicate that shale oil may cost no more and perhaps less than new domestic petroleum. It is estimated that crude shale oil could be produced and sold profitably for a wellhead price of no more than $2.50 per barrel. By comparison the posted prices of Rocky Mountain area crude oils range from $1.81 to $3.10 per barrel. Quality and location determines the price level for a specific crude oil.

The investment for shale oil production facilities of significant output is sizable. A 25,000-barrel-per-day plant may cost from $30 million to $50 million depending on location, retorting process selected, and the degree of refining conducted at the production site. In addition, pipelines must be provided to move the oil either to existing trunk pipelines or to a market area.

While the minimum investment for economical production cost is high, the unit investment seems reasonable compared with current exploration and development costs for petroleum. One estimator (47) places the investment in new and replacement petroleum productive capacity in the United States between 1955 and 1960 at $7,500 per daily barrel. Shale oil capacity certainly is less than this figure.

Why no commercial shale oil production?

Since the lifting of World War II restrictions, there has been no shortage of petroleum products for the American consumer. Until 1948, the United States produced more oil than it consumed and was a net exporter of petroleum and petroleum products. As foreign crude oil became available in quantity at low cost, we have gradually increased imports until, on balance, we are a net importer to the extent of 15 to 20 percent of our petroleum demand.

Shale oil is not being produced commercially because there is no market for additional oil supplies. The National Petroleum Council estimates that we now could increase petroleum production from present sources by at least 2 million barrels per day, were there a market. This production is available with little additional investment, but it cannot compete with foreign imports.

Owing to shale oil's large initial investment and the necessity to utilize new technology, production on a commercial basis will begin only when presently developed petroleum productive capacity is being used to the maximum practical extent and there is protection from competition by imported oil.

Growth of the shale industry after 1975

While the water requirements for the expansion of the industry after 1975 are not considered in this report, it should not be implied that growth will stop at this point.

There are ample reserves of oil shale for several times the production rate of 1,250,000 barrels per day. In a study for the Corps of Engineers (17) Ford, Bacon & Davis cite a figure for 5,950,000 barrels per day as a possible production rate based on available reserves in Colorado alone. This level could be maintained for a minimum of 40 years. Smaller rates of production would, of course, extend the life of the deposit.

There seems no likelihood that the demand for shale oil, once established, will diminish. Students of our economy are unanimous in the belief that U.S. energy needs, including liquid fuels, will continue to grow for the foreseeable future. Atomic energy is not a competitor for most uses of petroleum. It seems reasonable to expect that shale-oil production will continue to increase as domestic petroleum production declines until some economic or physical limitation is reached. Assuming the availability of an adequate water supply we foresee nothing to prevent shale-oil production reaching several million barrels per day.

OIL SHALE INDUSTRY DEVELOPMENT PATTERN

It is believed that the development of an oil-shale industry will proceed in four distinct phases. This pattern probably will be followed regardless of when the industry starts. These phases are as follows:

Phase I—Experimental
Phase II—Prototype
Phase III—Primary expansion
Phase IV—Secondary expansion

Phase I. Experimental

The experimental phase started about 15 years ago and is now in its final stages. During this period satisfactory methods for each step in the production of shale fuels have been developed. Some additional experimental work is being done now, but the technology essentially is marking time. Little additional experimentation is necessary before building a prototype commercial plant.

Phase I might be termed the preprototype phase, which will continue until the need for beginning commercial shale-oil production becomes evident to oil company management.

Phase II. Prototype

The prototype phase involves building the first commercial-scale plant (or plants). This might also be termed the pioneer phase.

Since the technology to be used is new, many significant improvements are to be expected as a result of this first experience at full-scale production. This is also the period of maximum technological risk. The objective of the prototype phase is not to produce large quantities of oil, but to firmly establish the technology and economics of shale fuels production before making the large investment required for shale oil to contribute significantly to our oil supply.

To keep the investment for phase II to a minimum, the product of the first plant(s) will be marketed insofar as possible by existing transportation systems. (Unfortunately, the local market cannot absorb the output of even the smallest prototype plant.) Studies have shown that 25,000 barrels per day of shale oil can be fairly economically transported to market in California by way of connections to an existing pipeline (7). Other crude-oil-pipeline systems in the area also could be used to transport shale oil to refineries in Colorado, Utah, and Wyoming. These existing pipelines now convey about 195,000 barrels per day of petroleum and at maximum capacity can move 300,000 barrels per day. It seems reasonable that at least 25,000 barrels per day of carrying capacity can be allocated to shale oil when the time arrives.

It is thought that the phase II plant(s) will not include shale-oil-refining facilities except for a means of reducing the pour point and viscosity of the crude oil to meet pipeline specifications. The processes by which shale oil will be refined already are in commercial use, and need no demonstration such as is the case for mining and retorting. Furthermore, the investment for refining facilities is large, about equal to that for oil production. It is probable that the ultimate refining of the product of phase II will be at existing refineries in the market area.

Other supporting facilities of the prototype plant(s) also will be kept to a minimum. Electric-power generation using byproduct gases will not be a part of the first plant or plants. Instead, electricity will be purchased from public utilities serving the area.

The existing local labor supply will be utilized to the maximum extent. It is estimated that qualified personnel to the extent of about one-half of the staff, can be employed locally. Supervisory personnel, technicians, and certain skilled operators and craftsmen will need to be brought in, but essentially all can be housed in the towns and communities between Glenwood Springs and Grand Junction.

In summary, phase II, the prototype plant(s), located in the Grand Valley-Debeque area of western Colorado, will produce about 25,000 barrels per day of crude shale oil. We expect this development to occur between 1960 and 1965. The crude oil will be moved through existing pipeline systems to refineries in logical market areas. Local labor supply can be used for a large percentage of the staff. Existing communities and supporting facilities will meet the needs of the prototype phase.

Phase III. Primary expansion

After sufficient operation of the prototype mining and retorting units to establish the soundness of the methods and to bring about the improvements which are certain to result, shale-oil production can be expanded with confidence and at minimum cost. Again transportation of the oil to market will be the controlling factor. The size of the primary expansion of the industry is likely to be the capacity of smallest economic shale-oil pipeline to the Pacific coast, which we estimate will be about 150,000 barrels per day. Although larger quantities of oil may be pipelined at a lower cost per barrel, it is unlikely that a larger line would be laid at this stage of development.

Several mines, retorting plants, and one or more refineries will be required for phase III. The principal product will be a high-quality partially refined shale oil, needing minimum additional refining. The availability of low-cost byproduct fuel gas from retorting makes it more economical to refine the shale oil at the site of production rather than at existing refineries in the market area.

The expansion of production to 150,000 barrels per day is a significant undertaking in terms of capital investment and human effort. Production, refining, and transportation facilities alone will cost at least $750 million (6).

Housing and community facilities for an additional population of approximately 45,000 persons will be required.

Most, if not all, of the phase III development will occur along the Colorado River between Rifle and Debeque and in the Parachute and Roan Creek areas. The communities from Glenwood Springs to Grand Junction will share in the population growth.

The byproducts of shale-oil production and refining are fuel gases, ammonia, sulfur, and coke. The low-heating value retort gases will be used to generate electricity and supply other process energy requirements. Some electricity may be generated for local consumption in the surrounding communities. There will be no excess energy from retort gas for outside industrial use.

Excess refinery gases will be used as a domestic fuel for the local communities, supplemented by natural gas from nearby fields. Byproduct ammonia, 250–300 tons per day, can be marketed in the Rocky Mountain areas as a fertilizer. The coke and sulfur will have no local market and must be shipped outside the area.

The usage of petroleum products in the area will grow in proportion to population, and industrial uses of fuels, particularly diesel, will increase greatly. However, the local market still will be small compared with production, probably less than 10 percent.

The principal supplies consumed in shale oil production and refining are drill-bits, explosives, lubricants, water-treating chemicals, catalysts, and miscellaneous maintenance materials. Essentially all such materials during phase III will be manufactured outside the area. Construction materials such as steel, cement, lumber, and other manufactured items, through required in quantity, also will largely be shipped in.

In summary—during phase III, the production of shale oil will increase to about 150,000 barrels per day. The product will be a partially refined oil of exceptional quality. Most of the oil will be marketed on the Pacific coast through a single pipeline constructed specifically for shale oil.

The development of phase III should begin after a year or two of prototype plant operation, and be completed within 5 years or about 1970.

The industrial development will be limited to shale oil production, refining, and transportation facilities, and essential supporting utilities. Neither manufacturing plants utilizing byproducts of shale nor industry producing supplies for the shale mines and plants are foreseen during this period.

A population increase of 40,000 to 45,000 over phase II seems likely, with the majority living in existing communities from Glenwood Springs to Grand Junction.

Phase IV. Secondary expansion

The growth of the shale industry following phase III should be rapid. The technology will be firmly established. The demand for petroleum fuels is expected to be such that rate of growth of shale oil production will be limited only by the ability of the industry to expand.

The 5-year period following phase III should see an increase of shale oil production to about 1¼ million barrels per day. This is thought to be the maximum rate at which the industry can grow with normal economic incentives. The effect of some national emergency which might accelerate growth is not considered.

The phase IV expansion will require an investment in the range of $5 billion, not including community facilities, supporting industry and other improvemets. An additional population of about 300,000 will be needed.

The Chase Manhattan Bank (43) has estimated that petroleum industry expenditures for exploration and production in the United States for the period 1961–65 will be $27.5 billion. The investment of $5 billion during a 5-year period for shale oil production facilities does not seem unreasonable.

The Parachute-Roan Creek area and the main stem of the Colorado River between Rifle and Debeque will continue to be the center of activities and most of the production during phase IV will be from shale outcrops along the river and tributary streams; however, production of oil from the deep shales in the Piceance Creek area to the north and from the shales in northeastern Utah should begin. Total production from these new areas may be 250,000 barrels per day.

The largest market for shale oil will continue to be the Pacific coast. Petroleum demand in the five States comprising the west coast area is growing more rapidly than the country as a whole, and domestic production already is in decline. By 1975 demand may reach 3 million barrels per day (21). In 1958, California production, the only west coast State with significant oil reserves, was less than 1 million barrels per day (38).

The Pacific coast oil deficit, now 375,000 barrels per day (38) is supplied by overseas imports, and oil pipelined from Canada and the Rocky Mountain area. By 1975 when 2 million barrels per day of outside supply will be required it seems likely that a shale oil market exceeding 500,000 barrels per day will exist.

The other major market for shale oil from phase IV probably will be in the Middle West. Petroleum and petroleum products now come to this area, largely by pipeline, from Texas, Oklahoma, the Rocky Mountain area, and Canada. Production in the area is small compared with demand. The output of a 1,200 mile, 500,000 barrel per day shale oil pipeline to the Chicago area should be easily absorbed 10 or 15 years from now.

Local demand for shale oil products will have increased several-fold on account of the increase in population and the level of industrial activity. This demand will be in the range of 50,000 barrels per day.

We anticipate significant changes in the technology as a consequence of phases II and III. The methods used for phase IV production will require less investment per unit of production, will make better use of the raw material, giving higher yields of superior products, and most likely will utilize the lower grade shales not now considered economical. However, the probability of using in situ combustion, atomic explosions or some other revolutionary method during this period seems remote.

We believe that refining technology and economic conditions will improve such that in the new refineries built during phase IV the crude shale oil will be hydrogenated directly rather than being coked before hydrogenation. This step will result in a significant increase in the yield of liquid product and, of course, will eliminate coke as a byproduct. It also will still further reduce the availability of byproduct gases from retorting and refining. It is probable that a supplementary energy source, such as coal or natural gas, will be used to supply a part of the energy requirements of the shale oil plants.

The principal byproducts of shale oil production and refining during phase IV will be ammonia and sulfur. Coke production probably will have increased slightly over the level of phase II, but it is doubtful that refinery gases will be an important product for outside use.

It has been suggested that shale oil production would provide raw materials for a petrochemicals industry. While several shale oil fractions, in particular the lighter hydrocarbons from hydrogenation refining, are suitable petrochemical raw materials, it is doubtful that they will be used as such in western Colorado. First, petroleum consumed as petrochemicals amounts to only about 2 percent of the petroleum demand, and raw materials from current sources seem adequate for the foreseeable future. Second, western Colorado is far from chemical markets and is handicapped by high freight rates. If shale oil is used as a petrochemical raw material, it is likely to be converted to chemical products at pipeline terminals in the market area.

The use of oil shale directly, as a chemical raw material, is a distinct possibility in the future, but the technology to derive valuable chemicals from shale has not yet been fully developed. The lack of readily usable processes and plentiful raw materials from other sources makes it doubtful that oil shale will be used for chemicals production to an appreciable extent during the next 15 years.

The growth of shale oil production to the proportions envisioned in phase IV will bring with it some related industry. Tonnage quantities of explosives will be required. Ammonium nitrate, which can be manufactured from byproduct ammonia, seems likely to be the principal shale-blasting agent. As much as 500 tons per day will be consumed for shale mining alone. This amount will support a large-sized ammonium nitrate plant. Sulfuric acid for general industrial use may also be manufactured from byproduct sulfur.

Cement is perhaps the largest tonnage manufactured material required by shale industry and its community.

The usage of cement in this area will be sufficient for a plant of economic size. Raw materials are available. Spent shale may be used as an ingredient.

Water treatment and the building industry will greatly increase the demand for lime in the area, and this industry should expand considerably.

Many small service and manufacturing operations will be conducted to serve this $5 billion industry and the 400,000 or more population in the area. There will be more new businesses of this type than were the development to occur in a more populated area. Very little supporting industry of the kind required now exists.

To summarize: Shale oil production during phase IV from 1970 to 1975 will increase to about 1¼ million barrels per day. This is less than 8 percent of anticipated U.S. petroleum demand in 1975.

The product, principally hydrogenated shale oil, free of contaminants and equivalent to the highest quality crude petroleum, will be transported by large-capacity pipelines to markets on the Pacific coast and in the Middle West. The gasoline and other fuel requirements of the local community also will be served from a complete shale-oil refinery in the area.

In addition to shale-oil facilities costing an estimated $5 billion, a moderate supporting industry will begin during this period. Explosives, sulfuric acid, lime, and cement are most likely to be manufactured. Numerous manufacturing and service facilities of lesser magnitude also will be started.

It is unlikely that oil-shale byproducts will be utilized locally except for explosives, sulfuric acid, and possibly cement manufacture.

A population of nearly 300,000 in addition to the phase III development is foreseen making the total population for shale and related industries about 340,000. Rio Blanco County and Uintah County, Utah, will share this population growth.

Water Requirements for Shale Oil Production

The production of the crude shale oil requires very little water. Consumption of water for mining chiefly is for drilling blast holes and as a dust palliative. Retorting uses only bearing coolant water and a small amount of steam for heating and cleaning purposes. Processes have been developed which do not require water for cooling and condensation of the oil. (Certain European processes consume steam directly in the retort, but this type process is not now under consideration for Colorado shale.) Personnel, of course, require drinking and sanitary water. Overall water requirements for crude oil production, both mining and retorting, are less than 10 gallons per barrel of oil, of which a small amount can be reused or returned to the stream.

Shale oil refining requires relatively large quantities of water both as a process coolant and for the generation of steam. Since steam is consumed in the manufacture of hydrogen, where refining processes use hydrogen as a reagent, this particular requirement is larger than in conventional refineries. Steam also is used to drive pumps and compressors.

Cooling water requirements for refining are large even when exchanging heat between hot outgoing and cool incoming process streams. In the refining process some of the oil fractions are heated to elevated temperatures several times and the products must be condensed and/or cooled between process steps as well as when refining has been completed. Water usually is the most economical coolant for this purpose.

Cooling water may be used once or recirculated. On a once-through basis, most of the water would be returned to the stream essentially without loss, but at a higher temperature. A recirculation system uses some type of evaporative cooling to re-cool the water and very little is returned to the stream.

Once-through usage requires a large year round water supply and if the stream contains considerable impurities, the expense of treating may be significant. For a recirculating cooling water system, only make-up water is required, usually no more than 10 percent of the quantity needed on a once-through basis.

Because of seasonal fluctuations in stream flow and the probability of having to chemically treat the water to make it usable, we have assumed the use of recirculating cooling water systems for our estimate of water requirements.

Electric powerplants are another significant consumer of water. Here again, cooling and condensation is the largest requirement. For average steam-electric plants using recirculated cooling water, 7 pounds of water are consumed for each kilowatt-hour of electricity generated.

The total water requirement for shale oil production and refining including electric power generation, may vary from 50 to 100 gallons per barrel depending on the refining process used. Perhaps 10 percent of this water would be returned to the stream.

Shale-related industry, which will not become important until the beginning of phase IV, the secondary expansion of shale oil production, will require additional quantities of water. For instance, a 500-ton-per-day ammonium nitrate plant will require 6 million gallons of water per day. It is impossible to determine water usage by the many small supporting plants, but it is certain that requirements will be significant.

A large usage of water attributable to a shale industry will be in the homes and cities of the workers and supporting personnel. The per capita usage of water in western communities is higher than in areas where lawn irrigation is not practiced. The larger western Colorado towns use up to 480 gallons per day per person. The factor for Grand Junction is now 297. A recent survey of large western cities by Langbein showed most used greater than 300 gallons per day per capita. A water-use factor of 300 gallons per person per day is assumed in this report. On the average about two-thirds of this water should return to the stream.

Water requirement for phase I

The usage of water for shale during the experimental phase before any commercial production begins has been variable, but insignificant. There is no reason to believe that future experimental work, if any, will require water supplies additional to those already developed. However, since prototype production is expected to start between 1960 and 1965, a water supply capability of at least 2,500 acre-feet per year, if not already in existence, is suggested starting in 1960.

Water requirements for phase II

The production of 25,000 barrels of shale oil daily during the prototype phase is estimated to require 1,300 acre-feet of water per year of which 550 acre-feet would be returned. Municipal water for the new population is included. Tables 3 and 4 summarize supporting data for this estimate.

It should be noted that over half the personnel for phase II presently reside in the area. The relatively small new population is expected to live in existing communities; therefore, it is unlikely that additional water supplies will need to be developed for municipal use during this phase.

Industrial usage for phase II also is small, but whether or not a firm year-round supply is available depends on who builds the plant(s) and their location. It is possible that water usage by the prototype plant(s) could be larger than estimated if the oil is more highly refined at the site of production, than assumed. As much as 1,750 acre-feet per year would be required for a production rate of 25,000 barrels per day if a hydrogenated coke distillate were the product. It would seem prudent to assume this larger water usage.

For planning water supplies it is suggested that a factor of 2.0 be used to insure an ample margin for larger production quantities than assumed. On this basis the water supply capability for phase II should be 5,000 acre-feet per year.

Water requirements for phase III

The production of 150,000 barrels per day of partially refined shale oil is estimated to require 27,000 acre-feet of water per year for municipal and industrial use of which 11,000 acre-feet would be returned to the stream. Tables 3 and 4 give supporting data. These figures are inclusive of any water diverted for use during phase II.

Since a basic assumption is that all the shale oil will be refined in the area, the estimate of water use probably is maximum for this oil production quantity. For planning water supplies it is suggested that a factor of 1.5 be used to cover errors in estimation and larger production quantities than assumed. Applying a factor of 1.5, the water supply capability for phase III should be 40,000 acre-feet per year.

Water requirement for phase IV

From tables 3 and 4 it may be seen that estimated water use for the production of 1,250,000 barrels of refined shale oil per day is 252,000 acre-feet of which 93,000 acre-feet would be returned. These figures are for industrial and municipal use for both shale oil production and shale-related industry. Usage is inclusive of that estimated for previous phases of development. All shale oil is assumed to be refined in the area, thus water use should be maximum for the oil quantity assumed.

For planning water supplies, we suggest taking the water usage estimated without application of a factor to account for errors. The period in question is sufficiently far in advance to allow reappraisal when the actual pattern of development becomes evident. Our current recommendation for a water supply capability for oil shale development for the period 1970 to 1975 is 250,000 acre-feet per year.

TABLE 3.—*Summary of water use data for commercial shale oil development*

[Figures rounded]

	Prototype	Primary expansion	Secondary expansion
Period	1960–65	1965–70	1970–75
Shale oil production, barrels per day	25,000	150,000	1,250,000
Water requirements, acre-feet per year, shale oil production, and refining:			
Diverted	550	12,000	127,000
Consumed	500	11,000	114,000
Shale-related industry:			
Diverted			10,000
Consumed			5,000
Municipal (new population):			
Diverted	750	15,000	115,000
Consumed	250	5,000	40,000
Total municipal and industrial:			
Diverted	1,300	27,000	252,000
Consumed	750	16,000	159,000
Location (percent):			
Garfield-Mesa County	All	All	80
Rio Blanco County			12
Uintah County, Utah			8
Recommended water supply capability, acre-feet per year	5,000	40,000	250,000

TABLE 4.—*Summary of population for commercial oil shale development*

[Figures rounded]

	Prototype	Primary expansion	Secondary expansion
Period	1960–65	1965–70	1970–75
Shale oil production, barrels per day	25,000	150,000	1,250,000
Permanent shale personnel:			
Production [1]	900	6,900	50,000
Construction [2]		1,500	9,000
Other industrial			1,000
Total employed	900	8,400	60,000
Service personnel, new [3]	360	7,100	53,500
Households, new [4]	630	12,500	93,000
New population [5]	2,300	45,000	340,000
Location:			
Garfield-Mesa County	2,300	45,000	275,000
Rio Blanco County			40,000
Uintah County, Utah			25,000

[1] 500 production workers from existing local population.
[2] Prototype construction personnel local or temporary; ½ construction personnel for expansions permanent.
[3] Trades and professions not directly employed in the shale industry. Calcluated as 90 percent of shale personnel added to community.
[4] Calculated as 1.2 employed personnel per household.
[5] Calculated as 3.6 persons per household.

BIBLIOGRAPHY

1. American Petroleum Institute, "Report of the Committee on Petroleum Reserves," Washington, D.C.
2. Anderson, C. C., "Petroleum and Natural Gas in the United States: Relation of Economic and Technologic Trends." Paper presented before World Power Conference, Montreal, September 1958.
3. Barnett, Harold J., "Energy Uses and Supplies, 1939, 1947, 1965," Bureau of Mines Information Circular No. 7582, U.S. Department of the Interior, October 1950.
4. Burke, H. G., Jr., "Statement on Behalf of Esso Standard Oil Company." Presentation before the U.S. Tariff Commission on the subject of oil imports, 1951.
5. Cadle, A., "Personal Communication, April 17, 1959," on projection of petroleum supply and demand through 1975.
6. Cameron, R. J., and Miller, E. P., "Shale Oil Nears Competitive Level With Domestic Petroleum," Journal of Petroleum Technology, August 1958.
7. Cameron & Jones, Inc., "Colorado Shale Oil Production Costs." Private study, June 12, 1958.
8. Carson, M. V., Jr., "Personal Communication, April 22, 1959," on probable imports for the next 10 to 15 years.
9. Colorado Conference Committee and the Colorado Water Conservation Board, "Water Requirements of an Oil Shale Indstury." Presentation as to water requirements of an oil shale industry by a committee composed of major oil shale landholders, Sept. 24, 1953.
10. Colorado River Conservation District, "Stage Development Plan for Supplying Municipal and Industrial Water for Potential Oil Shale Industry in Western Colorado," Glenwood Springs, Colo., 1958.
11. Coqueron, Frederick G., Hammer, H. D., Winger, J. G., "Future Growth of the World Petroleum Industry," the Chase Manhattan Bank, New York, November 1958.
12. Coqueron, F. G., "Financial Requirements of the World Petroleum Industry," Investment Dealers Digest, Dec. 1, 1958.
13. Davis, M. J., "Lets Stop Selling U.S. Reserves Short," Oil and Gas Journal, Dec. 8, 1958 (p. 80).
14. Davis, W., "Future Productive Capacity and Probable Reserves of the U.S.," Oil and Gas Journal, Feb. 24, 1958 (pp. 105 to 116).
15. Davis, Warren B., "Personal Communication, April 24, 1959."
16. Elliott, Martin A., von Fredersdorff, C. G., "A Rational Analysis of the Future Rate of Production of Natural Gas." A report from the Institute of Gas Technology.
17. Ford, Bacon, and Davis, "The Synthetic Liquid Fuel Potential of Colorado," Corps of Engineers, Department of the Army, Dec. 14, 1957.
18. Gejrot, Claes, "Descriptive pamphlet of Swedish Oil Shale Operation," Svenska Skifferolje, AB, Orebro, Sweden, 1958.
19. Hartley, F. L., "Progress in Oil Shale Research." Paper presented before the 38th National Meeting of the A.I.Ch.E., Salt Lake City, Sept. 22, 1958.
20. Hill, R. A., et al., "Depletion of Surface Water Supplies of Colorado West of the Continental Divide." Bulletin No. 1, Surface Water Series, Colorado Water Conservation Board, Oct. 31, 1953.
21. Hill, K. E., Winger, John G., "Future Growth of the West Coast Petroleum Industry Paper presented before the spring meeting of the API Division of Production, Pacific Coast District, Los Angeles, Calif., May 16, 1957.
22. Hill, K. E., Hammer, H. D., Winger, John G., "Future Growth of the World Petroleum Industry." Paper presented before the American Petroleum Institute Division of Production, Rocky Mountain District, Casper, Wyo., Apr. 25, 1957.
23. Holaday, W. M., et al., "Fuels—Their Present and Future Utilization," Petroleum Processing, November 1949.
24. Hopkins, G. R., "A Projection of Oil Discovery 1949–65," Journal of Petroleum Technology, June 1950.
25. Hubbert, M. K., "Techniques of Prediction with Application to the Petroleum Industry." Publication 204, Shell Development Co., Exploration and Production Research Division, Houston, Tex., March 1959.
26. Independent Petroleum Association of America, "Facts and Forecasts for the Independent Oil Producer," March 1959.

27. Independent Petroleum Association of America, "Energy Supremacy," an industrial manifesto, April 1959.
28. Interstate Oil Compact Commission, "Oil for Today and for Tomorrow," Oklahoma City, Okla., 1953.
29. Kemp, L. C., Jr., et al., "Subcommittee Report to National Petroleum Council's Committee on Synthetic Liquid Fuels Production Cost," National Petroleum Council, Washington, D.C., 1951.
30. McCollum, L. F., "Report of the National Petroleum Council Committee on Petroleum Productive Capacity" May 5, 1955. The National Petroleum Council, Washington, D.C.
31. ——— ———, "Report of the National Petroleum Council Committee on Petroleum Productive Capacity" May 28, 1953, Washington, D.C. The National Petroleum Council.
32. ——— ———, "Report of the National Petroleum Council Committee on Petroleum Productive Capacity," Oct. 3, 1957, Washington, D.C. The National Petroleum Council.
33. Miller, E. P., et al., "Comparison of National Petroleum Council, Bureau of Mines, and Koppers Co,, Inc., Proposals for an Industry-Scale Oil Shale Project," intrabureau report, Oil Shale Engineering Branch, Rifle, Colo., November 1953.
34. National Petroleum Council, "Petroleum Productive Capacity," Report of the committee on oil and gas availability, Jan. 29, 1952.
35. Netschert, Bruce C., "The Future Supply of Oil and Gas." Published for Resources for the Future, Inc., by Johns Hopkins Press, Baltimore, 1958.
36. Oil and Gas Journal, "What is U.S. Productive Capacity?" May 19, 1958.
37. Oil and Gas Journal, "What Mandatory Controls Means," Mar. 16, 1959.
38. Oil and Gas Journal, "Review and Forecast Section," Jan. 26, 1959.
39. Paley, W. S., "Resources for Freedom, Volume III: The Outlook for Energy Sources," A report to the President by the President's Materials Policy Commission, June 1952.
40. ——— ———, "Resources For Freedom, Volume IV, The Promise of Technology." A report to the President of the United States by the President's Materials Policy Commission, June 1952.
41. Panel on the Impact of Peaceful Uses of Atomic Energy, "Peaceful Uses of Atomic Energy," to the Joint Committee on Atomic Energy, 84th Cong., 2d sess., volume 2, U.S. Government Printing Office, Washington, January 1956.
42. Petroleum Week, "Centennial Forecast," May 15, 1959.
43. Pogue, J. E., Hill, K. E., "Future Growth and Financial Requirements of the World Petroleum Industry." Paper presented before the AIME, petroleum branch, Feb., 21, 1956.
44. Prien, C. H. "Water Requirements for a Colorado Oil Shale Industry," Denver Research Institute, Denver, Colo., Apr. 16, 1954.
45. Resources for the Future, Inc., "Annual Report for Year Ending September 30, 1958," December 1958.
46. Rubel, A. C., "Liquid Fuels From Oil Shale—A Critical Review." Paper presented before the southwest meeting of the petroleum branch of the AIME, Dallas, Tex. (Preprint, no date given.)
47. Schroeder, W. C., "Economic Possibilities for Liquid Fuels From Oil Shale and Coal in the United States." Paper presented before the First Energy Resources Conference, Denver, Colo., October 1955.
48. Teitelbaum, P. K., "Nuclear Energy and the U.S. Fuel Economy, 1955–80," National Planning Association, July 1958.
49. Tonry, C. E., "Study of Requirements and Costs of Housing for Oil Shale Plants in Western Colorado," intrabureau report, Oil Shale Demonstration Branch, Rifle, Colo., June 1952.
50. U.S. Bureau of Mines, "Information Relating to Water Requirements for Production of Liquid Fuel from Oil Shale" Unofficial memorandum prepared by the staff of the Oil Shale Experiment Station, Rifle, Colo., circa 1953.
51. U.S. Bureau of Mines, "Mineral Facts and Problems," Bulletin 556, Government Printing Office, Washington, D.C., 1956.
52. U.S. Bureau of Mines, "Minerals Yearbook Fuels, Volume II," U.S. Government Printing Office, Washington, D.C., 1959.
53. U.S. Department of the Interior, "Oil Import Regulation 1," Code of Federal Regulations, title 32–A, National Defense, appendix, "Chapter X: Oil Import Administration," Mar. 13, 1959.

Representative PATMAN. Thank you very much. We are indebted to you for a very fine statement. It will be useful and helpful to the committee. Thank you again for your testimony.

The next witness is Mr. Darbyshire, who has been out of the country and returned just yesterday. He has not had time to complete his statement, which will be submitted for the record.

Would you like to orally present some of the points you expect to cover, Mr. Darbyshire?

STATEMENT OF BERNARD N. DARBYSHIRE, PETROLEUM ECONOMIST; MEMBER, INTERSTATE OIL COMPACTS, SUBCOMMITTEE ON FOREIGN OIL; ADVISER TO MIGROL, ZURICH, SWITZERLAND, AND FRISIA REFINING CO., EMDEN, GERMANY

Mr. DARBYSHIRE. I would like to make a few brief remarks at this time, if I may.

Representative PATMAN. You may proceed.

Mr. DARBYSHIRE. The subject on which I was asked to testify was entitled, "World Petroleum Needs, Supplies, and Organization as Related to the Domestic Scene." You will appreciate that even with 1,000 pages of testimony it would be virtually impossible to do full justice to this vast subject. I have but a few minutes, and I therefore propose to deal briefly with the matters which I believe to be of the greatest importance, and I will submit some prepared testimony on any points which require elaboration or in response to any questions from the committee.

I think these hearings abundantly bring out that the United States economic development, industrial leadership, and high living standards have resulted from the availability of cheap energy. Economic progress is only possible on the basis of the application of energy, and the cheaper and more abundant the energy, the more rapid the progress. So it is throughout the world in relation to the other countries which have not proceeded so far down the path toward prosperity, but which are now trying to follow.

This morning Dr. Gonzales in his chart 2 brought that out, I think, very well, and Commissioner Murray, too, also referred to the same problem of lifting living standards in backward nations—the necessity of applying energy to them as cheaply and as quickly as possible.

Earlier this year in Dallas, at a meeting I heard a member of this committee, Senator O'Mahoney, say that this Nation has not yet realized the nature, the full nature, of the struggle in which we are engaged with the Communist world. Perhaps the recent visit of Mr. Khrushchev and the more recent developments in Russian rocketry may have served to focus attention on the progress which the Russians have been making. It is clear in my mind that there is, at the present time, a real economic struggle developing between the East and the West for the demonstration of the merits of the respective economic systems under which we operate in producing prosperity, both for ourselves and for the rest of the world. Will free competitive capitalistic enterprise prove to be a more effective and efficient instrument than State planning and collective ownership and control? We are faced with the need to prove that it can be so. Mr. Khrushchev has challenged us to do so.

In relation to the so-called underdeveloped nations of the world, the problem is how can we get energy to them quickly enough to enable them to lift their living standards rapidly. We know now what we did not know 10 years ago, that there is no real fear that the world will run out of energy supplies. That atomic energy and hydrogen fusion lie really close at hand, and 50 years from now one can anticipate that they will be playing a dominant role in the total supply of world energy. Therefore, to my mind there does not seem to be any need to be conservative in relation to those fossil fuels which are easily at hand and which can be quickly developed at the present time. I feel that we should now utilize them as rapidly as possible in order to provide cheaper energy to the underdeveloped nations of the world and to give them an opportunity of lifting their living standards so rapidly that the population increase problem referred to by Commissioner Murray may well be overtaken with an even more rapid rise in living standards.

How can we do this? Well, fortunately we know that very vast reserves of petroleum do lie in the Middle East, additional reserves are currently being discovered almost daily in the new areas of north Africa, and, in addition, in the last 2 or 3 years large new reserves of petroleum have been discovered in Venezuela. (See app. 1.)

Additionally, in many countries around the world exploration is going on, and there are evidences of future success to come.

The problem is, as far as the other nations of the world are concerned, I think, hinging on the difficult question of price. This morning, Mr. Chairman, you did say in response to part of Commissioner Murray's statement in relation to the possibility of price control in the future that you hoped it would not exist in our free economy. I would like to point out that in relation to the petroleum industry, in effect, I believe that within quite narrow limits it does exist today, or at least there is a considerable inherent threat that it does, as a result of actions by the U.S. administration during the course of this year.

At the time when the imports control program was introduced in March of this year, that introduction of the program was accompanied by a statement by the President which was to the effect that in the event that price increases occurred whilst the import program remains in being, then the director is required to determine whether such increases are necessary to accomplish the national security objectives of the proclamation. This has been taken to mean that if there was a tendency for them to rise, the program would be altered in such a way as to increase the amount of foreign oil coming in and correct thereby a rise in price.

As such, I think that as long as it is considered that that will be the policy of the Government, there is no doubt that there is a very real deterrent in relation to an upward movement of crude oil prices in the United States.

Curiously enough, apparently at the same time as that program was initiated by the President, the U.S. Government had to justify the import program to the Venezuelan Government, which was not very happy about the restriction on Venezuelan oil coming into the United States. They had to advance some arguments for the program and the argument which was used, I understand, was that in return for restrictions on imports, the prices of crude oil would be stabilized.

Now, if you have two arms of the administration at the same time, one indicating that prices will not be allowed to rise, and the other expressing the view that prices will not fall, I think that there is a very definite threat that price control already exists over the industry.

In relation to the price of crude petroleum here in the United States, there is no doubt that the cost of petroleum production, relative to other areas of the world, is rather high, and the profits made on petroleum production are not very great here in the United States. Nevertheless, we have an unfortunate continued linkage between the price structure in the United States and the price of oil elsewhere in the world. The relationship has been brought out in various reports from time to time. The report entitled "The World Petroleum Cartel," 1952, produced by the Federal Trade Commission, the report produced by the United Nations Economic Commission for Europe in Geneva, in 1955, entitled, "The Price of Oil in Western Europe," both clearly demonstrated that the actual cost of production from the vast reserves of petroleum in the Middle East does not exceed some 35 cents a barrel. There is no doubt that the oil has been sold over the past 7 years at prices ranging between $1.50 and $2 a barrel, a very vast difference between the actual cost of production and the selling prices. A great deal of this oil in the Middle East has been going to the underdeveloped nations, the nations who are starved for energy and the nations who have been receiving American aid during that period.

I do feel that it would be an appropriate subject for this committee, concerned as it is with economic affairs, to investigate the effectiveness of the foreign aid program as related to the supply of energy in the nations which have been receiving aid. We are seeing at these hearings that no real progress can be made without cheap energy. We read in the newspapers of the abundance of American manufactured consumer goods in certain of the nations which are receiving aid, such as Vietnam. I understand it is very easy to obtain typewriters and material of that sort of American origin in Vietnam, but still the basic essentials of the economy are not being met, and I think it is probable that in many of these countries it is because the essential problem necessary for economic progress, the provision of cheap energy, has not yet been tackled in a systematic fashion. As a result despite vast sums of aid disappointing economic development has taken place.

I do feel that one of the great things necessary to the winning of the economic war that we are now engaged in with the Communist world for the demonstration of the benefits of our respective economic systems is that it is essential we should provide this cheap energy which is available at low cost to the backward nations. It is a matter I cannot overstress.

From my appendix 1, the fabulous concentration of the world's reserves of crude petroleum in the Middle East and almost entirely under the control of American and allied companies will be observed. Russian reserves are small in comparison. This is an economic weapon that we have and they have not, and yet so far we have not used it, for we have kept energy prices in the underdeveloped nations high by permitting the oil companies which control these reserves (more than 60 percent American) to maintain artificially high prices. If it is that the prices are being maintained as a result of lack of price competition among the oil-producing companies, then I would suggest that it is a serious problem for investigation, either by this committee or another, with a view to some action being taken. A great deal of foreign aid has, I am sure, been spent on excessively high priced oil supplied to the countries by American companies.

Some 7 years ago under the Democratic administration, there was pending an antitrust suit against the international oil companies on that particular matter. During the course of the last 7 years, I have heard very little about the progress of that suit, and I do not know the exact situation at the present time. If that is the only method of bringing selling prices nearer to cost of the production in the oil regions of the Middle East, then it might be appropriate to consider looking at that matter again.

I have just a few more remarks.

Dr. Gonzales this morning, quite rightly, I think, indicated that competition in the United States has led to reasonable prices of oil. I have worked until the last 15 months very largely overseas and my experience has been of different marketing conditions to those which exist here. For instance, the British newspaper New Chronicle interviewing Mr. Eric Hardiman, general manager of the marketing organization of Esso Petroleum, the British subsidiary of Standard Oil of New Jersey, on September 28, 1959, quotes him as saying, "the aim for petroleum products generally over the last 10 years has been price stability with a continual search for better products." It is my experience that this is true. Competition has been concentrated on advertising, acquisition of service station outlets, and improved products, but not on prices, unless an outside organization has attempted to break into a particular market.

I am particularly familiar with the situation in recent years in Switzerland. The company with which I have been associated there, the Swiss concern Migrol, has been responsible for upsetting the former cartel which operated there, and has led to roughly a 25 percent reduction in the selling price of gasoline over the last 4 or 5 years, thereby rendering a very considerable service to the Swiss consuming public. We have come across a good deal of opposition from the major international oil marketing companies in the process. There is a curious example which I would like to bring to your attention very briefly, and I can submit the necessary data subsequently.

According to the statistics of companies importing into Switzerland, it is fairly easy to calculate that on premium gasoline, premium grade gasoline sold in Switzerland today, the companies are currently losing the approximate equivalent of 2 cents per gallon and on regular, 4 cents per gallon. Virtually the same grades of gasoline brought up the Rhine under the same cost and sometimes in the same barge and marketed a few miles away in Germany are making profits of some 10 cents per gallon on premium and 6 cents per gallon on regular. The reasons why in one country there should be definite dumping is because of the existence of the competition provided by the small Swiss company with which I have been associated. There is a very definite, concerted attempt by dumping of gasoline at the present time to kill off that competition.

On the other side of the Rhine in Germany, where that competition does not exist, you have a clear profit of 10 cents a gallon being made in retail margins, according to the figures which are available from the companies themselves. (See app. 2.)

I do feel that excessive profitmaking on the one hand and dumping on the other are not really practices in which American companies operating overseas should participate in this important matter of supplying essential fuels to friendly countries. Both of these practices would be illegal if perpetrated in America, tending as they do to eliminate small businesses. If it is really believed that a free competitive capitalistic system with antimonopoly and antidumping laws such as exists in America is the best economic system for the free world then the great oil companies operating overseas should be constrained to act as they have to do at home. Otherwise the foreigner can justifiably complain of our economic hypocrisy.

I must abbreviate my remaining remarks. I do have quite a number of other points that I would have liked to make.

Representative PATMAN. You will be privileged to extend your remarks and your testimony, and supplement your remarks with anything that you think is germane.

Mr. DARBYSHIRE. Thank you.

Very briefly, then, I should say that the question of imports, I think, would normally fall under my subject matter at these hearings. Other witnesses have mentioned the importance of the import situation on petroleum. I think I would briefly say that according to my rough calculation some 7 percent of U.S. energy demands are currently supplied from imported petroleum, and therefore in any consideration of the overall energy picture in the United States it is essential to consider imported petroleum as a very important source of energy which may conceivably increase in the future. If there was no quota program on imports at the present time, there is no doubt, in my mind at least, that the imports of petroleum would be increasing very rapidly indeed. The whole question of the propriety of the import program, whether it is a satisfactory program, is one on which one could have an elaborate series of hearings. It is possible that it should be given more consideration by this committee than I can possibly undertake at the present time.

I would very briefly venture the notion that a limited import quota system cannot be really very satisfactory as a long-term solution of the problem, particularly when those quotas are based on the sort of principles which are utilized today. It does inhibit and penalize unfairly the activities of many of the companies who have undertaken exploration at great expense overseas and have no domestic refinery capacity and no historical record of importing. There is, of course, the tremendous problem inherent in how far one should allow imports in without imperiling national security. I can, perhaps, if the committee so wished, include in my testimony a draft of a plan which I worked out during the course of this year. Last winter when I was at the University of Texas as a guest lecturer I had some time to reflect on this problem, and my plan might perhaps provide a new approach to the problem. It is basically the notion that national security could not be imperiled by an increasing level of imports if such quotas were specifically geared to shut-in capacity in the United States.

Representative PATMAN. The committee would like to have your suggestions along that line.

Mr. DARBYSHIRE. I have prepared that in some detail, and I would be very happy to submit it for you. (See app. 3.)

Representative PATMAN. And any recommendations you have would be appreciated.

Mr. DARBYSHIRE. Yes, sir.

Well, Mr. Chairman, you will appreciate the very wide range of the problems which should be considered under the subject matter which I was requested to testify on. I am well aware that my remarks really raise more questions than they answer. Any aid that I can give to the committee at any time in the future, naturally, if it lies within my power and ability, I will be very happy to try and give. In the last 13 days I think I have been in nine countries, and as you said at the beginning, I only arrived last night, at a good deal of personal effort and cost. But I want to say that that is only a partial measure of my personal appreciation of the privilege that I do consider it to have been invited to testify here.

If anything that I have said will help you to improve the supply of energy at lower prices to the underdeveloped parts of the world, then I will count my time and effort very well spent indeed.

As an old friend, but only a rather recent immigrant to the United States, I do thank you for the very great honor in being allowed to come here.

Representative PATMAN. Thank you, sir. You may extend your remarks as suggested. (See app. 4.)

(The following was subsequently submitted for the record:)

APPENDIX 1

Proved Reserves of Petroleum

[In thousands of barrels]

United States of America	33,000,000
Venezuela	16,500,000
Canada	4,000,000
Mexico	2,500,000
Rest of Americas	2,843,000
Total, Americas	58,843,000
Europe	1,437,000
Algeria	3,500,000
Rest of Africa	618,500
Total, Africa	4,118,500
Indonesia	8,500,000
Rest of Far East	1,146,500
Total, Far East	9,646,500
Kuweit	60,000,000
Saudi Arabia	47,000,000
Iran	33,000,000
Iraq	25,000,000
Neutral Zone	6,000,000
Quatar	2,500,000
Rest of Middle East	451,000
Total, Middle East	173,951,000
Total, free world	247,996,000
Russia and satellites	27,705;000

NOTE.—70 percent of the non-Communist world's proved petroleum reserves are concentrated in the Middle East. 60 percent of these reserves are in American company ownership.

Source: Oil and Gas Journal, Dec. 29, 1958 (pp. 87–88).

Appendix 2

Comparison of gasoline marketing margins of international oil companies operating in Switzerland and Germany, end September 1959

	Octane gasoline	
	98/100 RM	86/90 RM
A. Switzerland, prices in centimes per liter: [1]		
Companies declared cost at Basel [2]	17	15¼
Swiss taxes	26	26
Gas station operators margin	7	6
Storage, distribution, and administration costs (minimum estimate)	1	1
Total	51	48¼
Sale prices at pumps in Basel	49	44
Loss on operations through dumping to eliminate competition	2	4¼
	94/96 RM	86/88 RM
B. Germany, prices in pfennig per liter: [1]		
Companies cost at Weil [3]	17	15¼
German taxes	33	33
Gas station operators margin	9	8
Storage, distribution, and administration costs (minimum estimate)	1	1
Total	60	57¼
Sale prices at pumps in Weil	70	63
High profits through lack of price competition	10	6¾

[1] The Swiss centime being almost exactly the same value as the German pfennig these prices are directly comparable. By coincidence of exchange rates and measures these figures are almost the same as if they had been expressed in U.S. cents per gallon, and can be taken as roughly comparable.
[2] Companies operating in Switzerland must declare the value of their product arrived at the frontier to "Carburant" for purpose of valuing strategic reserve stocks.
[3] Basel and Weil are on opposite sides of the Rhine.

Appendix 3

Proposed New Basis for an Oil Imports Program Designed Specifically in the Interests of National Security and Conservation

It is my belief that the present imports program does not and cannot fully succeed in obtaining its objectives of reestablishing a healthy domestic oil industry. The reason for this is that the program is essentially based upon the principle of allocating import quota rights in relation to refinery runs or in some proportional relationship to the position of historical importers. The net effect of this principle for the allocation of quotas is to confer upon the refiners and importers concerned a free gift whose value is variously estimated as ranging between $0.80 and $1.20 per barrel of quota rights received. This was a feature of the Carson plan which was retained substantially in the present imports program when after many delays it was finally introduced in March of 1959. It is my considered contention that the only real protection afforded to the domestic industry by the present imports program is that of providing a definite quantitative limit on the amount of petroleum which may be imported by sea into the United States. These quantitative limitations, however, apparently will be variable by decision of the administration every 6 months and therefore no one can determine what they may be a year hence and for this reason domestic industry cannot look with any certainty to the future. Pricewise the present imports program conveys no help to the domestic producer. There have been various crude oil price cuts since the program was introduced and these clearly indicate that if the program was intended to protect the domestic price structure, it is, as currently designed, an ineffective instrument in so doing. Furthermore the fact that we have previously noted, namely, the conferring upon the refiners and importers of a virtual subsidy places them in a position, if they are going to behave competitively pricewise, where they can afford to initiate otherwise uneconomic price cuts in products prices in order to enlarge their share of the market. This will have a permanent weakening effect on the domestic products price structure and thereby almost directly upon the domestic crude oil price structure.

The imports program was finally introduced because the need to aid the domestic crude oil industry in the interests of national security had been emphatically proved in recent years. The present program does not accomplish that purpose and therefore a new program is called for.

My proposal is essentially based on the principle of relating import quotas to deliberately shut in proved crude oil-producing capacity. In other words, to bring the barrel into the country you must have a barrel shut in. If this principle can be followed, there need be no upper limit on the amount of foreign oil that can be brought into America. Indeed, the more the better for we will be using up cheaply produced foreign oil from the Middle East and Venezuela saving in the ground for time of international strife or for posterity American oil which costs much more to find and to produce. There can be no imperilment of becoming too dependent on foreign oil if for every barrel brought in there is a barrel of shut-in capacity immediately available and connected up by pipeline to storage facilities. The broad principle is perfectly clear, but there are many technical legal and financial objections to be overcome before it could be converted into a practical program. Nevertheless I believe that this is perfectly possible, provided that sufficient people realize that it is essential to accomplish such a program in the national interests. I will take some of these more important difficulties in turn and discuss them and how I think they could be overcome. First of all, on technical grounds, it is clear that no producer would shut in capacity in an oil field if other producers in the same field were going to continue to drain the common reservoir. Obviously therefore no oilfield could qualify for the purpose of being shut in in order to obtain import quotas unless it was either wholly owned by one company, or else it was being operated on a unitized basis and all the participants in the field agreed to shut in their capacity. If we assume for the moment that there would be an adequate financial incentive to encourage domestic producers to shut in their capacity, then it is clear that such an import program would immediately give considerable impetus toward voluntary unitization of a great many of the oilfields which are currently not operated on a unitized basis. There are few in the industry today who oppose voluntary unitization and I would contend therefore that this side effect of my proposed program would in itself be no bad thing for the domestic petroleum industry and would probably aid conservation and ultimate recovery.

The other main technical objection is potentially much more serious. In order that such a program should have the necessary flexibility equating supply to demand from month to month according to the season and the changing needs of the domestic market, it is essential that the quotas should not be geared to maximum economic recovery rating of wells shut in, but rather to the allowables that would be granted to shut-in wells as a result of prorationing in relation to market demand by State conservation authorities. This would be an essential feature providing elasticity and flexibility in the program but it leads to the very great difficulty of establishing a common policy and principles of determining maximum economic recovery rate and proration allowables between the various oil-producing States. At first sight this would seem to lead to a head-on conflict with the Department of Justice. I am not so sure however that this is really the case. If we examine the present import program, we can see that it has in effect already established a very considerable degree of Federal control over the pricing of crude petroleum. Certainly the upper limits are to some extent pegged as a result of the statement by the President when the program was announced, and ipso facto if the program does not succeed in reasonably maintaining the crude oil price level, then it will have failed to protect the domestic industry and will have to be replaced. If therefore the Federal Government can impose a degree of price control on the crude oil industry under one program, it can hardly complain if there is a degree of price control resulting from an alternative program. In fact, however, there is no certainty at all that an agreement between the oil-producing States on common principles of assessing maximum economic recovery rates of wells would have this rigid effect. The case would only arise if every one of the oil-producing States simultaneously each month, having fixed their maximum economic recovery rates according to common principles, then proceeded to put their heads together and determine domestic demand for the forthcoming month and simultaneously announce the same allowable for all their wells. This would be a very direct system of prorationing against domestic demand and would clearly have a controlling and stabilizing effect upon the price structure of the crude oil industry and any movements in prices would directly result from the common decision as to whether to produce more or less oil. However my proposed program would not involve such closely concerted action. It would definitely require the adoption of common principles in determining the maximum economic recovery rate of oil wells which could qualify for the purpose of obtaining import quotas by being shut in, but it would not necessarily require that each State conservation commission came up with the same permissible allowables every month. What would be necessary in the interests of equity between producers in the various States would be that over the longer term period the allowables in the various States should be equated so that no State and its producers was benefiting at the expense of the others. This could assuredly be accomplished by requiring any State which had produced its wells excessively pro rata to the other States during the period of say 5 months to compulsorily cut back an appropriate amount in the sixth month in order that over the total period of 6 months each State should be upon an equal footing. I feel that even under the present law that such an operation would not necessarily incur the displeasure of the Department of Justice, but of course in order to put it into effect it is almost certain that further Federal legislation would be required quite probably in the form of strengthening the powers of the Interstate Oil Compact Commission to act as a moderator or referee in determining the compliance of the various States with the principles of determining maximum economic recovery rates and also in keeping their allowables on a comparable level over the longer period of time.

If this major hurdle can be overcome then there seems to be no insuperable objection to such a program on other grounds. Indeed, the adoption of common principles in relation to the determination of maximum economic recovery rates and a periodic equalization of allowables among the various oil-producing States is currently highly desirable, in order to correct the position whereby certain States which have no control over production whatsoever, such as Kentucky, or no control over prorationing in relation to demand, such as California, are able to take undue advantage of the markets available to them solely because other States are deliberating restraining their production. In addition there is from time to time a good deal of criticism in the industry, and between the various States, as to the prorationing decisions made by the various State conservation authorities, it being claimed from time to time that Texas and Oklahoma frequently are forced to carry too much of the burden of cutting back their allowables in order to keep national supply and demand in balance whereas other States adopt more liberal allowable patterns thereby permitting their domestic producers to operate on a more economically favorable basis which would not be possible if Texas and Oklahoma were not carrying an undue share of the burden. A further essential effect of my proposed program therefore would be to establish a substantial motive for those States who do not have any control over production or prorationing to enact such legislation forthwith in order to qualify for participation in the imports quota program, and at the same time eliminate any friction and jealousy between the various oil-producing States which may currently exist as a result of differential prorationing decisions by the various conservation authorities. These might take place from month to month but the State which benefited over the short period would have to cut back appropriately in greater degree over the long period. This can hardly be considered as undesirable.

From the financial point of view there are several objections which immediately spring to mind but I confidently believe that they are all fully answerable. The first one is the question of the position of the royalty owner whose production may be shut in in order to qualify for import quotas. The answer to this is that under existing law no royalty owner can be shut in for such a purpose without his consent. Therefore a royalty owner would have the right to veto, and to win his consent a producer who desired to shut in capacity would have to give him suitable financial remuneration or compensation. If we consider that the average price of crude oil today is something under $3 per barrel and the general average royalty is 12.5 percent one can see that the average royalty owner is probably receiving somewhere in the region of 37.5 cents per barrel of oil produced from his property. We know that the companies which produce oil overseas are making profits on the production and transportation of that oil to the United Staes, profis of the order of $1.80 to $2 per barrel, and even at the present time in order to obtain import quotas they are prepared to indulge in crude oil trade-outs which confer upon the holders of the quotas economic advantages of the order of 80 cents to $1.20 per barrel according to the particular bargain concerned. Knowing this to be the case, it is perfectly obvious that a determined importer who controls production of his own in the United States and desires to shut it in in order to increase his right to import more oil can very well afford to pay the royalty owner some 37.5 cents per barrel or whatever the royalty owner required within that general range to compensate him for his loss of revenue although of course the royalty owner would have his oil still in the ground yet to be produced at some date in the future.

In similar situation to the royalty owner would be the States governments who are dependent upon oil production for some proportion of their State revenues. In the State of Texas production taxes approximate some 13 cents per barrel of oil produced. There appears to be no legal objection on grounds constitutionality toward the imposition of a tax on allowables granted by a State conservation authority but not taken by the producer. If this is true then there is no reason to fear that State revenues would suffer. All that is necessary would be State legislation permitting the taxing of allowables as distinguished from production. Thus for a cost of some 50 cents per barrel any domestic producer who had capacity which he wished to shut in would be able to obtain appropriate quotas. Domestic producers who did not wish to import crude oil would be able to go about their business but they would be in a very much better position than they are today because domestic production through the system of allowables would be directly equated to domestic demand, and whereas imports today are currently taking some 17, or 18 percent of the domestic market, imports under this proposed program would only take that part of the domestic market which had been deliberately vacated by shut-in allowable capacity. Therefore domestic producers would be starting from a very much stronger vantage point under this program than they are at today. Inevitably of course some of the oversea producers would wish to increase their imports beyond the extent of the producing capacity which they owned themselves and were in a position to shut in. They would be able to do so by purely commercial arrangements with domestic producers and economic calculations indicate that such arrangements would be perfectly feasible. We have seen that it would require some 50 cents per barrel in payments to satisfy the royalty owners and the State's revenues for loss of income resulting from shut-in capacity. The profits made by domestic producers can vary according to the basis of calculation and the costs that have been incurred in discovering and developing and lifting the oil. However, there is no doubt at all that a great range of producers make profits in the order of 50 to 70 cents per barrel and there is also no doubt that oversea producers with their much higher profits could afford to pay domestic producers compensation of the order of 50 to 70 or even 80 cents per barrel if they would agree to shut in their production. The advantage to the domestic producer resulting from an agreement of this sort would be that in return for his agreement to shut in his production he would obtain a payment from the importing company, equal, or approximately equal, to the profit that he would have made by producing the shut-in capacity. This would keep up his income flow without at the same time depleting his capital; namely, the oil left in the underground reservoirs. This oil in form of proved reserves underground would be a definite capital asset against which he would if he so wished be in a position to borrow money to finance the exploration for oil elsewhere in the United States. A further advantage too would be that he would know that any oil discovered as a result of further wildcatting could immediately be produced and find its appropriate share of the American domestic market through the system of direct proration to market demand, or alternatively it too could in turn qualify to be shut in and thereby added to the "oil bank" and be replaced in the supply picture by imported oil.

From the point of view of the oversea producer desirous of increasing his markets in the United States, this program would have certain very definite advantages over the present situation. It is true that insofar as he may be entitled through his affiliates, or because of his historical position to obtain import quotas on his own behalf, the oversea producer under the present program is receiving a considerable windfall on that proportion of his oversea production that he is allowed to bring into the United States. Nevertheless if he wishes to add to his quota he must apparently go out into the market and make expensive trade-outs with quota owners who do not themselves wish or need to use the quotas. In addition he is now thoroughly restrained by the existence of the quota system from participating in the domestic market in excess of the level of imports fixed by the administrator of the program in accordance with the objectives that have been laid down; namely, that imports must not be allowed to arise above the level that will imperil the health of the domestic industry in the interests of national security. This level is currently fixed around 17 percent of domestic consumption to be supplied by imports, it may vary a little from time to time but there is little doubt that it would never be permitted to rise above 20 percent of domestic consumption. However, under a program which equated imports to shut-in capacity there would be no need whatsoever to fix an upper limit on the amount of oil that could be brought into the United States. This could quite safely be permitted to rise to 60 or 70 percent of American domestic consumption without imperiling national security in any way. This therefore gives the oversea producers with vast reserves of oil which can be cheaply produced the opportunity to increase their imports into the United States during the coming years by some 350 or possibly 400 percent. In view of the fact that their concessions all have a relatively limited period of life that there is little doubt that political conditions in the countries in which they produce oil are steadily deteriorating and that the demands of the producing countries are always being raised for further participation in profits and royalties, there should be a very powerful incentive from the point of view of the importing companies to adopt a program which should permit them without imperiling the security of America to develop and utilize their oversea reserves to this great extent. No other type of program could possibly have the same results.

The advantage to America should be perfectly clear. It would mean that high-cost American production and limited American reserves could be conserved for the future or against any new international crisis, in a state of immediate preparedness and readiness to meet sudden needs. In the meantime cheap foreign production could be utilized for the purpose of supplying a substantial part of American energy needs which oil currently occupies. An increasing proportion of American petroleum would be retained in the ground for the future when its value may be vastly enhanced not as a source of energy but as a basis for the petrochemical industry. This imports plan may seem a little too good to be true. People will be inclined to ask wherein lies the snag. Apart from the administrative and legal difficulties inherent in initiating such a program and which I have already discussed, there is no snag. The program in effect sets up an oil bank but does so without requiring Federal Government subsidy. In the case of the soil bank, subsidies are paid to the farmer to put his land into a state of reserve. In the case of the oil producer, payments would be made to preserve his oil in the ground in a state of readiness, but these payments would not be made by the Federal Government; they would be made by the oversea producers who control vast reserves of cheap oil and are desirous to find increasing marketing possibilities for them in the United States. If they were allowed to do so without any let or hindrance at all, the natural result would be that they would wreck the domestic petroleum industry and in consequence leave the Nation in a state of potential peril, but by gearing their import program to shut-in capacity on a barrel-for-barrel basis they would automatically provide the subsidy to the domestic industry whether it be their own company affiliates or independent producers and thus truly insure a healthy domestic industry and fully satisfy not only the needs of national security but the establishment of a petroleum reserve adequate to meet the sudden demands of the western nations in the event of further trouble in the Middle East or in Venezuela resulting from international hostilities.

The above program of course relates solely to crude oil. The principle of gearing imports to shut-in capacity could also be extended to cover the importation of petroleum products. All that would be required would be two certificates instead of one. In order to obtain an import quota for crude oil, one would have to have a certificate from a conservation authority stating that they had granted allowables on certain properties and that these allowables had not been produced. In order to import products, one would have to produce a certificate indicating that one had deliberataely shut in an appropriate quantity of crude oil and that in addition one had at the same time shut down an appropriate amount of refinery capacity which could be quickly reactivated in time of national emergency. Provided that theses two conditions were met by importers, no level of imports could really imperil national security. Once the framework for such an import program were to be established the actual level of imports would be determined purely as a result of commercial bargaining among the various sectors of the petroleum industry concerned and from then on this would be purely an industry matter and there would be no need for any close and continuing regulation by any governmental agency. The above is necessarily only an outline of the main principles involved in an import program based on the concept of shut-in capacity. Undoubtedly there would be many points of detail to be worked out but I believe the advantages are so obvious for all concerned that there are no inherent difficulties which could not be overcome.

AUGUST 7, 1959.

APPENDIX 4

SOME SPECIFIC SUGGESTIONS IN THE EVENT THAT THE SUBCOMMITTEE ON AUTOMATION AND ENERGY RESOURCES SHOULD CONSIDER FURTHER INVESTIGATION OF THE INTERNATIONAL ASPECTS OF AMERICAN ENERGY POLICIES

1. Consideration of the American foreign aid programs with special regard to energy. If the energy base has not been assured, true development cannot take place and vast sums may have been and may continue to be, largely wasted.
2. Consideration of the oil imports program with regard to the need for a program more specifically designed to conserve American reserves, meet the needs of national security, and to help the ailing domestic industry.
3. Investigation of the possible need for an international oil compact to regulate the production of the one form of energy which moves in great volume in international trade. Would this be desirable from the point of view of American policy and what would be the resultant pricing mechanism?
4. New regard to the operations of American oil companies operating overseas in the special context of the East-West economic conflict. Are they, through competitive pricing, supplying the cheap energy which they control in the Middle East oil reserves in adequate volume to the countries which need it or are they still artifically restricting output and maintaining higher prices than can be justified?
5. Is it good policy to have American companies operating overseas indulging in marketing practices which would be illegal in the United States? Are American economic ideas on fair competition and small business preservation for export along with foreign aid, or are they solely for home consumption?
6. Consideration of the whole subject of energy prices both at home and overseas. How prices are formed in the energy industries, nationally and internationally, and whether there is a need for a national energy policy and what would be the implications of such a policy on the sources of energy which move in international trade.

Representative PATMAN. Tomorrow we will have an analysis of the coal industry by Mr. George A. Lamb, manager, Consolidated Coal Co., "Coal Economics and Technology"; "Current Status and Prospects," by Mr. William Schroeder, Department of Chemical Engineering, University of Maryland; "The Commercial Exploitation of Lignite and Subbituminous Coals" by Mr. Veryl Hoover, general manager, Wyoming division, Pacific Power & Light Co., Casper, Wyo.; and "Coal and a National Fuels Policy," by Mr. Joseph E. Moody, president, National Coal Policy Conference, Inc.; president, Southern Coal Producers' Association; treasurer and member, board of directors, American Coal Shipping Association.

We will meet tomorrow morning at 10 o'clock.

We will stand in recess until that time. We will reconvene here in this room.

(Thereupon, at 12:30 p.m., a recess was taken until Thursday, October 15, 1959, at 10 a.m.)

ENERGY RESOURCES AND TECHNOLOGY

THURSDAY, OCTOBER 15, 1959

SUBCOMMITTEE ON AUTOMATION AND ENERGY RESOURCES
OF THE JOINT ECONOMIC COMMITTEE,
Washington, D.C.

The subcommittee met at 10 a.m., pursuant to recess, in room P-63, the Capitol, Hon. Wright Patman (chairman of the subcommittee and vice chairman of the committee) presiding.

Present: Representative Patman.

Representative PATMAN. The committee will please come to order.

We have as our first witness Mr. George A. Lamb, manager of business surveys, Consolidation Coal Co., Pittsburgh, Pa.

We are glad to have you, Mr. Lamb. You may proceed in your own way.

STATEMENT OF GEORGE A. LAMB, MANAGER, BUSINESS SURVEYS, CONSOLIDATION COAL CO., PITTSBURGH, PA.

Mr. LAMB. Mr. Chairman, it is an honor to appear before you and your committee regarding an important subject such as this. I appreciate the opportunity to present an analysis of the bituminous coal industry.

A. ENERGY CONSUMPTION IN THE FUTURE

It is estimated that American energy consumption will reach 78 quadrillion B.t.u. in 1980, equivalent to 3 billion tons of coal, or 88 percent above 1958. Forecasters agree generally that energy consumption will rise steadily in the future, advancing to huge proportions within 20 years, although they may differ as to volume levels. An increase in energy consumption of 88 percent between 1958 and 1980 falls on the low side compared to some other estimates.

A larger energy appetite follows with expansion of the economy. Population grows and per capita use of energy increases. Since the midtwenties, energy consumption has doubled while population grew at half that rate. Per capita consumption was up approximately 30 percent although marked advances were made in energy utilization. In the same period, industrial production expanded about three times.

Looking to 1980, population probably will be 260 million according to an estimate of the Bureau of the Census. It will be 50 percent above the 174 million of 1958, a rate of growth that occurred between 1925 and 1958. Per capita consumption has increased 1 percent annually and it will move to 11 tons in coal equivalent in 1980 from 9 tons in 1958. The projected population and per capita use data result in an energy consumpttion in 1980 that approximates the 78 quadrillion B.t.u. estimated.

Energy consumption moves with the Federal Reserve Board index on industrial production although at a somewhat lesser rate. The trend on this index rises 3 percent compounded annually and is expected to be at 300 (1947–49=100) by 1980. It would tend to support a 1980 energy consumption of 78 quadrillion B.t.u.

During the intervening periods to 1980, energy consumption is estimated at 52 quadrillion B.t.u. in 1965, at 60 quadrillion B.t.u. in 1970, and at 68 quadrillion B.t.u. in 1975. These estimates likewise are made with regard to changes in population, per capita use, and industrial production.

TABLE 1.—*Population industrial production and energy consumption in the United States—Actual and projected*

	Actual					Projected			
	1925	1935	1945	1955	1958	1965	1970	1975	1980
1. Population (millions)	116	127	140	165	174	196	214	235	260
2. Federal Reserve Board Index of Industrial Production (1947–49=100)	49	47	107	139	134	190	220	260	300
3a. Total energy consumption: (1) Quadrillion B.t.u.'s.[1]	20.9	19.1	31.5	40.0	41.5	52.0	60.0	68.0	78.0
3b. Bituminous coal:[2]									
(1) Quadrillion B.t.u.'s	13.1	9.3	14.7	11.1	9.6	11.8	13.7	15.7	18.3
(2) Percent of total	63	49	47	28	23	23	23	23	24
3c. Anthracite coal:									
(1) Quadrillion B.t.u.'s	1.6	1.3	1.3	0.6	0.5	0.4	0.3	0.3	0.2
(2) Percent of total	8	7	4	2	1	1	1	(*)	(*)
3d. Total coal energy:									
(1) Quadrillion B.t.u.'s	14.7	10.6	16.0	11.7	10.1	12.1	14.0	16.0	18.5
(2) Percent of total	71	56	51	29	24	23	23	24	24
3e. Oil and gas energy:									
(1) Quadrillion B.t.u.'s	5.5	7.6	14.1	26.8	29.7	38.3	43.5	48.8	54.4
(2) Percent of total	26	40	45	67	72	74	73	72	70
3f. Hydro energy:									
(1) Quadrillion B.t.u.'s	0.7	0.8	1.5	1.5	1.7	1.7	1.8	1.9	2.0
(2) Percent of total	3	4	5	4	4	3	3	3	3
3g. Nuclear power energy:									
(1) Quadrillion B.t.u.'s	-----	-----	-----	-----	(*)	(*)	0.7	1.3	3.1
(2) Percent of total	-----	-----	-----	-----	(*)	(*)	1	2	4

[1] Increments may not add due to rounding.
[2] Includes a small amount of lignite.
* Less than 1.0.

SOURCES OF HISTORICAL DATA

Line 1: "Current Population Reports, Population Estimates," Bureau of the Census, U.S. Department of Commerce. Also shows population projections in Series P–25, No. 187, Series II.
Line 2: Federal Reserve Board.
Lines 3a–3f: Bureau of Mines, U.S. Department of the Interior.

Most of the increase in energy demand by 1980 will fall upon oil and natural gas. Among the smaller components in energy supply, waterpower will add 25 percent to its capacity and anthracite's contribution will change little. Nuclear energy, which will make its appearance on a commercial basis will represent 4 percent of the energy load, more than hydro and anthracite together. These smaller components combined take care of 7 percent of the energy needs.

It is believed that bituminous coal's contribution will total 700 million tons in 1980; i.e., 24 percent of the total energy consumption, approximately the same proportion as in 1958. For comparative purposes, 1958, although the latest complete year on statistics, has to be used with caution because of its business recession that hit the coal market especially hard. Additional discussion of the bituminous coal forecast will follow.

This leaves 54.4 quadrillion B.t.u.—70 percent—of the energy consumption to be contributed by oil and natural gas together in 1980. It is a proportion slightly lower than oil and gas had in 1958, which is explained partly by coal's depressed market during that year. A division based upon 1958 would have oil supplying 32 quadrillion B.t.u. equivalent to 5.5 billion barrels of crude, and natural gas supplying 22.4 quadrillion B.t.u. or 22 trillion cubic feet. These volumes represent increases of 84 percent compared to 1958.

B. THE BITUMINOUS COAL OUTLOOK

Physically, coal can be the source for satisfying most all of the country's energy needs. The U.S. Geological Survey has estimated that the remaining recoverable reserves of coal amount to 950 billion tons, which would last over 300 years at the projected 1980 energy consumption of 3 billion tons in coal equivalent. The greater part of these reserves and nearly all of the coal marketed is of bituminous grade. Coal can be used in solid form for certain uses and it can be converted into oil and gas.

Commerically today, coal is not made into oil to compete with petroleum products refined from crude and it is used in a limited way for making gas. This situation may change in the future because of technological advances and other circumstances which would erase cost disadvantages in converting coal to oil and gas. In this forecast, coal's potential for providing oil and gas is not taken into account.

Coal can be substituted for oil and natural gas much more extensively than often thought. There are a number of industrial plants today burning oil or gas or both that have multiple burning equipment which permits them to shift to coal upon short notice. More important, however, is an indirect shift to coal which would take place over a period of time. In 1958, according to the Bureau of Mines, 500 million barrels of light oil was used for heating, cooking and various household purposes. A large part of the natural gas marketed was burned for similar uses. Coal generated electric power could be substituted effectively for these uses should oil and natural gas become short. A gradual shift of oil and gas customers to electric power for emergency reasons is not included in this coal forecast.

The forecast on bituminous coal is based upon an analysis of the present market pattern. The most important consumer group is the electric utility industry and bituminous coal's growth depends primarily upon the expansion of this industry.

TABLE 2.—*Bituminous coal consumption and exports, actual and projected*

[Millions of tons]

	Actual					Projected			
	1925	1935	1945	1955	1958	1965	1970	1975	1980
1. U.S. consumption:									
(a) Electric utilities	34	31	72	141	153	236	315	400	510
(b) Coke	75	51	95	107	77	110	117	123	130
(c) Railroads and space heating	234	161	249	69	39	25	20	15	10
(d) Other	156	114	143	106	98	80	70	60	50
(e) Total consumption	499	356	560	423	367	451	522	598	700
2. Exports:									
(f) Overseas	4	1	6	34	38	20	20	20	20
(g) Canada	13	9	22	17	12	10	10	10	10
(h) Total exports	17	10	28	51	50	30	30	30	30
3. Consumption and exports	516	356	588	474	417	481	552	628	730
4. Total production [1]	520	372	578	465	410	481	552	628	730

[1] Difference between consumption-exports and production is accounted for in stock changes and coal in transit.

Sources of historical data: Bureau of Mines, U.S. Department of the Interior.

Electric power generation has better than doubled in each decade. The indications are strong that power generation will at least double in each of the several decades ahead. Thus, with total power generation likely to be 700 billion kilowatt-hours in 1959 and 760 billion kilowatt-hours in 1960, a probable increase is to 1,450 billion kilowatt-hours in 1970 and 2,800 billion kilowatt-hours in 1980.

Presently, over 80 percent of the electric power is generated at steamplants. Waterpower as an energy for electric generation has been on a gradual decline. Two-thirds of the steam generation is fueled by coal and the rest by oil and gas. Eventually, nuclear energy will generate power for the utilities.

Utilities have featured steady improvements in operating efficiency. It required 1.3 pounds of coal on the average to produce a kilowatt-hour in 1948 but only 0.91 pounds in 1958. The amount of fuel per unit of output will continue to drop, probably reaching 0.60 pounds of coal per kilowatt-hour by 1980. This advancement in utility fuel utilization is included in the bituminous coal forecast.

Representative PATMAN. Will you elaborate just a little bit on that statement, that it required 1.3 pounds of coal on the average to produce a kilowatt-hour in 1948, but only 0.91 pounds in 1958? It is about 75 or 80 percent.

Mr. LAMB. That is correct; yes, sir.

Representative PATMAN. Excuse me. You may proceed.

Mr. LAMB. It is believed that bituminous coal will gradually enlarge its proportion in the fuel supply of the utilities. Currently, excess foreign oil is dumped into the utility market as is offpeak natural gas. In the more distant future, it is unlikely that gas will be burned under boilers where coal can be used effectively because of a growing demand for it for superior uses. This may not be true as to oil if it remains abundant in foreign lands and the country is willing to take a chance of depending upon foreign sources for a large proportion of its fuel supply. In the forecast, the utility use of oil and gas is nearly doubled between 1958 and 1980.

Nuclear energy has made its appearance in demonstration electric power units. Allowance has been made for its development in the forecast by figuring it will generate 80 billion kilowatt-hours in 1970 and 400 billion kilowatt-hours in 1980. Nuclear energy required in the 1980 estimate would be equivalent to 120 million tons of coal. This allowance for nuclear energy may be too large since this new fuel has cost barriers to hurdle before it becomes commercially established. It is entered to complete the forecast and its effect may be to make conservative the estimates on the conventional fuels. The estimate on electric utility generation and energy sources in 1980 compared with 1958 may be summarized as follows:

	1958	1980
Total generation (billion kilowatt-hours)	645	2,800
Hydrogeneration (billion kilowatt-hours)	140	200
Fuel generation (billion kilowatt-hours)	505	2,600
Total fuel use (million tons coal equivalent)	251	780
Nuclear (million tons coal equivalent)		120
Bituminous coal (million tons)	153	510
Oil and gas (million tons coal equivalent)	77	150

Bituminous coal is a raw material for making coke as well as for generating electric power. Most all of the coke produced is used by the steel industry. Not all coal will coke and some that does is not suitable for metallurgical purposes.

In recent years, the steel industry has made rapid strides in reducing the amount of coke needed in producing pig iron. In making a ton of pig iron, it took 1,704 pound of coke in 1957 but only 1,613 pounds in 1958. By 1980, it is estimated that only 1,200 pound of coke per ton of pig will be required on the average. The effect of this change in coke utilization is that the volume of metallurgical coal consumed, will change little although steel output may increase substantially in the future. In the forecast, the 1980 production of steel is 200 million tons but total metallurgical coal requirements are 130 million, only 22 million tons above metallurgical consumption in 1957 when steel production was 113 million tons.

Left among the consumer categories are railroads, space heating or retail, and "all other," the latter consisting largely of manufacturing industries. Their consumption of coal will decline. The railroads burned 129 million tons as late as 1945 but only 4 million tons in 1958 as the shift from steam to diesel locomotives was nearly completed. Space heating on retail sales dropped from 119 million to 34 million between the same years and will continue downward in the year ahead. The so-called other uses will burn less coal but this category will still take a sizable tonnage in 1980.

Total U.S. bituminous coal consumption in 1980, the product of the consumer categories, is 700 million tons, of which 510 million tons or 73 percent is in the requirements of the electric utilities. Consumption figures for the intervening periods are 451 million tons in 1965—522 million tons in 1970—598 million tons in 1975. In comparison, actual consumption was 367 million tons in 1958, and 414 million tons in 1957.

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The oversea export market for bituminous has had wide fluctuations since World War II, ranging from 1.5 million tons in 1950 to 58 million tons in 1957. It was 38 million tons in 1958 and probably will be 25 million tons this year. Over 80 percent of the oversea shipments move to Western Europe where coal consumption is declining because of inroads being made by oil and natural gas. Future oversea exports will be for special purpose coals and probably will have a maximum volume of 20 million tons annually, a level already approaching because of foreign restrictions. Export sales to Canada likewise are declining as that country develops its vast oil and gas resources. They dropped from 18 million tons in 1957 to 12 million tons in 1958, and likely will not exceed 10 million tons annually in the years ahead. Oversea and Canadian exports together, while totaling 30 million tons in 1965 and after, will be only a small component in the overall bituminous coal market. Their additions to the total consumption figures give the bituminous coal production levels in the forecast.

C. COAL'S CURRENT POSITION AS AN ENERGY SUPPLIER

The bituminous coal industry has largely liquidated that part of its market vulnerable to technological progress. Left is a market that consists principally of customers with increasing fuel demands for which coal is well suited. It would seem that the bituminous coal market, which started to shrink soon after World War II, had completed its decline and should be rebounding with steady growth in conformity with the rising trend in energy consumption. The market is not rebounding presently in relation to energy requirements, however, and as a consequence the bituminous coal industry is sagging. Energy forecasts indicate that this market condition cannot continue indefinitely but the longer it prevails the less chance the bituminous industry will have to supply additional tonnages efficiently when called upon.

Bituminous coal production was 631 million tons in 1947 and 600 million tons in 1948. Thereafter, a steady decline took place, reaching a low of 392 million tons in 1954, a depression year. Losses mainly in sales of railroad fuel and space heating coal, together with a slump in exports, had steadily reduced the bituminous market.

By 1955 it looked like bituminous coal had passed its market low and had growth ahead. Between 1955 and 1957 electric utility consumption advanced sharply and export volume increased to reach new peaks. Production was 501 million tons in 1956 and 493 million tons in 1957. The optimism proved to be unfounded because a good part of the market improvement was due to two factors appearing suddenly. One was that the extraordinary rise in utility generation and coal consumption was partly the result of the atomic power program completed in the period. The need for greater amounts of electric power in nuclear energy output was a particular occurrence separate from the trend in utility expansion. The second factor was the appearance of the Suez crisis in 1956, which threatened fuel supply in Western Europe. As a precaution, Western European countries imported extra tonnages of coal from America. Western Europe had an excess tonnage of coal in stocks following the opening of the Suez Canal, and, soon after, the decline in European coal consumption began. Related to the Suez situation was the temporary tight supply on oil which was reflected in the American fuel market, and to the advantage of coal in certain instances. Effects of the Suez disturbance in tightening fuel supply were dissipated by late 1957. If the atomic project and Suez crisis had been absent in the several years ending with 1957, bituminous coal's maximum output may have been less than 450 instead of 501 million tons, still a rebound although a modest one from its market decline.

The full impact of the 1958 business recession was accompanied by large excesses in world oil supply. These excesses included products of foreign refineries, of which residual or heavy fuel oil has been the more disrupting to the energy market. Nearly all of the residual oil imported moves to consumers along the eastern seabord States, known as district No. 1. In 1957, with prices above coal's prices by $2 to $4 per ton, a total of 289 million barrels was sold for industrial and bunker uses and the heating of large buildings. Sixty percent of this residual was imported. In 1958, with industrial fuel demand down because of the recession, foreign refineries, mainly in Venezuela and the Netherland Antilles, had excesses of residual which they decided to dump into district No. 1. Their most likely customers were the eastern utility plants that usually burn coal but which have multiple burning equipment that permits them to switch to residual, and sometimes to gas, upon short notice. Residual prices were cut between $1 and $1.50 per barrel, the coal equivalent of $4 to $6 per ton, to promote the dumping. Prices on all residual—domestic and foreign alike—were reduced as a result. In district No. 1 residual imports were increased between 1957 and 1958 from 172 to 180 million barrels despite the recession through the dumping activity, although total sales were advanced only 2 million barrels because some residual went to storage and domestic refineries lowering their output. A major reason sales were as high as they were was that residual was dumped into the utility market to displace coal. Residual imports amounted to 84 million barrels during the first quarter of 1959, 60 percent above the similar quarter in 1958. The quota on residual imports—related to 1957 shipments—became effective on April 1, but the receipts of foreign residual in 1959 will be a record because of the huge volume of this fuel imported during the first quarter.

Effects of the dumping of residual imports into the coal market are twofold: Coal loses tonnage and its price structure is weakened. The tonnage lost is not large compared to national figures—probably 5 million tons in the last year although increasing in the early part of 1959—but it concentrates in certain markets and upon particular coalfields. Moreover, the residual sellers tend to keep part or all of the extra business they get during the dump period. During the majority of years, prices on coal are lower than those on residual. In the dump periods, however, the tendency is for the relatively low residual prices to fragmentate the coal price structure. A customer on the east coast who is burning coal and is offered residual at dump prices will tell his coal supplier that he will not go all the way to residual if some concession is made on coal prices. A lowering of coal price to one customer means that all other coal customers expect similar treatment. The general reduction of 25 cents per ton on steam coal in the East last April 1, coming at a time of wage increases, indicates the far-reaching effect of the residual dump prices.

Natural gas likewise is dumped against coal in certain markets during the warmer or off-peak months. This was done to maintain the gas pipelines at full flow. Probably gas in the coal equivalent of 10 million tons is used under industrial boilers at dump rates. In other markets, underground storage has been developed to take care of excess gas in the offpeak periods. These markets, as a consequence, have better balanced rate schedules, a narrower differential between household and industrial rates.

Oil and gas can dump because they can recover price losses incurred by dump residual oil and offpeak gas sales through increased prices on other sales free from coal competition. A lower price on residual means a higher price on gasoline and additional oil products if the average of all oil prices is to be maintained. Similarly, the loss in revenue from dump gas can be offset by higher rates on domestic and other superior uses. Coal is at a disadvantage, however, because it is against its main product—steam coal—that oil and gas dump. Coal has no other product upon which to recoup losses if it lowers its steam coal price to meet dump quotations.

The dumping of foreign residual oil is an economic burden to the country. Price benefits to a comparative few are subsidized by higher prices paid by the public on other oil products. At the same time, this practice damages to coal industry and the railroad and other industries which are essential to the country's welfare and security. It may be noted here that the bituminous coal industry does not oppose residual oil imports as such. What it opposes is the excess in residual import volume pushed into the country to satisfy foreign interests that want to increase their sales beyond what the fuel market requires.

Bituminous coal does not argue about the many millions of tons of business it has lost to natural gas or to oil for heating and other household uses, or certain industrial uses, where those fuels have superior applications. It does feel it is wasteful, however, to extend the sales of oil and natural gas to uses where those fuels have no superiority over coal. Certainly, if the forecasts on the growth of energy requirements are even half correct, it will not be too many years ahead before it will be a problem for oil and gas to supply adequately superior uses if their wasteful practices continue.

Oil and gas dumping practices have had much to do with the sag in the bituminous coal industry. From a volume standpoint, the amount of coal business lost annually because of these practices does not appear large, probably 20 million tons presently. But it has been increasing with the threat of sharp growth in the future. These practices disrupt the coal price structure and, furthermore, tend to discourage the maintenance of mine capacity in relation to prospective needs. Coal is not in a position to hold itself on a standby basis while certain foreign oil as well as natural gas interests want to run at full or even at higher operating rates and at the same time clear up supply excesses for which they are responsible.

Another threat to the bituminous coal industry is the possibility of subsidized nuclear electric powerplants. The industry supports the development of nuclear energy for industrial purposes but it objects to the building of nuclear powerplants at public expense, especially when they are more costly to operate than coal plants privately financed. Nuclear powerplants will be established on a commercial basis eventually and will be needed. There is no need for the Government to build such plants because they will be privately financed once the use of nuclear energy is proved costwise.

Bituminous coal production was 410 million tons in 1958. In 1959, prior to the steel strike, production was running 6 percent higher than in 1958, although industrial production had soared to a record high. U.S. bituminous coal consumption had increased only 8 percent while exports declined. Bituminous coal was still losing ground as a supplier of energy.

D. THE IMMEDIATE PROBLEM

Bituminous coal's ability to survive under private enterprise as a strong and dynamic industry will be severely tested during the immediate years. It can, though perhaps under strain, operate effectively during the next 5 years if it realizes the modest market growth that it should get as indicated by energy forecasts. Unfortunately, this market growth is not in evidence because of the disruption in the fuel market caused by competitors.

Today, bituminous coal has a capacity of approximately 2 million tons daily, equivalent to between 450 and 500 million tons annually, depending upon the number of days worked. Coal, like oil and gas, is a depleting industry. Mines exhaust their coal reserves and they are replaced by new mines if capacity is to be maintained. With market conditions as they are, there is little if any incentive to replace capacity. The average mine has a life of about 30 years and the average life will be over 15 years because capacity has not been maintained in recent years. Probably one-fifth of the mining capacity should be replaced within the next 5 years.

Mining is highly mechanized and a new mine with modern equipment represents an outlay of $6 to $12 per ton of annual production. It means an investment of about $1 billion for building 100 million tons of new capacity. This is the kind of investment outlay the coal industry has to consider in capacity replacement. Market stability has to be established if such an investment is to be accumulated.

Bituminous coal has an outstanding record in mining operations, reflecting the emphasis by management and labor on greater and greater efficiency. Between 1948 and 1958, output per man-day at the mines increased from 6.3 to 11.3 tons, or 80 percent. This improved productivity has permitted little change in the labor cost per ton during the period although the basic day wage increased from $13.55 to $22.25. Price stability over an inflationary period has been the result. The average mine price was $4.99 in 1948 and $4.86 in 1958. Today, it is even lower though unduly depressed, reflecting the more recent dump practices connected with foreign residual oil.

Improvements likewise are showing in the transportation of coal. Railroads have put rates into effect related to volume of shipment. The long-distance movement of coal by pipeline has become a fact. Likewise, the long-distance transmission of electric power—sometimes called the movement of coal by wire—has proved economical. Sometimes it is cheaper to generate electricity near the mine and deliver it to distant markets than it is to generate within such markets and incur the fuel transportation cost.

Current figures are not available on the income of the bituminous coal industry, the last published by the Bureau of Internal Revenue being for 1956. In depression 1958, the industry had conditions similar to what it had in 1954 when it lost $700,000 after Federal taxes. Results are no better today probably than they were in 1958. Since the first of 1959, wages have been increased $2 daily while prices have declined generally, and it is doubtful if improved productivity at the best could do any more than keep the industry's return where it was last year.

The bituminous coal industry's return will be on the profit side with market improvement although the profit cannot be large with the small market growth in prospect. It will be able to show a profit under the conditions only because of its highly efficient mining operations. At the same time, to realize this market improvement, coal has to get free of the dump practices of its competitors. This will require recognition, particularly by the Government, of coal's place as a supplier of energy presently and over the long run. The Government has much to do with oil and gas markets and it controls atomic development. Its policies and decisions regarding those fuels cannot ignore coal if energy supply is to be fully considered.

In this regard, coal's importance as an energy supplier, particularly in terms of national security, received consideration in establishing the oil-import quota which became effective April 1 by order of President Eisenhower. Residual oil imports, which had increased substantially in 1958 and early 1959, were given a ceiling related to 1957 receipts which reduced their volume for the last 9 months of 1959. The full effects of the quota are not apparent yet because of the huge volume of foreign residual unloaded prior to April 1. Residual sellers continue to supply customers to whom they dumped before the quota became effective. In time, the operation of this quota may have the effect of holding residual imports in line with market needs which will prevent dumping.

The need for considering energy supply upon an integrated basis becomes clear in the case of natural gas. Pipeline companies moving this fuel interstate are regulated by the Federal Power Commission under a specific body of law. This regulation has no guides or standards by which to consider natural gas in relation to total energy supply. It can be administered expertly as to legal requirements and, at the same time, run counter to the supply developments necessary to assure an adequate energy supply in total. Gas dumping would diminish as a problem with a national fuel policy in effect.

E. SECURITY CONSIDERATION

Energy requirements increased 50 percent during World War II, and a similar rise could occur in the event of another world conflict. Furthermore, the difficulties in energy supply might be even greater in a next war should it be of several years' duration.

The start of such a war would cause rapid expansion in butuminous coal consumption: Steel and electric utilities would immediately reach peak operations and other coal users would want more tonnage. Bituminous coal consumption would hit a rate of 500 million tons annually a few months after the start of the war, a rate that would have a steady rise in the war years to follow.

Aside from its regular customers, coal would be called upon to supply tonnage where other fuels are short. In the last World War, coal was utilized to supplement oil supplies as well as to service new plants that could get neither oil nor natural gas. Presently, the use of coal as a direct substitute for oil and gas has limitations. It is confined primarily to industrial plants with multiple burning equipment or others that might readily install coal furnaces. However, the use of coal for new plants, or for generating electric power to be used to supplement other fuels, could increase tonnage substantially. An annual demand of 600 million tons for bituminous coal might well develop before the end of the war.

Because of these security considerations, the bituminous coal industry should have a capacity much larger than it has today. It should have a mining structure that would provide adequate tonnage in times of emergency. A wartime capacity of 600 million tons annually would be assured if the coal industry had a peacetime market of 500 million tons. According to the energy forecasts, bituminous coal probably will not have a 500 million ton market until after 1965. Today, its wartime capacity approximates 500 million tons and it is tending to shrink as its market appears insecure. Once the gradual market growth, as indicated by the forecasts is established, improvements in mining capacity will follow. As it is, coal mining capacity appears inadequate in terms of wartime requirements. Related is the coal carrying capacity of the railroads, which has been declining with the coal market. It is not large enough to handle coal shipments during a 600 million ton year and it likewise needs a growing coal market to enlarge its carrying potential for emergency purposes.

Representative PATMAN. Thank you, Mr. Lamb.

Mr. Widnall, would you like to ask the witness any questions?

Representative WIDNALL. No, Mr. Chairman.

Representative PATMAN. Thank you very much.

The next witness is Mr. William C. Schroeder. Mr. Schroeder is with the Department of Chemical Engineering, University of Maryland, and formerly Assistant Director of the Bureau of Mines and Chief of the Office of Synthetic Liquid Fuels.

STATEMENT OF W. C. SCHROEDER, PROFESSOR OF CHEMICAL ENGINEERING, UNIVERSITY OF MARYLAND

Mr. SCHROEDER. With your permission, Mr. Chairman, I will read my statement.

Representative PATMAN. That will be satisfactory.

Mr. SCHROEDER. In the earth's crust carbon is not a common element. It has been estimated that the carbon content does not exceed one-tenth of 1 percent. If this were uniformly distributed, industrial civilization as we know it today, with its dependence on concentrated forms of energy, would be impossible.

Unlike many minerals, carbon has accumulated in the form of coal, gas, and oil in some areas in concentrated forms. These accumulations are not distributed uniformly, and a struggle goes on constantly for control of the areas rich in potential fuels.

The known world resources of coal, lignite, and peat are accumulated in five great areas as follows:

Probable world reserves in seams at least 1.2 feet thick, to a depth of about 4,000 feet

Parts of world	Coal		Lignite		Peat	
	Trillions of tons	Percent	Trillions of tons	Percent	Trillions of tons	Percent
Western Europe	450	9	70	5	10	8
Eastern Europe (Russia excluded)	100	2	15	1	30	25
U.S.S.R.	1,000	20	200	16	70	59
Asia (U.S.S.R. excluded)	1,100	22				
North America	2,100	43	950	74	10	8
Rest of world	200	4	50	4		
Total	4,950		1,285		120	

Data from Coal Science by vanKrevelen and Schuyer.

These reserves are in seams down to about 1.2 feet thick and 4,000 feet underground. Under present-day conditions in the United States seams less than 30 inches thick and deeper than 1,500 feet are not being mined. This is not true in the rest of the world, however. In Europe 2-foot seams are now mined at greater depth. As time goes on and mining methods improve more and more of these reserves will become economically accessible.

Not all of the coal is recovered in the mining process. In underground mining recovery is usually in the order of 50–60 percent. In strip mining recovery can be in the order of 90 percent and above where conditions are favorable. Even allowing for losses, however, it is apparent that these reserves are much greater than the known or potential reserves of liquid or gaseous fuels, and in fact are probably in the range of 20 to 30 times the other fuels.

World production of coal and lignite in 1950 was estimated as follows:

[Expressed in millions of tons]

Parts of world	Coal	Lignite
North America	590	6
Western Europe	500	300 (Western and Eastern Europe combined)
Eastern Europe	91	
U.S.S.R.	270	
Asia (Far East)	140	
Rest of world	45	19
Total for world	1,636	325

From these estimates it is apparent that the production of coal and lignite even in the highly industrialized countries is small compared to the available reserves. Even with allowance for growing populations and vastly increased uses, coal reserves should last for generations, and very probably for centuries.

North America is especially well endowed with coal and lignite, the known reserves amounting to about 3,000 trillion tons. This is considerably more than any other country in the world, but these reserves may in part represent the results of more concentrated exploratory work.

For the next 50 or 100 years the magnitude of the total U.S. reserves is of less significance than the size of the minable reserves. In 1950 the U.S. Geological Survey estimated the recoverable reserves (assuming 50 percent recovery) in the United States as follows:

Rank of coal:	*Trillions of tons*
Bituminous coal	616
Subbituminous coal	234
Lignite	356
Anthracite and semianthracite	7
Total	1,213

The minimum thickness of coal considered in this estimate was 14 inches for bituminous coal and anthracite and 2½ feet for subbituminous coal and lignite. Maximum overburden was 2,000 feet. It was concluded that the recoverable reserves of coal in the United States exceed 1,600 times present annual production.

In spite of these very large reserves, coal production in the United States, and in fact in most of the world, is not expanding. In this country production rose steadily until about the middle of the 1920's and then fell during the depression years. During and shortly after World War II production hit a peak of slightly over 600 million tons per year. Since that time production has fallen and for 1958 it amounted to 405 million tons. Production is expected to be greater during 1959, but this depends on how long the steel strike lasts.

This loss of markets has sometimes been ascribed to increased cost to the consumer. Where such increases have occurred they result largely from increased transportation and handling costs, not from increased mining costs. The coal industry has done a remarkable job of holding mining costs nearly constant in face of rising labor and material costs. This is shown in figure 1 indicating that the selling price for a million B.t.u.'s at the mine is now only slightly higher than the 1948–53 average. The values shown in figure 1 are averages for all bituminous coal and lignite. In many of the more efficient mines the selling price is well below this average.

The coal industry has had no special immunity from increasing costs of materials, supplies, and labor. The means by which mine selling price has been held nearly steady for over 10 years in the face of rising costs in almost every other field is increased productivity. This is shown in figure 2, indicating that the output in net tons of coal per man-day has about doubled in the 10 years between 1945 and 1957.

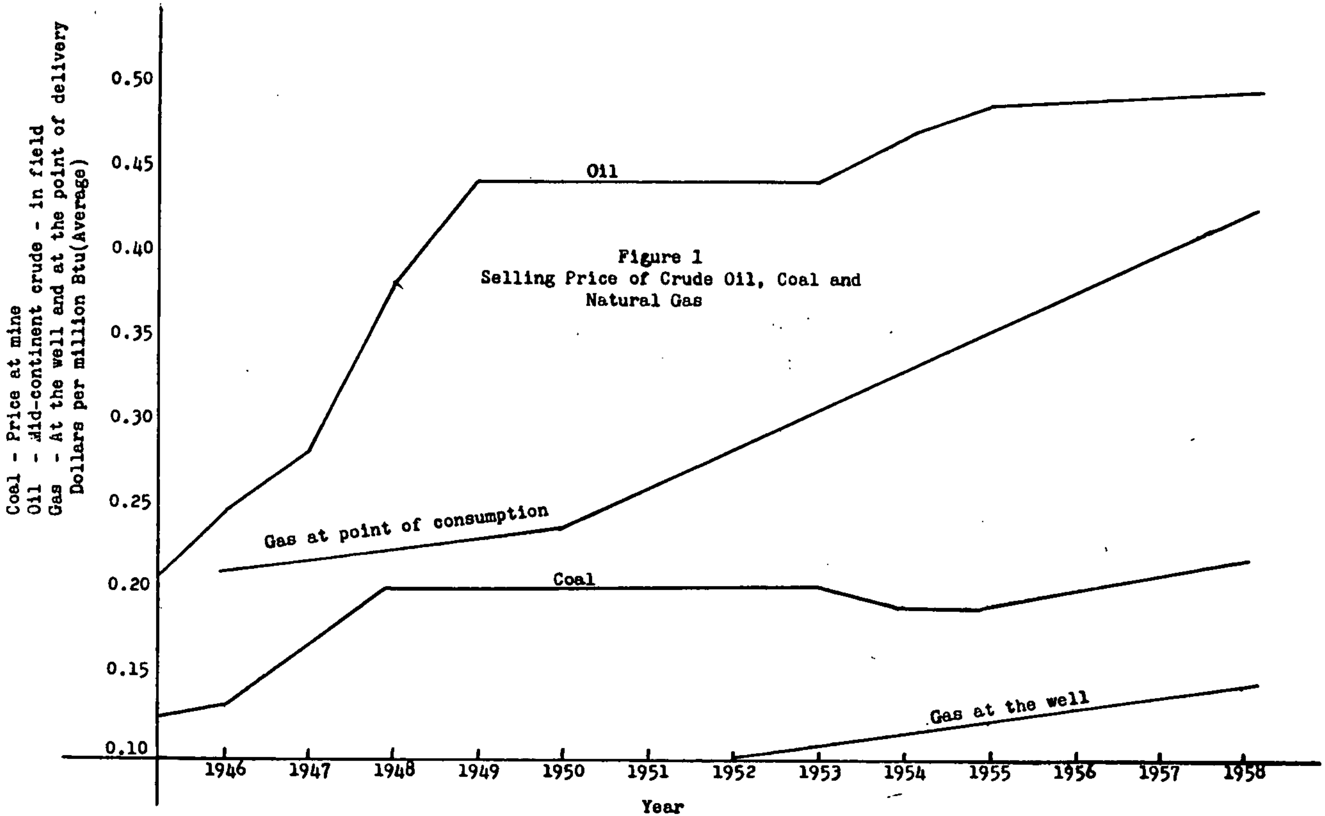

Figure 1
Selling Price of Crude Oil, Coal and Natural Gas

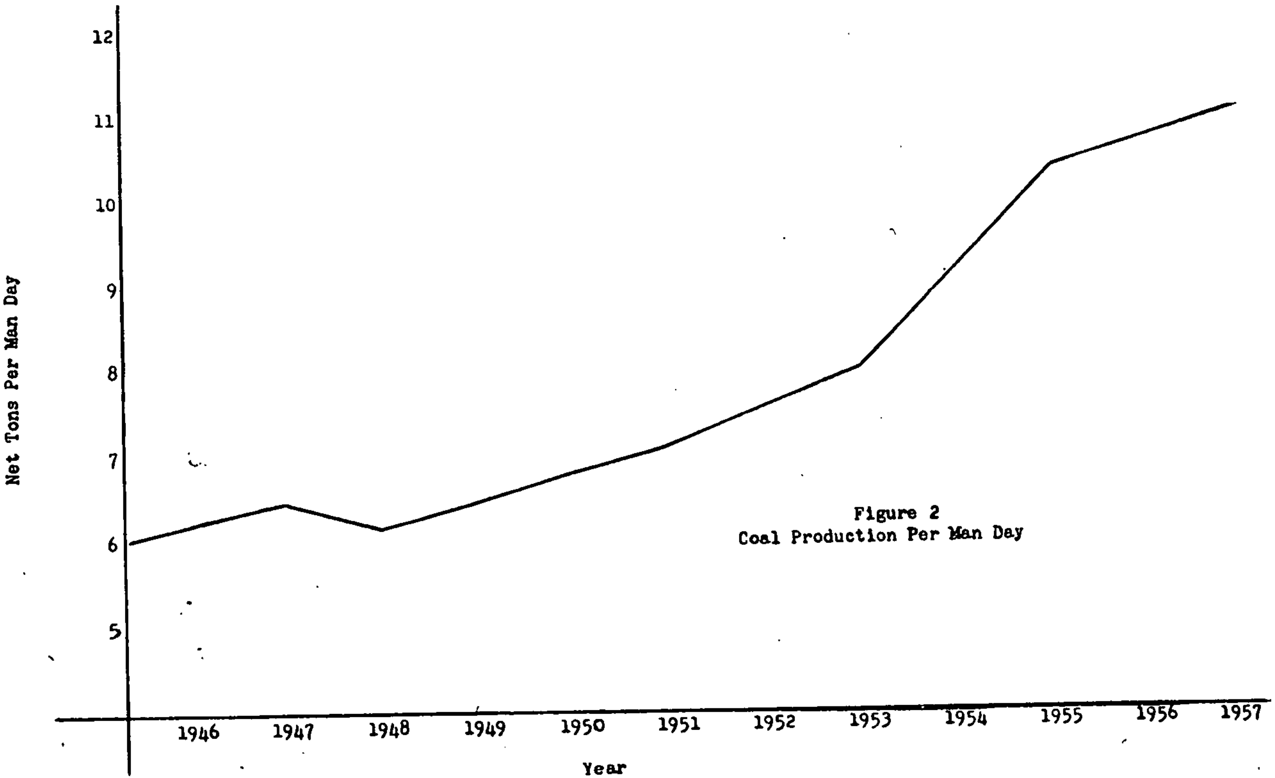

Figure 2
Coal Production Per Man Day

The past 5 years has seen the introduction of continuous mining equipment in many underground mines. There have also been important developments in loading and conveying equipment. For open-pit mining extremely large and efficient earth- and coal-moving equipment has been developed which has achieved outputs per man-day very much in excess of even these high average figures.

In addition to this spectacular development in mining machinery there has been a steady improvement in every detail of the mining and handling operations brought on by the cooperation of labor and management. These factors have been very important in helping to maintain a low-cost product.

These developments indicate a progressive and vigorous attitude on the part of the coal industry.

Referring again to figure 1, it is seen that coal's position with respect to selling price on a heating value basis has greatly improved with respect to crude oil. The price of crude oil has increased about 2½ times over the past 14 or 15 years, while coal has increased much less.

The price of natural gas is also shown on figure 1. Gas at the well is very cheap compared even to coal. At the point of consumption, however, it is between oil and coal. It is also seen that since 1950 delivered gas has risen sharply in price and is now approaching oil.

In spite of this favorable price situation, coal has not expanded its markets. Oil and gas, on the other hand, are being consumed in increasing quantities in the face of price increases. These latter fuels have taken over almost entire markets, which formerly used coal. Some of these are the railroads, ships, and domestic heating. One market in which coal is doing well is in the generation of electric power. Here the use of coal is increasing steadily.

From this history it is clear that the factors of easy and convenient use often weigh more heavily with some of the ultimate consumers than questions of price.

GASEOUS FUELS FROM COAL

A wide variety of processes are available for the production of liquid and gaseous fuels from coal. Some of these processes have had extensive use and some are still in use abroad, although most of them have died out in the United States.

The manufacture of city gas from coal or coke, using coke ovens and water gas generators, was common practice in the United States until the 1930's. About that time the long-distance transmission lines began to bring natural gas from the Southwest to all parts of the United States and this has driven manufactured gas from the market in practically all areas. Gas manufactured in coke ovens and water gas machines cannot compete with natural gas, and this would be true even if coal were available at the point of use for $2 or $3 per ton. In addition, manufactured gas has only about one-half the heating value on a cubic foot basis, which makes it much less satisfactory for transmission and distribution purposes.

In England and Europe a good deal of manufactured gas is still used. In Germany a new gas manufacturing process has been developed during the past 15 years, called the Lurgi process, which uses noncoking and relatively cheap coals to produce a gas of about 400 or 500 B.t.u per cubic foot. These machines are being used to produce pipeline gas.

The Lurgi machines could be used in the United States, and processes are available to increase the heating value of the gas to about 800 or 900 B.t.u. per cubic foot. Extensive calculations have indicated, however, that gas manufactured by these processes, even from relatively low cost coal, would be in the range of $0.75 to $1 per 1,000 cubic feet. This could not compete with natural gas which is available at the pipeline to most cities at less than $0.50 per 1,000 cubic feet.

Since the end of World War II a new process has developed for the use of residual oil from refineries to manufacture city gas. At the present time this method is being applied in England for the production of city gas, and it appears that it will be economically successful. However, gas in England is worth two or three times as much on a heating value basis as it is in the United States. I do not believe that this process would be economically successful in this country in competition with natural gas.

The shortage of indigenous supplies of gas in England and Europe has led to many proposals for bringing natural gas to these countries. A great deal of surplus gas is available in some of the oil producing areas, such as the Middle East, the Caribbean, and South America. A gas pipeline has been proposed from the Middle East to Europe. Problems created by national and political differences make this difficult to realize.

Another and perhaps more practical method, under present-day conditions, is to bring in the gas by ship. To do this the natural gas must be liquefied at very low temperature, and kept in the ship as a liquid during the voyage. The storage space must, of course, be well insulated to make this possible. Such a ship has been built and has made several voyages from the United States to England carrying liquid methane. The ship is unloaded and the gas is fed into storage and then into pipelines. This development can make natural gas available to much of Europe at economical prices, as well as provide a use for gas now going to waste in some oil fields.

So far as coal is concerned, these developments have all tended to close the gas markets to this industry.

Serious effort has been made for many years and the work is continuing vigorously on the part of the gas and coal industries and the Government to develop new economical processes for making gas from coal. There are two major reasons for this: (1) the demand and new markets for gas are growing strongly and (2) coal supplies are often available near centers of population, which would avoid long distance pipeline transmission.

So far these efforts have not been successful. The reason is that a very large amount of hydrogen must be added to coal to convert it to gas, and hydrogen is an expensive material to produce. It must also be remembered that on a pound basis gas sells for very much less in the United States than most liquid fuels. In effect, this means that in making gas, expensive hydrogen is being converted to our lowest value fuel. Perhaps a better approach to this problem would be a plant producing both liquid and gaseous fuel from coal.

LIQUID FUEL FROM COAL

At the present time in the United States, coal sells from about 0.1 to 0.3 cents per pound. Gasoline and oils are worth from about 1 to 1.5 cents per pound. This offers a strong economic incentive to convert the coal to liquid products.

Extensive work in this direction has been carried on during all of the present century. The effort was particularly strong in Germany since this nation has relatively little oil, but good supplies of coal. By 1913 the Bergius coal hydrogen process had been developed and commercial application was being started.

The technical approach to the conversion of coal to oil is relatively simple. Aside from carbon and some extraneous material, coal contains from 5 to 20 percent oxygen and 4 to 7 percent hydrogen. Oil on the other hand is essentially a combination of carbon and hydrogen. By treating the coal with hydrogen the oxygen could be removed as water and the hydrogen content of the molecule increased, which should and does produce liquid from the coal. The yields of oil secured from this process are excellent. Operating conditions are severe, however, and demand temperatures around 950° F. with pressures in the range of 8,000 to 10,000 pounds per square inch.

To make these plants reasonably economic they had to be very large and the capital cost was formidable.

Between 1913 and 1940 in spite of these costs Germany went ahead with the development of the coal hydrogenation industry and during World War II about a dozen large plants were in operation. Most of the aviation gasoline for the Luftwaffe came from these plants. In addition, they furnished considerable amounts of valuable aromatic chemicals.

On the basis of German experience a coal hydrogenation plant was built in England between 1932 and 1936. This plant operated successfully and during World War II was used to hydrogenate tar to make aviation gasoline.

Only one commercial coal hydrogenation plant was ever built in this country. This was a relatively small plant at Charleston, W. Va., to produce aromatic chemicals of various kinds. It is understood that this plant is not now in operation.

After World War II the Bureau of Mines conducted an extensive investigation of the coal hydrogenation process and in particular estimated both the capital and operating costs for coal hydrogenation plants under conditions in the United States. Most of this work was done in the early 1950's and it was concluded that the capital cost was in the range of $12,000 to $15,000 per daily barrel of productive capacity. This is a very heavy capital burden to carry in comparison with petroleum, which has probably about half this capital cost. As a result a coal hydrogenation plant could be viewed as economically feasible only if a considerable portion of the product was high value chemicals.

Extensive improvements were made in the details of the coal hydrogenation process after World War II, but the main features of the plants were essentially those of the earlier process. In particular the necessary pressures were over 8,000 pounds per square inch, the coal was exposed to the action of hydrogen for a half hour or longer, the introduction of the coal into the pressure system was a complicated step, and the hydrogenation itself was carried out in two steps rather than a single operation.

Work since that time, carried out by the chemical and gas industries, has greatly altered many of these concepts. Pressures have been reduced to about one-fourth those previously necessary, retention time for the coal is now less than a minute, and the introduction of the coal has been simplified. It is believed that the capital cost of the plant will be about one-half of previous estimates.

It is too early to say that coal can now be used economically to make gasoline and oil and gas. Under special circumstances with low-cost coal this may be possible. However, what happens in this respect will depend to a considerable degree on the course of oil prices in the United States.

COST OF OIL IN THE UNITED STATES AND ABROAD

The increased cost of finding and producing petroleum in the United States has been apparent for a considerable number of years. Physical indications of higher costs are the increase in dry holes, increase in average well depth, and a decrease in the discovery of oilfields with an ultimate production of over 1 million barrels.

In 1956 the Chase Manhattan Bank[1] presented data on financial requirements for the petroleum industry which made it possible to estimate the average cost of future productive capacity.[2] This estimate, which included exploration and production, transportation and refining, and distribution was as follows:

Estimated average capital cost for new and replacement production in the United States per daily barrel

[In terms of 1955 dollars]

Years:	
1950–55	$6,000
1955–60	7,500
1960–65	9,000

From these estimates it would appear that a modern coal hydrogenation plant could now be built at about the same capital cost as for new petroleum productive capacity in the United States. Whether or not the plant could compete on the basis of operating costs has not yet been determined.

There is, however, still another factor that appears in this question of capital costs, and that is effect of imported oil. In 1955 the free foreign world was producing about 6,800,000 barrels of oil per day from reserves estimated at 148 billion barrels. Estimates indicated that the capital requirements per barrel of capacity per day were about $3,000, or roughly half the outlay required in the United States. Exploration and production costs amounted to only 35 percent of the total compared to 70 percent in the United States. Even more important, however, over the 10-year period to 1965 these capital costs were expected to increase only very slowly, reaching about $4,000 per barrel per day by 1965.

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[1] "Future Growth and Financial Requirements of the World Petroleum Industry," the Chase Manhattan Bank (presented at Feb. 21, 1956, meeting of the A.I.M.M.E.), Joseph E. Pogue and Kenneth E. Hill.

[2] "Economic Possibilities for Liquid Fuels From Oil Shale and Coal in the United States," W. C. Schroeder. Energy Resources Conference, Denver, Colo., 1956. Published in Oil and Gas Journal, Feb. 25, 1957, pp. 120–124.

From this analysis it was anticipated that the domestic petroleum industry would be in a less and less favorable competitive position with respect to foreign oil. It appears that these effects are now being felt, and the Government, in an attempt to support and maintain the domestic industry, is now exerting some control over imported oil.

It is my belief that the hydrogenation of coal to furnish chemicals, liquid fuels, and gas could move in on a competitive basis with domestic oil in the relatively near future. The position appears more difficult if foreign oil comes in inabundant quantities.

The hydrogenation process was not only the method developed for converting coal to oil and chemicals. A second method, generally called the Fischer-Tropsch or gas synthesis method, was developed and commercially applied. Much of the process development work was carried out in Germany and a substantial industry existed by World War II. At the end of the war a plant of this type was built in Texas to make gasoline from natural gas. This plant was not economically sucessful and was closed down about 2 years ago.

A similar plant was built in South Africa to make gasoline from coal and has been in operation for about 2 years.

The gas synthesis process operates at pressure of about 350 pounds per square inch and modest temperature. However, the capital cost of the plant is high and the thermal efficiency of the process is low. Estimated capital cost is in the range of $13,000 to $16,000 per daily barrel of capacity at present day prices. This is too high to make the process of interest for the conversion of coal to gasoline and oil in the United States, but it may be of interest with respect to the production of some types of chemicals.

CHEMICALS FROM COAL

Coal has long been nad still is the source of a large volume of chemicals. A considerable proportion of these are byproducts from operations to produce coke for the steel industry. Such chemicals include benzene, toluene, xylene, and other aromatics; tar acids, such as phenol, toluol, and cresols; napthalene and pyridine and dyes.

In a number of plants coal or coke was used for the production of hydrogen which was then used to make ammonia. At the present time, however, all these plants have abandoned the use of coal and have converted to natural gas as raw material.

Many attempts have been made to develop an economically successful method for the low temperature, or partial carbonization of coal to produce a solid fuel for combustion and a tar or liquid product to be used in producing oil or chemicals. In recent years this has taken the path of treating pulverized coal to remove part of the volatile constituents before the coal was burned under a boiler. The tar produced in this operation is a very complex material and thus far processes for upgrading the tar have not been sufficiently inexpensive to justify the operation.

In general, the production of chemicals does not seem to offer prospects for a large market for coal. The amount of chemicals used is too small to be very significant to a fuel industry. On the other hand, an industry producing fuels, both liquid and gaseous, with chemicals as a byproduct, may in the future be very important to the coal industry.

CONCLUSIONS

The total reserves of coal and lignite in the world are sufficient to support present production as well as considerably expanded production for several centuries. Reserves of coal in the United States are very large, and at the present time are around 40 percent of the world's known reserves.

Mining costs in the United States have risen only slightly since 1948. The industry is paying higher wages, and has higher costs throughout all its operations, but these increases have been compensated for by increased productivity which has maintained almost constant selling prices at the mine. Where shipment by rail or water is involved, the cost of the coal to the consumer has gone up because of increased transportation costs.

Coal's major problem, one that has become increasingly severe in the past few years, is the loss of markets to competing fuels. In general, these lost markets are more a matter of simple, convenient handling for the competitive liquid and gaseous fuels, as compared to handling a solid like coal rather than a question of price.

The increasing spread in price on a heating value basis at the point of production between oil and coal during the past 10 years has increased the incentive to develop processes for converting coal to liquid fuels. At present-day costs coal at the mine is worth from 0.1 to 0.3 cents per pound. Converted to oil or gasoline it is worth over 1 cent per pound. The technology for carrying out such conversions has been known for over 40 years, but economic considerations, particularly the high capital cost of the plant for processing the coal, have prevented application of the processes in the United States.

Recent developments in two directions are tending to change this picture. The first is that the capital cost for finding, transporting, and refining oil in the United States is rising and will continue to rise in the future. This is caused largely by increased costs for finding and producing oil, which at the present time are about 70 percent of the total capital cost for establishing productive capacity. The second development relates to the progress that has been made in reducing the capital cost for coal conversion plants, particularly for coal hydrogenation. It is my belief that these capital costs are now about comparable with the cost of bringing in new domestic petroleum production. An additional factor favoring the use of the coal is that the synthetic plant will continue to operate at rated capacity for 20 to 25 years, whereas petroleum productive capacity generally falls off greatly in a period of 8 to 10 years.

Coal can also be converted to a gas essentially equivalent to natural gas. At present-day prices natural gas is generally a somewhat less valuable material on either a pound or heating value basis than oil or gasoline. From this standpoint the incentive for conversion to natural gas is not now as great as the incentive for conversion to liquid fuels. However, a plant producing both gaseous and liquid fuels has both technical and economic advantages which are important.

Foreign oil is becoming of greater and greater importance, both with respect to our domestic oil industry and in the future development of a synthetic fuel industry. At the present time the capital cost of productive capacity in certain foreign areas appears to be

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about half the cost in the United States. Equally as important is the fact that foreign costs for the next 10 or 15 years will rise only slowly while domestic costs are increasing sharply. This would indicate that under the play of normal economic factors there will be strong incentive to import more and more oil with a consequent decrease in our own productive capacity. This would have a direct effect on the domestic oil industry. At the same time it would affect coal, first, in that foreign oil, particularly the heavy oil, would compete for coal's markets, and, second, it would make it more difficult for synthetic plants to develop using coal as a raw material.

It is not certain, of course, that normal economic factors are the only ones that will affect the cost of foreign oil. Already in certain countries there has appeared a strong tendency to demand an increasing share of the profits from the oil operations. This will increase the price of oil in the United States. To date, however, this does not appear to be a factor which will control the flow of foreign oil. Furthermore, through competition between the several countries now producing oil in substantial quantities, it may not become a controlling factor.

Importation of oil conserves the oil and to some extent the coal reserves of the United States, and from this standpoint may be considered beneficial. At the same time, however, it can retard the development of our domestic fuel industry. If oil in unlimited amounts is brought in at prices below which it can be produced in this country, the domestic industry cannot grow and will ultimately go downhill. If this process continues long enough, our industrial activity will depend on foreign supplies. This is obviously a prospect some considerable distance in the future, since at the present time the United States is not using its full petroleum productive capacity.

The questions are probably indicative of the need for the oil, gas, and coal industries to look forward to their future. Strong and growing domestic industries for supplying energy would seem to be one of the prime needs for the future.

Thank you, Mr. Chairman.

Representative PATMAN. Thank you very much.

Representative WIDNALL. I am very interested in what you say about the comparable cost in constructing a hydrogenation plant. What would be the comparison between the depletion allowances as applied to the operating value of oil production and the hydrogenation plant?

Mr. SCHROEDER. That question we have considered for some time. The oil industry, as you know, gets 27½ percent depletion allowance, and the coal hydrogenation plant would suffer somewhat since we would only get, I believe it is, 15 percent on the coal produced. So we would be under some disadvantage from that viewpoint.

Representative WIDNALL. The initial capital costs would not be the true evaluation of the project unless you consider the others?

Mr. SCHROEDER. That is correct.

Representative WIDNALL. That is all.

Representative PATMAN. Thank you again. We appreciate your testimony.

Our next witness is Mr. Joseph E. Moody. Mr. Moody is president of National Coal Policy Conference, Inc., president of the Southern

Coal Producers' Association, treasurer and member, board of directors, American Coal Shipping Association.

Mr. Moody, we are glad to have you.

You may proceed as you desire, Mr. Moody.

STATEMENT OF JOSEPH E. MOODY, PRESIDENT, NATIONAL COAL POLICY CONFERENCE, INC.

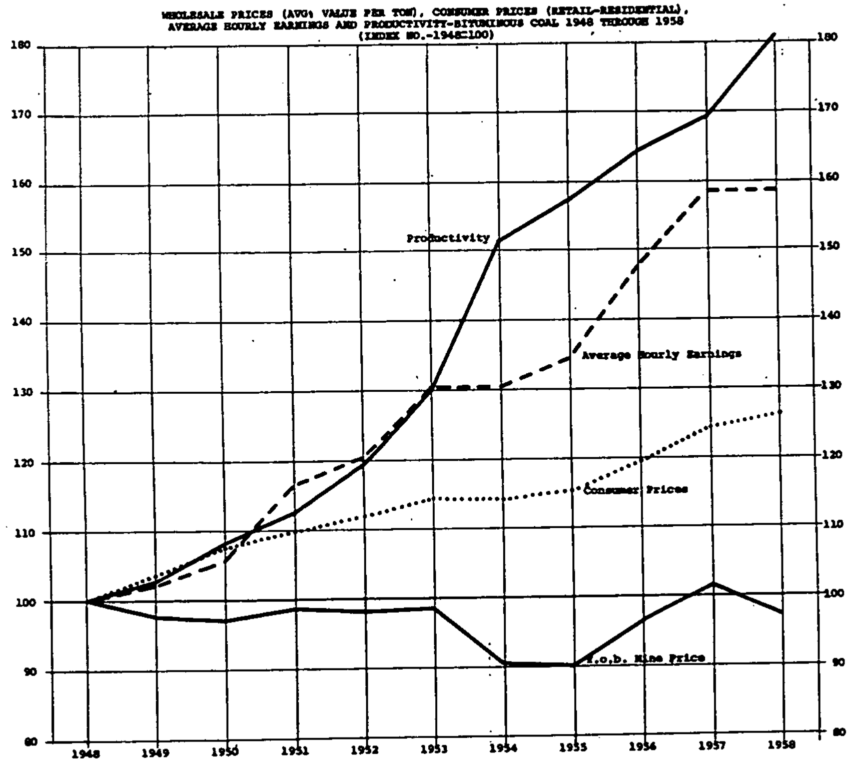
Mr. MOODY. Thank you, Mr. Chairman.

Mr. Chairman, in listening to the testimony of Dr. Schroeder and Mr. Lamb, I just this morning made up a chart in our office that I think might be of interest to the committee. With your permission I will show it to you. It pretty well tells the story of the coal industry.

You will notice that the first line on the chart pertains to productivity. It runs up to over 180. The next is the hourly wage earnings for the last 10 years. Then your consumer delivered price, and, of course, the price at the mine. I don't think there is any other industry in the country that can show anything even vaguely similar to the job done in the coal industry of increasing production, maintaining a high level of income to the miners and at the same time being the chief anti-inflation commodity of the country by selling it for less today than 10 years ago.

Representative PATMAN. That is a very interesting chart. We would like to insert that into the record at this point.

(The chart referred to follows:)



Mr. MOODY. I might say if anyone wants copies, I assume by this time they have additional ones at the office.

Mr. Chairman and members of the subcommittee, I am Joseph E. Moody, president of the National Coal Policy Conference, an organization of coal operators, the United Mine Workers of America, the coal-carrying railroads, coal-equipment manufacturers, and coal-burning electric utilities.

In speaking for this group, I speak for one of the basic bulwarks of our economy—coal.

The production of some 435 million tons this year will provide, among other things, adequate fuel supply for 68 percent of our steam generating utilities—plus the single largest revenue commodity for our great railroad industry. Actually, in 1958 the f.o.b. mine value of coal was approximately $2 billion, and the railroad revenue in hauling this coal to market amounted to more than 1 billion additional dollars. Overall, the industry I represent here today contributes to our national economy some $5 billion annually in fuel, freight, equipment, wages, and services.

This industry employs about 200,000 production workers in the mines, but the number of Americans—workers and families—directly dependent on coal for their livelihood approaches 2 million.

While here as a representative of those interested in maintaining and promoting the welfare of the coal industry, I should like, with the subcommittee's permission, to address my remarks to an even wider area than that one industry.

One of the questions that we are seeking to answer here is: What public policies are necessary to insure an adequate energy supply for our Nation while at the same time promoting the healthy and balanced development of the American economy? It is my firm conviction that the first and most important step needed to accomplish those objectives is the adoption of a single, overall national fuels policy. There are four principal reasons behind this strong belief:

1. Since the late thirties, every commission, committee, or study group that has dealt objectively with America' energy resources has urged that an integrated fuels or energy policy be adopted by the Government. These include Presidential advisory groups under the Roosevelt, Truman, and Eisenhower administrations, the two Hoover Commissions, committees of the Congress, and spokesmen for the independent agencies. All who have gone thoroughly into this question have agreed that an energy policy is badly needed. We are here today urging a study which should outline the specifics of such a program.

2. The maintenance of a strong, dynamic energy base in the United States is one of the most essential ingredients of our national security. It is obvious that we cannot allow our energy industries to decline through lack of use and then expect them to meet the exaggerated demands that would be dictated by a national emergency.

3. The economic challenge of the cold war, so emphatically underlined by the visit of Premier Khrushchev, is yet another compelling reason for the adoption of such a policy. The United States is involved in international competition, whether we like it or not, and this competition demands healthy, vigorous energy industries which will

permit our Nation to realize the maximum benefit from it growth potential.

4. Factors growing out of the lack of a national fuels policy are already tending to distort our domestic economy. As the Paley Commission pointed out, the Nation's energy prblem must be looked at in its entirety and not as a scattered collection of independent pieces; a problem in one sector must be handled with full consideration of its effects on related problems in other areas. I think the members will agree that dislocations already are apparent, through failure to deal with this energy problem as a whole—for example, in the New England residual oil situation, the restricted oil production schedule in Texas, and the depressed economy of West Virginia. Without a fuels policy, these problems can only become more severe and widespread.

I would like to spend a few minutes discussing these four points.

THE VIEWS OF ENERGY EXPERTS

For years knowledgeable persons and agencies have been pleading for a national fuels policy, ever since a Government Energy Resources Committee recommended in 1939:

> The energy resources—coal, petroleum, natural gas and water power—lie at he foundation of our industrial civilization * * *. From the evidence reviewed in this study, it appears beyond argument that the Nation's patrimony should be safeguarded, that a sound national policy must be concerned with the conservation and prudent utilization of these basic resources.[1]

In 1951, the introduction to a study conducted by the Senate Interior and Insular Affairs Committee included:

> * * * Do present Federal, State, and local laws and regulations promote the public interest in the wise development of our natural resources? Do we even know in specific terms what the public interest is when it comes to technical problems?
>
> Answers must be found for these questions and information must be developed that will permit the formulation of policies designed to increase the availability of reliable energy resources by drawing more heavily on those that are inexhaustible * * * by improving the methods of producing exhaustible resources; and by encouraging the more efficient consumption of energy—all to the end that the American people may have the assurance that their energy resources will not be dealt with so improvidently as to limit the ever higher and higher level of living possible with our national genius and our wealth of resources.[2]

Again, in 1952, the Paley Commission, officially the President's Materials Policy Commission, recommended:

> The Commission is strongly of the opinion that the Nation's energy problem must be viewed in its entirety and not as a loose collection of independent pieces involving different sources and forms of energy. So numerous and vital are the interrelations among all sectors of the energy field that problems in any one sector must be dealt with always in full consideration of the side effects on all other sectors.[3]

The idea of a national fuels policy was received in 1955 by the Presidential Advisory Committee on Energy Supplies and Resources Policy, and just 4 months ago the situation was well summed up by the Hon-

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[1] Proceedings, Energy Resources Subcommittee of the National Resources Committee, Harold L. Ickes, Chairman, 1939.

[2] "Basic Data Relating to Energy Resources," S. Doc. 8, 82d Cong., 1st sess., 1951, p. xxi.

[3] "Resources for Freedom," vol. I, a report by the President's Materials Policy Commission, June 1952, p. 129.

orable William R. Connole, Vice Chairman of the Federal Power Commission, when he said:

The need for a national energy policy seems so patently obvious that I am simply unable to understand how thoughtful people concerned with this business can overlook it * * *.

When we think that our energy resources are consumed at such an incredible rate that, for an example, all the fossil fuel consumed in the history of the world up to the year 1900 would last only 5 years at today's rate of consumption, we know how important this whole subject is to all the peoples of the world.[4]

These investigations that I have referred to briefly have been of great importance in providing the basic factual data which is an essential prerequisite to the formulation of a national fuels policy. For this reason, they serve as a valuable point of departure for the present inquiry that we propose.

Unfortunately, none of these previous investigations, despite their usefulness, resulted in the dvelopment of an effective fuels policy adequate to the needs of the Nation as a whole. Furthermore, the major changes that have occurred in the fuel and energy economy since these investigations were conducted require that measures be taken to obtain more up-to-date information concerning major problems in these areas.

As I am sure the committee is aware, the need for the formulation of an integrated national fuels and energy policy has been recognized in other major industrial areas of the world. Scarcely a month ago the Canadian Government established a National Energy Board which, according to the empowering legislation, is designated to—

* * * Study and keep under review all matters relating to energy within the jurisdiction of the Parliament of Canada, and shall recommnd to the Minister of Trade and Commerce such measures as it considers necessary or advisable in the public interest with regard to such matter.[5]

In addition, a special committee of the European Coal and Steel Community has already proposed an integrated energy policy for the whole of Western Europe which is now being considered by the individual governments.

Facing this kind of documentation, I fail to understand how an impartial observer could rmain unconvinced that a comprehensive study of America's fuels situation, such as has been proposed and is pending in the Congress, is in the best interests of the Nation.

The implementation of this proposal, so obviously in the public interest, would also, in our opinion, help the coal industry. It would provide a perspective from which to viw our many problems; it would help clarify some of the murky areas of fuels competition that have developed in recent years; it would introduce some continuity and stability into what has often been a violenty mercurial industry—coal; and it would give us some insight into the years ahead. We know only too well where we've been; we're now vitally interested in where we're going.

ENERGY AND NATIONAL SECURITY

The maintenance of a strong domestic energy base is an essential part of national security. America's experience in two world conflicts has taught us that the extravagances of war require a tremendously increased output of energy. Consequently, our defense posture must be

[4] Commissioner William R. Connole, Vice Chairman, Federal Power Commission, speaking before the National Coal Association, June 3, 1959.

[5] Bill C–49, the House of Commons of Canada, as passed June 3, 1959.

such that we can keep our far-ranging fighting forces fueled without curtailing our industrial might here at home. I think some of the national security data on the coal industry might illustrate the problems to be solved in this area.

Since 1950 the number of operating bituminous coal mines in this country has decreased from 9,429 to an estimated 7,588 in 1958, a loss of better than 1,800 mines. The annual productive capacity of the domestic coal industry is estimated currently to be 520 million tons. In the event of a national emergency and the resultant crash program of industrial mobilization, the demand for coal would soar many millions of tons above that figure, probably considerably more than the 150-million-ton increase in annual production demanded by World War II. Not only would present coal users need additional tonnage but those industries on the eastern seaboard now burning imported residual oil would also, in all probability, be forced to revert to coal.

It is interesting, I think, that from 1941 to 1945 our consumption of all forms of energy, in terms of bituminous coal equivalents, increased by 188 million tons. Thus, the coal industry in World War II supplied better than 80 percent of America's increased energy needs.

To produce the additional coal required, we would have to open new mines or reopen old ones. We would also have, as things now stand, a serious manpower problem. A coal mine shut down or a coal miner dislocated cannot be returned to the economy by the flicking of a switch. It takes as many as 4 years to develop a modern coal mine; it takes almost as long to train a miner in the use of modern coal-mining machinery. Consequently, the effective loss of these assets to our economy is one which should not be taken lightly.

In my opinion, and that of many qualified observers, the coal industry, as a result of this situation, could not now duplicate its remarkable war record of 1941–45, much less surpass it.

And even if the coal could, by some miracle, be produced, we would still have the problem of transporting it. As coal production has declined so, naturally, has the capacity of the railroads to haul coal. In just the last 2 years the number of railroad cars available to carry our product has declined by over 25,000. This is a problem that also demands solution.

Nor is this situation peculiar to the coal industry. The same basic problem exists in the domestic production of oil. My friends in the petroleum industry tell me that it takes from 3 to 5 years' time to bring in one producing well because the exploration process is so time consuming. Only one out of every nine wells drilled produces any oil, the others are "dry holes." Of course, where wells are already in production this "dry hole" operation is not necessary, but I also understand that there is a definite limit to the number of wells that can operate economically from one pool of petroleum. Therefore, the oil industry would have the same difficulty in meeting a national emergency as would our industry and for primarily the same reasons.

And, of course, the gas industry faces similar problems not only because of production delays but also because pipeline construction cannot be accomplished over night.

All of us here, I'm sure, are well aware that if a general war should break out, traffic on our sealanes will be greatly curtailed, or, perhaps, halted. The awesome threat of the Soviet undersea fleet is by now well documented. We also know that while our oversea sources of supply are being shut off the domestic demand for fuels will soar as industry shifts into a wartime production schedule. Can we, then, in conscience allow our energy industries to become so feeble that they are unable to meet that double demand? A sound national fuels policy could insure that such a disaster would not occur.

The Soviet Economic Challenge

As Premier Khrushchev so clearly emphasized on his recent visit to this country, America is in an all-out production race with the Soviet Union. Although we did not choose this particular arena for competition, the Communist leaders have already thrown down their challenge and we must accept and win; we have little choice in the matter. However, I must admit that in recent months I have become somewhat disturbed about the strength America can bring to bear in this competition. It is completely apparent that we cannot afford complacency. Our greatest danger would occur if the United States took the commonly accepted position "We've got it made."

But this is a much broader canvas than we can fill in here today. Now we're discussing the immediate problem of our energy resources and how they can help America surmount the Soviet challenge. For the basic necessity for winning an emonomic race is a greatly expanded output of energy fuels, the very heart of industrial production. Already it is a matter of record that in 1958 the Soviet Union surpassed the United States in coal production for the first time in history. How soon they will catch up with our other basic industries is, of course, a matter of conjecture, but the figures available from Soviet publications are disquieting.

The National Coal Policy Conference has recently compiled from basic Soviet sources a study of the energy economy of the U.S.S.R., which is now being published. As soon as the document is available, I would be happy to supply copies to the subcommittee members, but in the meantime I would like to summarize some of our findings.

For example, in just 1 year, 1957, the Soviets posted the following percentage increases over energy outputs in the preceding year:

Oil production was up 17 percent.
Coal production increased 8 percent.
Natural-gas production was up an impressive 48 percent.
Hydroelectric power increased 36 percent.
Steam-electric power was up 9 percent.

On the other hand, the following statistics are available for U.S. production in 1957 as compared with the previous year:

Oil production decreased a fraction of a percent.
Coal production decreased 2 percent.
Natural-gas production was up 5½ percent.
Total electric power increased only 4½ percent.

In terms of absolute quantities, the United States was, in 1957, still well ahead in all categories; but we must act now to insure that this advantage is not eventually lost to us.

It should be mentioned here that while these figures compare the two economies in the same calendar year, the state of economic development in the two countries was not at all the same. For example, the natural gas industry in the U.S.S.R. is still in its relative infancy while ours is well matured; consequently, the Soviets would be expected to display more growth in this area than the United States. So the wide margins shown by the figures above are, to some extent, not an accurate reflection of the true situation. They do, however, indicate that the United States is lagging, especially in coal production, a more comparable area than the others.

Despite the efforts of the Communists to expand their energy industries, the basic fuel for Soviet industrial growth is and will for many years be coal. This was stated by Mr. John A. McCone, Chairman of the Atomic Energy Commission, when he told a subcommittee of the Joint Committee on Atomic Energy:

> I think it is quite significant that Koslov told Admiral Rickover at Shippingsport that they [the Soviets] had been badly misled by their scientists on the cost of nuclear power and therefore they were not proceeding with it as a program. That is what Koslov told Rickover and Admiral Rickover reported to me. They have found that nuclear power was much costlier than they expected. Therefore, they are meeting their growing power demands by conventional means using coal. He further went on to tell Rickover that they were not proceeding with their hydroelectric developments because of capital costs. I think that was quite significant as well.[6]

In terms of percentage of gross national product, the U.S.S.R. is devoting to capital expansion twice the amount we do in this country. Economists predict that if this rate continues the Soviet Union will equal or surpass the United States in heavy industrial output by 1982, only 23 years away.

If we chart past performance, it appears that this prediction may be a conservative one. A statistical analysis of the fifth 5-year plan, covering the years 1951–55, shows that overall Soviet production increased in that period over 75 percent compared with only 23 percent here in the United States. Heavy industrial output in the U.S.S.R. increased at an even greater rate.

Premier Khrushchev, in a speech delivered on the 40th anniversary of the October revolution, predicted that by 1972 Soviet production of steel would double and his country's overall energy base would more than triple. These predictions may, of course, reflect a certain amount of optimism for propaganda's sake, but informed observers believe his claims have considerable substance.

In order to achieve these growth rates, the Communists are necessarily making integrated use of their energy resources. The following quotations from two separate Izvestia articles emphasize this:

> In the 7-year plan for the development of our national economy, it is extremely important to find a practical solution to the problems connected with the integrated use of natural fuels resources.[7]

And from the second article:

> Therefore, in our long-range plan for development of our natural fuel resources, we are planning for the extensive but intelligent use of oil, natural gas, and coal for our powerplants, for our industry, and the everyday needs of community living * * * but the time factor must not be forgotten. We must gain time in our competition with capitalism so as to overtake the United States of America in per capita production in the shortest possible time.[8]

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[6] Mr. John A. McCone, Chairman of the Atomic Energy Commission, testifying on July 23, 1959, before the Subcommittee on Research and Development of the Joint Congressional Committee on Atomic Energy.

[7] Izvestia, Sept. 10, 1958.

[8] Izvestia, Sept. 24, 1958.

It is apparent, then, that the Soviet Union is formulating an overall fuels policy on a "crash" basis, if, indeed, this has not already been accomplished.

ENERGY AND THE DOMESTIC ECONOMY

This brings us to the question of maintaining a healthy and dynamic domestic economy under the duress of the changing forces expected in the next several decades. While predictions of this sort are always hazardous, the Census Bureau estimates conservatively that our population will increase by as many people during the 25-year period from 1950 to 1975 as it did in the preceding 50-year period, and that by 1980 the U.S. population will stand at roughly 250 million persons.

If our economy is to keep pace with our skyrocketing population, this Nation must be able to supply in 1980 approximately twice the amount of energy currently being consumed. It is, of course, possible that by 1980 our scientists will have found a way to derive low-cost power from the atom or will have perfected a system of wringing energy from the rays of the sun. However, at the present time that is only speculation. As Mr. Philip Sporn told the subcommittee on Tuesday, a projection of our energy picture even as far as the year 2000 reveals that approximately 80 percent of America's total energy needs will be supplied by conventional means. So that our economic growth will not be stunted, we must take positive action now to insure that the energy requirements of the future will be met. A wise national fuels policy would, in my opinion, provide that insurance.

In addition to simply meeting the needs of our future, we must also prevent our economy from being stretched out of shape by the various forces that tug on it from all sides. Obviously, this is a problem with many more aspects than could be treated by the single policy I am discussing. A thorough inspection of this question would involve consideration of America's balance-of-payments situation, trade relations throughout the world, and international politics and finance, among other subjects.

It is, however, becoming increasingly obvious that America's situation as a result of the interaction of these forces is growing more serious. We are losing gold at an unprecedented rate because of a continuing deficit in our overall international transactions; we are dizzily trying to keep up with spiraling inflation; our trade deficit grows larger every day; dollar futures are, for the first time in history, selling at a discount in Europe; our citizens pay burdensome taxes to strengthen other economies while our own languishes relatively untended; and our industries are becoming less and less able to compete in world markets.

America must devote a greater effort to the solution of domestic economic problems. These are not simple problems. They have many subtle ramifications. For instance, it was pointed out to me not long ago by a leader of the West German coal industry that his Government's decision to impose a tariff on oil imports was not, strictly speaking, a protectionist move; it was dictated solely by the desire of the West Germans to protect their tax income. This is one of the many problems created by importing more than we export, our Government loses tax revenue.

For example, from the time a coal mine begins operation through the sale of coal to the consumer, taxes are paid to support all levels of government. Real estate taxes, corporate taxes, revenues received from the coal-hauling railroads, employees' income taxes, sales taxes, and even taxes on the house eventually made of coal-derived cinder blocks. When these are added up, it becomes clear that each ton of coal produced in this country provides an important source of revenue for our various government treasuries. On the other hand, imported residual oil pays a token tariff of only a nickel a barrel. The result, naturally, is that every ton of coal ousted from its markets by imported residual deprives the local, State, and Federal Governments. In 1958 alone we imported the residual oil equivalent of roughly 40 million tons of coal—a staggering loss of tax funds, to say nothing of the loss of employment to coal and railroad workers and other grave losses.

This is just one symptom of many indicating that in a very basic way we are distorting our economy in the area of the energy industries. Let me suggest a few others.

New England says it is heavily dependent on imported Venezuelan residual oil—a supply that will almost certainly be unavailable in time of war and is unreliable in time of peace. Coal-rich West Virginia is now one of the most chronically depressed areas in the entire United States. Other coal areas also are depressed. Natural gas, in some cases, is sold to large-volume consumers for as little as one-fourth the rate charged the householder in the same area. The flowing wells of petroleum-rich Texas are, at the present time, allowed to produce oil only 9 days of every month. And while the oil, gas, and coal industries squabbled among themselves, the Federal Government, in just 6 years has poured over $800 million into a program designed to produce competitive electricity from nuclear energy and thus curtail the markets for all three. These paradoxes, I think, you will agree, indicate a basic imbalance somewhere in our energy economy—an imbalance that will undoubtedly grow worse unless it is soon corrected.

They also indicate there are many unanswered questions and unsolved problems within our energy industries. While I am not going to venture into the realm of opinion—and biased opinion, at that—I think the following contentions of the coal industry will illustrate what I mean. We feel, for example, that much if not all of the foreign residual oil being brought into eastern ports is sold at dump prices because a few giants of the oil industry find it economically convenient to do so. We also believe that, in some cases, natural gas distributors charge householders a rate that will permit virtually subsidized sales to industrial consumers.

These are, as I say, only opinions held by the coal industry. We think that they are correct, but we are not certain. We do not have access to all the data necessary to prove these theories. For that reason, we have urged and will continue to urge that a thorough, completely objective, nonpartisan study of the overall fuels situation be conducted and that the results of that study be incorporated in a national fuels policy.

We also feel that this inquiry will contribute immeasurably to the national welfare. The basic cause of the imbalance I spoke of a minute ago is that we are using our economic resources in an uneconomic way. If we are to persist as a strong Nation such extravagance cannot long be tolerated. A dynamic domestic economy can only be maintained through the intelligent, economic use of all the assets at our command—and this applies most particularly to our fuels.

CONCLUSION

It seems to me that sober attention to these four reasons for studying the formation of a national fuels policy—that it is universally recommended by unbiased energy experts, that it is vital to America's defense posture, that it will enable this Nation to keep pace with the Soviet economic offensive, and that it will insure a sound, dynamic domestic economy—forces any reasonable observer to agree with my position.

As you, of course, are aware, joint resolutions were introduced during the last session of Congress, sponsored by 42 Senators and 30 Representatives, which would create a joint committee to make an impartial study of our fuels situation and subsequently formulate a national fuels policy. The coal industry is supporting these resolutions because we are convinced they will serve the best interests of the United States and thereby the best interests of the coal industry. We have hoped that the other fuel industries would lend their support for similar reasons.

Very much to my amazement, however, some spokesmen for the oil and gas industries have come out against this study. They have accused the coal industry of seeking unfair, selfish advantages by this means, they have charged that this step would eventually mean unwarranted Government interference with and regimentation of private enterprise, and they have even suggested that since the Nation has survived for 150 years without a fuels policy there is no reason to consider one now.

As I say, I do not understand this action. In my view, opposition by the oil and gas industries to a national fuels policy study would amount to taking the fifth amendment. I can readily understand how any one of the fuels industries, coal included, might oppose some specific proposals that might be included in a fuels policy. But I am simply unable to comprehend how any industry can oppose an impartial and objective study—unless, of course, that industry has something to hide. Consequently, I am confident that the responsible spokesmen for the oil and gas industries will strongly support the pending resolution.

The charges leveled by some petroleum spokesmen are, of course, easily refuted. Naturally, as I have said before, the coal industry thinks that a national fuels policy derived from a factual analysis of our energy situation would help solve some of our problems. But we are not now recommending or stipulating what that policy should entail. All we are recommending is that a thorough, impartial inquiry be conducted by a nonpartisan, objective study group. Once all the facts pertaining to the energy industries are brought to light and documented then a policy could be derived on the basis of those facts.

The coal industry has a good story to tell, and it welcomes the opportunity to tell it wherever and whenever possible. We do not want to be misunderstood. We are tremendously proud of our industry—its past record and its future potential. We know that we have a strong, factual basis for that pride. Consequently, the coal industry, for one, would welcome a fair inquiry into America's fuel industries.

It seems to me that this is not the road to selfish advantage but rather the road to fair and open competition—a road the coal industry is anxious to travel.

The charge that a fuels policy study would lead to regimentation of private industry is also easily refuted. The fuels industries are already subject to Government regulation. We think this study would help rather than hinder the sensible administration of such regulation.

Certainly, no industry in this country has a better known reputation for individualism than the coal industry. I would like to go on record right now as saying that the coal industry does not and will not encourage unnecessary Government interference with free enterprise in any way. We do not want regimentation any more than our competitors.

I fail to understand how the action I am suggesting could possibly regiment anyone. We are recommending that the Government make an intelligent and thorough study of our overall energy situation to provide a basic framework for an important and sizable segment of our economy.

We think that our recommendation is a sound one. We think its adoption would mean ultimately a sounder working basis of all fuel industries and would very likely tend to reduce the Government's effect on their activities. At the present time, as you all know, there are many government agencies, at Federal, State, and local levels, concerned with the energy industries. The Department of the Interior, the Federal Power Commission, the Texas Railroad Commission, the Department of Commerce, the various public utility commissions, and others, all regulate to some extent or in some area the various energy industries.

At present, this regulation is accomplished on a haphazard, crazy-quilt basis. Specific problems are approached from specific viewpoints without consideration for related aspects which may be within the purview of other agencies. The study we are recommending would help coordinate this chaotic situation. It would provide a framework to weld the piecemeal regulation of the energy industries into a logical and cohesive whole, thus benefiting everyone concerned.

The Paley Commission foresaw the need for this approach when it declared:

> But on one point, the Commission is very clear; the hydra heads of energy policy must be reined together. This can be accomplished only if all parties concerned—the President and Congress, the State and Federal agencies, and the energy industries—work from a common base of understanding of the total energy outlook, the interrelations within the energy field, and of the relations between energy and the rest of the economy.[9]

Could anything be more logical?

I cannot see into the future; I do not know what will come of the efforts to establish a national fuels policy. But, come what may, the coal industry can be expected to compete. We certainly hope that we will be competing in a fair and open marketplace.

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[9] "Resources for Freedom," vol. I, report of the President's Materials Policy Commission, June 1952, p. 130.

Moreover, the coal industry is willing to lay its cards on the table in the knowledge that an objective, factual, nonpartisan inquiry into America's energy situation can only benefit the Nation and will thus benefit the coal industry.

Mr. Chairman, I might say that our office, through a study that we had, in reviewing Soviet newspapers, magazines and engineering papers delivered in Russia—in other word, Russians talking to Russians, and translated and so forth—we have compiled what we think is a review of what the Russians feel they have in energy resources. I thought I would have it here today, but it won't be from the printer until Friday. If the chairman will allow us, I would like to insert that in the record.

Representative PATMAN. We will be glad to have it.

Mr. MOODY. It is the most fascinating reading matter you will ever see.

Representative PATMAN. We will be glad to have it.

(The information referred to follows:)

ENERGY FUELS—THE POWER TO WIN THE COLD WAR

"When I said 'We will bury you,' I did not mean physically" explained Nikita Khrushchev in answer to a question at the National Press Club during his recent American tour, "I meant that in the normal course of economic and social evolution, communism as a way of life will bury capitalism in the sam way that capitalism buried feudalism. Mankind is always looking for a way to better itself and communism is the answer to a better way of life for all humanity * * *."

Communism is Khrushchev's meat. It is America's poison. We are lucky that we still have access to an antidote which, if we use it wisely, will insure that our way of life shall not vanish from the earth.

To the average American, the menace of communism is symbolized by Nikita Khrushchev's sputniks, intercontinental ballistic missiles, moonrockets, and swarms of submarines. These are the aspects of Soviet Russia that most often make the headlines. They are important, to be sure, but there are others even more significant, that never see the lead columns of our daily newspapers or the glittering pages of our news magazines. They do not lend themselves to banner headlines or full-page illustrations. They are dull by comparison with space-traveling dogs or jet-traveling premiers. They are the everyday aspects of Russian industrial and economic progress.

Writing in the Soviet newspaper Izvestia recently, special correspondents Budantseva and Sryvtsev observed "* * * it is important that we gain all possible time in our race with capitalism so as to overtake the United States in per capita production in the shortest possible time * * *."

They haven't made it—yet. But figures published in the Soviet press and technical journals for the edification of the Russian people themselves and not for oversea propaganda purposes, make it very clear that in a number of important fields, they are well on their way. Even discounting the "propaganda percentage" in these published figures and reports and considering the possible wishful thinking behind them, they are startling enough to make us sit up and take stock of what we should be doing to offset Soviet industrial, economic, and technological progress.

No one—not even the Russians—believes that Soviet Russia in on a par with the United States in productive capacity or industrial services at this moment. But many competent economists read in the figures of Russia's industrial development over the last 5 years the certainty that she will be before long. It is true that progress from nothing to near parity is easier and appreciably quicker than the final step to equality. The closer that Soviet Russia gets to U.S. production of raw materials and consumer goods and services, the less spectacular and slower the program will seem to be. But the rate of Russian achievement can be accelerated by a factor other than her own efforts. It can be enhanced by stagnation and retrogression in the industrial and social development of the United States.

COMPLACENCY WILL BE FATAL

We are fat and happy. We have the highest standard of living the world has ever known. The United States has more fulfilled and contented citizens than any nation has boasted in the history of mankind. This is as it should be, because the American people have worked hard for these advantages. But we have always had the blessing of a bountiful earth. From the days when the Pilgrims filled their bellies with corn and sweetpotatoes to the days when the American earth began to yield its vast reserves of coal, oil, and natural gas, its gigantic forests their timber and its fertile plains their wheat and myriad other food crops, our American way of life has been built on what our American earth yielded to us.

This is more true today than ever it was, but with a difference. As recently as 50 years ago, our country could have existed without another ton of coal, a barrel of oil, or a cubic foot of natural gas being wrested from the earth. Today, if these energy fuels—or even a significant portion of them—were denied us, our entire economic and social structure would collapse. There would be no mechanical transportation, no electric power or light, no telephones, no frozen foods, no television or movies, no heat or cooling in our homes, hospitals, or schools. In most communities, we could not even get water to drink.

The future of the United States, and indeed that of the whole free world, is limited only by our ability to utilize to their highest potential our domestic natural energy fuels.

How, then, are we handling these precious gifts? Are we handling them with the discretion and intelligence they deserve? Can we say without prejudice that our extraction, merchandising, and conserving of these fuels are being conducted according to a plan that will insure a secure future for our Nation—or are we dissipating this wealth for the purpose of attaining a sybaritic present?

William R. Connole, Vice Chairman of the Federal Power Commission, said in a recent speech, "Now, to me at least, the need for an energy policy for the United States is so patently obvious that I am simply unable to understand how anyone who considers himself to be associated with this energy business can seriously say we don't need one * * *."

On the other hand, an editorial in the Oil and Gas Journal of September 14 said, "But why do we need a national fuels policy? Why not adhere to the fuels policy this country has had for 150 years? This policy is free enterprise, fair competition, minimum regulation, and preference for domestic over foreign supplies. This policy has given America an abundance of energy fuels at low cost and made it the industrial leader of the world * * * any attempt to change this policy should be viewed with suspicion * * *."

There we have two opinions—the former presumably objective and the latter with perhaps a mite of vested interest. The significant phrase in the Oil and Gas Journal viewpoint is "has given America an abundance of energy fuels at low cost and made it the industrial leader of the world * * *." With this statement there is no argument. What we must ask ourselves, however, is whether unplanned profligacy for 150 years and competition that might be accused of putting profits ahead of the national interest, will not bring us to the point where abundance no longer exists.

FUTURE SOVIET PROGRESS IS BASED ON NATURAL ENERGY

Until the Bolshevik Revolution of 1917, Russia was one of the most backward countries in Europe. Her economy was predominantly agricultural and the vast reserves of natural fuels for low-cost energy were almost entirely ignored. The known coal reserves of pre-Revolutionary Russia were estimated at just over 200 billion tons. Today, after 40 years of Communist rule, intensive geological surveys place Russian coal reserves at the staggering figure of nearly 9 trillion tons. Known U.S. coal reserves are just over 2 trillion tons—less than one-quarter of Russia's reserves.

Great successes have been achieved by the Soviets in the development of oil resources. The most important achievement by Soviet geologists has been the discovery of the Urals-Volga oil region. More than 100 large deposits have been found there of which more than 70 are now being exploited. Many new oil deposits have been found in the Central Asia, Kazakhstan, Northern Caucasus, Sakhalin, and Ukhta areas. Oil derricks are now boldly striding out in the Caspian Sea, where vast underwater oil deposits have recently been found.

Also totally unknown in the old Russia, many huge areas of natural gas have been uncovered by Soviet geologists. They have been discovered in the Volga region, the Ukraine, the Stavropol Territory, the Komi Autonomous Republic, the Turkmenian Republic, Tyumen Province and the Yakut Republic. Soviet plans call for a fifteenfold increase of natural gas over the next 15 years.

In 1957, Soviet planners developed a production schedule for their natural energy fuels up to 1975. This schedule called for a production increase that would bring their annual yield up to and beyond U.S. figures. How successful this program is may be judged from a report printed in the New York Journal of Commerce issue of September 1, 1959, which says in part " * * * the Soviet Union's crude oil output this year will be well over the 1959 target of 130 million tons slated originally * * * "

According to the latest statistics reaching London from Moscow, Soviet oil production has been rising rapidly for some years. Immediately prior to World War II, Soviet crude oil output was 28.6 million tons per year. In 1950, this had risen to 37.6 million tons per year and in 1958, to 98 million tons. With the 1959 production conservatively estimated at more than 130 million tons, it is clear that the day is fast approaching when Soviet production of this one energy fuel will equal, if not surpass, the U.S. annual production of 360 million tons of crude. Present plans call for a fivefold increase in production over the next 7 years, making a target of approximately 500 million tons by 1967. This figure is conservative. So far, the average Soviet well has been producing around 61 barrels a day, but wells in some of the recently opened Russian fields have been yielding up to 1,200 barrels a day.

In August, Soviet geologists claimed to have found the world's largest natural gas deposit in Uzbekistan and further east, in the remote Lena River Basin, Siberia's tremendous gas deposits have been defined.

Writing in the newspaper Izvestia, Ye Lubokhov, first vice chairman of the Komi Economic Council said, "According to the old view, Komi land was barren and poor—taiga and then more taiga (forest land). But our geological discoveries show that in this Komi Republic there are hundreds of millions of tons of oil, more than 400 billion cubic meters of natural gas, and 260 billion tons of coking and fuel coals * * *."

From these figures from one small area, it is obvious that the natural energy fuels potential of the whole Soviet Union is gigantic. Even allowing for the possibility of exaggeration, it would seem reasonable to assume that before too many years have passed, Soviet Russia will be at least even with the United States in all energy fuels production. In the case of coal, they have already outstripped us. Last year, the Soviet Union produced 529 million tons of coal. The U.S. production was 405 million tons. Not only was this Soviet production 125 million tons higher than ours last year, it is only about 100 million tons less than the U.S. alltime record year of 1947, when we mined 636 million tons.

SOVIET EXPANSION STRESSES PLANNING

An editorial in Izvestia, discussing the rapid strides being made in the discovery and development of natural energy fuels in the Soviet Union, commented "Therefore, in working out a long-range plan for development of our national economy, we are providing for the extensive, but integrated, use of oil, gas, and coal for powerplants, industry, and transportation. This plan calls for considerable increase in the extraction of energy fuels and for their increased utilization in the national economy. We intend to keep a very watchful eye on the country's natural energy fuels balance * * *."

Last year, more than 8,000 scientists, economists, and government planners took part in the conference on development of production forces in eastern Siberia. The final plenary session of this conference adopted recommendations for accelerating oil prospecting, utilization of natural gas deposits and opencast coal mining, ever mindful of the need for working out intelligent conservation measures for these invaluable resources * * *." (Quoted from Pravda.)

V. S. Nemchinov, chairman of the U.S.S.R. Academy of Sciences Council for the Study of Production Forces, said in his windup speech to the eastern Siberia conference, "Large thermal powerplants are being built for the production of very cheap electrical power on the large coal deposits of the Kansk-Achinsk Basin, the Azeisk deposit in Irkutsk Province, the Gusinoozersk deposit in Buryatia, and the Kharanor deposit in Chita Province. Thermal power stations will flood all of eastern Siberia with power and send their surplus to western Siberia and the Urals. Eastern Siberia has all the requisites for creating a main U.S.S.R. base for power and fuel-consuming industries to complement the already vast power and fuel developments of western Siberia and European Russia * * *."

On August 31, 1959, Pravda wrote in an editorial "The coal industry is now and will long remain the most dependable, if not the most spectacular, source of energy fuel for the national economy. It will improve and develop its work. The tempestuous development of the ferrous metallurgy demands even greater supplies of coking coal. The priority demands of thermal powerplants has resulted in increased use of power coal, particularly coal mined by the opencast method.

"The Communist Party and the Soviet Government have shown and will continue to show immense concern for the coal industry and its workers * * * the constant concern of the party and the Government for improving the coal industry is inspiring the workers in the coal industry to new production achievements * * *."

Under the title, "Harness the Country's Natural Wealth for the National Economy," P. Antropov, U.S.S.R. Minister of Geology and Conservation of Natural Resources, wrote in Pravda recently "Comrade N. S. Khrushchev stressed in his report to the anniversary session of the U.S.S.R. Supreme Soviet the fact that all the conditions have now been created in the U.S.S.R. for not merely overtaking but surpassing the major capitalist country, the U.S.A., in the overall output of the most important types of production in the next 15 years.

"It is especially gratifying that Soviet geologists have discovered major sources of energy in the last few years. New enterprises and industries have been created on the basis of these discoveries.

"In the past, when geological discoveries were divided by departmental barriers, their value was not utilized in a rational and organized way. There were frequent cases of parallelism and duplication of effort. The creation of the U.S.S.R. Geological Development Service operating under a single policy makes it possible to eliminate these serious shortcomings and to bring about a significant improvement in the effectiveness of natural resources development * * *."

AWARENESS OF ENERGY'S ROLE

One thing is clear from the foregoing extract from Soviet thought and writings. The Soviet Government is acutely aware of the vitally important role that must be played by natural energy fuels in their relentless economic and industrial war against the Western World. They have decided, and rightly, that unless they harness and use intelligently their vast resources of low-cost domestic energy fuels, they will never win the cold war. The entire Soviet industrial plan for the next 15 years—the years when the struggle between East and West will be won and lost—is based on Russia's intention to use to the fullest possible advantage her natural energy fuels.

Senator Robert Byrd, of West Virginia, speaking in the U.S. Senate during the closing days of the last session, said "The Russian Institute of Bituminous Coal Research is under the guidance of member of the Russian National Academy of Science. Under him are nearly 400 scientists with the equivalent of our doctor of philosophy degree. They have assisting them 4,000 scientists who have the scholastic rank of an equivalent to our bachelor of science, bachelor of arts, or bachelor of engineering degrees. These men, in turn, are assisted by an additional 6,000 technicians, all of whom comprise a total far in excess of the number of scientists and technicians engaged in this work in the United States * * *."

THE UNITED STATES CAN NULLIFY THESE SOVIET GAINS

Let us take the Soviet Union's 15-year expansion period as our mean and look at what the United States can expect to use as an antidote to the potion of Soviet industrial progress.

By 1975, the consensus of competent research opinion says, the energy needs of the United States will have increased by some 88 percent. This compares to an estimated 41 percent increase in population during that period, which shows that energy use will increase more than twice as much as the population. In other words, our production of low-cost domestic energy fuels, in ratio to their individual percentage of use, will have to be almost twice as much as we are producing today—in the case of oil, 669.6 million tons of crude oil as against the current figure of 360 million tons per year.

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Reduced to very simple terms, that is the probable demand. What are our resources to meet this demand? The accepted practice in computing oil and gas resources (proved coal reserves are almost limitless) is to take the official proved reserve figures and compare these figures with the current demand level to obtain a life index. By this method, we find that we have about 12 years' supply of domestic oil and about 22 years' supply of natural gas in the United States. But as the oil and gas industries are quick to point out, this is not exactly the true story. These calculations do not take into account new discoveries, which have, up till now, kept the life index more or less constant. The oil and gas people strive to convince the alarmed that we will always have 12 and 22 years' supply to fall back on unless the pattern of the last quarter century changes. As Shakespeare wrote "Aye, there's the rub" * * *. The fact that discoveries have so far kept pace with consumption is no guarantee that they will continue to do so. Only in the case of coal can we feel secure. If not another seam of solid fuel was ever proved in this country, we would still have enough to last for 900 years.

Some knowledgeable authorities claim that we will see the peak of oil and gas output in the United States by 1975. Others maintain that the reserves of these fuels in the ground and not yet proved are really far in excess of what we now consider to be a fair estimate. But nobody really *knows*. It is but a short step from the field of reasonable deduction to the fields of conjecture and outright guessing.

One thing we must realize is that resources of natural energy fuels, on which our entire industrial and social economy depends, *are* limited. For this reason, it seems only good sense that the U.S. Government initiate a study directed toward establishing a national policy in the utilization of our energy fuels. These fuels are not just important and lucrative to their developers. They are the very life blood of our Nation. Whether the limits of these fuels are reached in 1975, 2000 or in two centuries, there would seem to be nothing but benefit for the country in establishing now some form of objective study or policy that would insure the maximum and most beneficial use of our coal, oil, and natural gas resources. Soviet Russia clearly places vital importance on just such a policy. So does Canada, which has just appointed a National Energy Board comprised of five of the top men in the energy field in that country. Great Britain, Germany, Belgium—all have recognized the prime importance of nurturing carefully their energy fuels.

A national fuels policy in the United States would not "regiment" the use of our energy fuels, as some opponents of the fuels policy study have claimed. Neither would it be the "genesis of creeping socialism in the fuels industry" as other critics have accused. It would not seek to dictate. But it would seek to insure that in the use of what are unquestionably our most priceless natural resources, the interests of the American people today and those of generations unborn, would be given at least an even break with the interests of immediate profit.

Representative PATMAN. Thank you very much.

Mr. Widnall has a question.

Mr. WIDNALL. You say that the number of operating bituminous coal mines had decreased from 9,429 to an estimated 7,588.

Mr. MOODY. That is correct.

Mr. WIDNALL. Were those mines abandoned because the veins had run out or for economic reasons? How is that broken down?

Mr. MOODY. That is pretty hard to define. It is very difficult to actually analyze. However, under the Bureau of Mines classification, these mines are indicated as working mines that were discontinued in operation, not worked out.

Mr. WIDNALL. And some because of being economically unsound?

Mr. MOODY. That is right. They could have been marginal mines. They could have been noncompetitive. They could have lost their markets. Or it could be that a company that had eight or nine mines would cut three off, but put in maybe an additional section in another.

Mr. WIDNALL. Would they be holding some of those mines in reserve?

Mr. MOODY. A coal mine is extremely difficult to hold in reserve, Congressman. It is very expensive. You can maintain them, but you have roof falls, you have water problems, you have breakdowns in your hallways and shafts and equipment. You can't afford to keep your equipment in there, your conveyor equipment. The result is that once a mine is down, unless you have some very real reason to believe that you are going to reopen it, it is much easier to pull your equipment and start another mine at some place else on the mountain than it is to go back into the old mine. It is extremely difficult to do.

Mr. WIDNALL. The mines that are now operating, the 7,588, can meet the foreseeable production needs during the next couple of years, is that so?

Mr. MOODY. Anything that we think we need in the next couple of years, of course, is anticipated by the industry, that is correct.

Mr. WIDNALL. You are actually operating at a rate of about 400 million tons as against a productive capability of 520?

Mr. MOODY. We hope even in spite of the steel strike it will be a 435 year, but we are getting a little nervous the way the thing is going.

Representative WIDNALL. That is all, thank you.

Representative PATMAN. Thank you, sir.

Our next witness is Mr. Veryl Hoover, general manager, Wyoming Division, Pacific Power & Light Co., Casper, Wyo.

I am sure Senator O'Mahoney would like to be here today but he has been unavoidably detained. Senator O'Mahoney, one of your U.S. Senators, was one of the first chairmen of this committee, and was chairman for a long period of time. He takes a great deal of interest in this committee's work.

STATEMENT OF VERYL N. HOOVER, GENERAL MANAGER, WYOMING DIVISION, PACIFIC POWER & LIGHT CO., CASPER, WYO.

Mr. HOOVER. We in Wyoming think a great deal of Senator O'Mahoney, and we wish wholeheartedly for his speedy recovery.

Representative PATMAN. You may proceed.

Mr. HOOVER. Mr. Chairman, I would like to preface my remarks by explaining that I have confined my statement generally to the Rocky Mountain area because that is the area with which I am most familiar, and particularly to the State of Wyoming as an illustration of what my company along with some others is doing to utilize and encourage the utilization of an almost dormant energy, lignitic and subbituminous coal.

My name is Veryl N. Hoover. I reside in Casper, Wyo., and am general manager of the Wyoming Division of Pacific Power & Light Co. It is both an honor and a pleasure to have the opportunity of appearing before you today.

With your permission I desire to comment briefly on the energy resources of Wyoming, and then outline how my company is utilizing a once-dormant energy—subbituminous coal—in the development of the Great State of Wyoming.

WYOMING ENERGY RESOURCES

Mother Nature blessed Wyoming with a variety of abundant energy resources. Among the States, Wyoming's energy reserves rank second in uranium, fourth in coal, fifth in petroleum, and seventh in natural gas. This unique concentration of potential energy leads us to think of Wyoming as the energy capital of the Nation. Such huge storehouses of energy assure a great future for Wyoming.

Here are some statistics of Wyoming's known energy reserves:

Uranium: 11,500,000 tons of 0.31 percent uranium oxide (U_3O_8). (Estimate as of January 1, 1959, by U.S. Atomic Energy Commission.)

Coal: 121,000 million tons, of which about 11 percent is bituminous and 89 percent subbituminous and lignitic. (1950, Circular 81, of U.S. Geological Survey.)

Last year coal was produced in 9 of Wyoming's 23 counties. At one time, 17 counties reported coal production.

Petroleum: 1,460 million barrels of crude oil and natural gas liquids, proved reserves. (Estimate as of Jan. 1, 1959, by Independent Petroleum Association of America.)

Natural gas: 3,650,000 million cubic feet of natural gas, proved reserves. (Estimate as of Jan. 1, 1959, by Independent Petroleum Association of America.)

Approximately 48 percent of Wyoming's land area is under oil and gas leases. There is oil and/or gas production from 20 of Wyoming's 23 counties.

That's all the statistics I shall present on Wyoming energy reserves. No doubt the subcommittee has many statistics available already on this subject, for my State, and the 49 other States.

To round out the picture, I should mention also the long-range possibility of extracting oil from shale beds in Wyoming, Utah, and Colorado. Much progress has been made to date, and this potential energy reserve will become more important in the future.

There are two other extensive sources of energy in our State, which should be borne in mind, and those are solar energy and wind energy.

Wyoming has 2,600 to 3,100 hours of sunshine annually, depending upon the location. As a comparison, it is reported that California has 2,400 to 3,800 hours of sunshine per year. Solar energy is not presently harnessed by Wyoming industry. Neither is there any industrial utilization of wind energy in our State. I doubt if any great use will be made of solar energy and wind energy in Wyoming for industrial purposes during our lifetimes, since we have such abundant supplies of fossil fuels, and these reserves have more desirable utilization advantages for modern industrial applications.

Before getting into the principal part of my presentation—the use of subbituminous coal in generating electric energy—I would like to comment briefly on the harnessing of falling-water energy.

The economically feasible hydroelectric sites of important magnitude have already been developed in Wyoming. Just north of the Wyoming border, in Montana, is the Yellowtail damsite on the Big Horn River. This proposed project would provide water for irrigation as well as generating a sizable block of power. Additional hydroelectric projects with special characteristics, such as peaking, may be built from time to time. But other new sources must provide our principal power base for the future.

Thorough investigations by our company engineers show that steam-electric generating facilities, fired with local coal, are an economical method of producing additional electric energy in large quantities in Wyoming.

It is doubtful if electricity will be produced from atomic energy in Wyoming during the next decade, even though there are abundant uranium reserves in the State. Wyoming's plentiful coal deposits are found under 41 percent of the land area. Much of it can be easily mined. It appears that for many years the costs of producing atomic power will exceed the cost of power generated from Wyoming coal. Most of the Wyoming coal is of low rank, in the lignitic and subbituminous classes, which is not now usable for coking or other specialized purposes, but does make satisfactory power plant fuel.

This doesn't mean that Pacific Power isn't interested in utilizing atomic energy for electric power production. Our company is actively participating with a group of other electric light and power companies and the Atomic Energy Commission in research and development of power from a gas-cooled reactor. Also, we have research progressing, in cooperation with other utilities, on direct conversion of heat to electricity. We shall be ready to use atomic power when the time comes.

GENERATING ELECTRIC ENERGY FROM COAL

After months of geological exploration and core drilling, a satisfactory field of low-rank coal, located about 15 miles northeast of Glenrock, was found sufficient and satisfactory to supply a steam-electric plant.

Discovering this particular coal deposit is a heartening story of a community's faith in itself. The potential coal deposit was called to our attention by a special group of citizens speaking for Glenrock's 1,200 people, who were seeking a new industry to take the place of an oil refinery that had been closed because of obsolescence. They were optimistic about the usability of coal deposits in the area and our explorations confirmed their optimism. Today, Glenrock is well on the way to becoming a thriving community. A substantial number of new homes are being built to take care of the population increase. According to Glenrock's chamber of commerce, the community's population at present is approximately 1,800 people.

Ground was broken at our Dave Johnston plant site along the North Platte River, about 6 miles east of Glenrock, on June 30, 1956. And, on December 20, 1958, an ultramodern 100,000-kilowatt steam-electric plant was officially dedicated. More than $23 million was expended for this generating plant and the related coalfield developments.

We are so well satisfied with this first unit that in May of this year we began the construction of a duplicate 100,000-kilowatt unit to be completed by the end of 1960 to meet the rapid growth in power requirements. This addition is estimated to cost $18 million. And we will add another unit when necessary to carry the load, and others after that as more power is needed. This steam-electric plant site was planned with at least four generating units in mind. In fact, it can be expanded to an ultimate total of 1 million kilowatts as power needs grow. Because of the characteristics of our Glenrock coal, it can best be utilized near the source. Our plant is practically a "mine mouth" operation.

We purchased 2,574 acres of land so that there would be plenty of space for various new industries to locate near our plant if desired.

Coal utilization

The coal is hauled in specially built, 70-ton trucks over our 16-mile private road, which cost us more than $1 million to build. At the plant, the coal is crushed and then pulverized for burning in the 170-foot-high boiler furnace. This is the only coal processing done.

Pacific Power leased 3,960 acres of Federal coal land, and 3,840 acres of State coal land. The overburden varies from 0 to 140 feet. There are two coal veins varying from 25 to 40 feet thick. The heat value averages about 7,000 B.t.u. per pound of coal.

Because of this coal's low-heat value, it requires about 1½ pounds of coal to generate 1 kilowatt-hour of electricity, even though we have installed the most efficient steam-electric equipment available, which operates at high temperatures and high pressures for best efficiencies. The plant was especially designed, at considerable extra expense, to burn this low-rank coal. Most of the thermal plants in other parts of the Nation burn a higher grade coal, having from 12,000 to 13,000 B.t.u. per pound and higher. Consequently, they generate 1 kilowatt-hour of electricity with less than 1 pound of coal.

Since this Glenrock coal has a low heat value, high moisture content, and breaks up easily, it is uneconomical to ship it any great distance to market. Thus, about the only economical use for it is as a local fuel, and the major market for it at present is in steam-electric generation. When converted to electric energy, the once dormant coal energy can be readily "shipped by wire" over electric transmission lines to many markets.

Pacific Power dedicated a new 161,000-volt transmission line on September 11, 1957, extending 251 miles from Casper, Wyo., to Billings, Mont., connecting central Wyoming with the Northwest Power Pool. This heavy-duty line and related substations represent an $8 million investment. This facility and other company powerlines were built to market electric power made from Wyoming's low-heat coal, as well as to bring in power whenever needed.

If it were not for the new Glenrock steam-electric plant, this low-rank coal would probably continue to lie unused. What's really important now, is that this new plant is playing a vital role in the expansion of the State's economy by making abundant electric power available for every purpose, and it should help attract new industry to our State.

The boiler furnace of the new 100,000-kilowatt powerplant unit at Glenrock consumes about 1,100 to 1,600 tons of coal per day. In a year's time this amounts to about 500,000 tons of coal.

A 100,000-kilowatt unit is equivalent to about 135,000 horsepower. In reviewing Wyoming's agricultural statistics for 1958, I find that there are only 51,000 horses in our State. This comparison is but one homely illustration of the growing importance of electric power in today's "space age."

Five fuels utilized

In addition to burning coal, the boiler furnace of this 100,000-kilowatt unit at Glenrock is equipped to burn four other Wyoming fuels: Light oil, heavy oil (known as bunker C), pitch, and natural gas. This unique arranagement makes it possible to utilize whatever fuels are most economical and best suited to ever-changing conditions of operation, as well as to meet emergencies in the curtailement of any fuel supplies.

Most of the time we burn coal at the Glenrock plant because it is the most economical fuel available. But, whenever the generation is less than 35,000 kilowatts on this 100,000-kilowatt unit, which happens occasionally during the night, we may also operate the oil burners to sustain the combustion of the pulverized, low-heat coal.

1958 coal legislation

The feasibility of coal-to-electric power developments, such as at Glenrock, was strengthened by congressional passage of a bill last year sponsored by the 1958 Wyoming congressional delegation, Senators Joseph C. O'Mahoney and Frank A. Barrett, and Representative Keith Thomson.

This legislation amends the Mineral Leasing Act of 1920. It provides for increasing the allowable coal acreage which can be leased on Federal lands by one person, one association, or one corporation, in any one State, from 5,120 acres to a total of 10,240 acres; and as much as 5,120 acres more, in multiples of 40 acres, in individual cases if, after public hearing, the Secretary of the Interior finds this to be in the public interest and necessary for economical operation of the applicant's business.

This provision makes it possible to obtain enough low-rank coal to supply several electric generating units at separate locations in any one State, which is so essential for the growth of steam-electric generation in this region.

COAL UTILIZATION RESEARCH

We anticipate a great future in Wyoming for electric power made from coal. And, we believe advancements in the technology of coal utilization will continue to make coal an economical fuel in Wyoming for generating electricity in the foreseeable future.

NRRI studies

Our State has an agency known as the Natural Resources Research Institute, functioning as the enginering experiment station of the University of Wyoming, and located on the campus at Laramie, Wyo.

The object of the institute is to aid in the development of the natural resurces of the State, and to promote its industrial growth and the wider utilization of the minerals, fuels, and other resources through laboratory investigations and research upon these resources.

The institute pursues research on fundamental long-range projects, largely sponsored by the university, as well as on industrial projects sponsored by industry, the Wyoming Natural Resource Board, and other governmental agencies.

Among its many projects, the institute has been conducting research on coal utilization since 1945. A three-man staff is presently assigned to coal studies, supplemented by assistants drawn from the university teaching staff and students.

Research work at the present is concerned mainly with the products derived from carbonization, a process whereby coal is converted into char or semicoke, tar, and gas. Methods are being studied for converting this tar and gas into products which are acceptable as petroleum refinery raw materials. Considerable effort is being expended to achieve this objective by hydrogenation and other processes. If such processing can be accomplished economically, then the solid products of carbonization, the chars, can be used directly as an efficient industrial fuel.

In its efforts to upgrade the char, to bring a greater financial return for coal operation, the institute has developed a process for making synthetic coke from char. Also, work is in progress to develop special carbons for adsorption purposes and for metallurgical uses. These efforts are all directed toward enlarging markets for Wyoming coal.

MARKET DEVELOPMENT

As far as we can tell, the major limitation of electric power production in Wyoming is its marketability, not the availability of fuel to produce it. There is plenty of coal in Wyoming to produce electricity.

We are constantly investigating new markets for electric service. One approach is to reach more distant markets economically by overcoming line losses in transmitting electric energy. Much progress has been made in operating transmission and distribution lines at higher voltage to reduce transmitting losses, and further advancements are anticipated in the future. Another program involves aggressive and enthusiastic business development, that is, (1) encouraging and working with present customers to help them use more electric service beneficially, and (2) securing new customers and new industries.

We consider it our duty and purpose as a citizen of Wyoming to help the State grow, for we grow only as the resources in the territory we servé are developed.

Wyoming has a vast storehouse of minerals, both metals and nonmetals, which are awaiting development. New techniques are constantly being perfected which eventually mean that the State's so-called low grade ores will be processed in the future, as demands for certain minerals increase, and as existing deposits elsewhere become depleted. To me, Wyoming is a sleeping giant which is now awakening and beginning to flex its industrial muscles.

Our management is very enthusiastic about Wyoming's future industrial development and economic expansion. A sizable investment has been made already to provide abundant electric power in advance to attract new industry. By the close of 1960, Pacific Power will have expended approximately $60 million for new electric facilities in a 5-year period, or approximately $1,500 for each of the 40,000 customers we serve in Wyoming.

The management of Pacific Power has affirmed many times the company's readiness to provide whatever quantity of electric power may be required in its service area for the development of new enterprises and the expansion of existing businesses and industry. Pacific Power is prepared to invest still more private capital to keep ahead of the

State's electric energy requirements, and serve the best interests of Wyoming power users, at no expense to the taxpayers.

Various utility companies plans

Utah Power & Light Co. has begun the construction of a 150,000-kilowatt thermal plant in southwestern Wyoming near Kemmerer scheduled for service in 1963. Electric energy from the new plant will be transmitted by high-voltage lines to Utah Power's customers in southwestern Wyoming, eastern Idaho, and throughout Utah. A dam and storage reservoir are being provided upstream on the Ham's Fork River for plant-cooling purposes. The Kemmerer site was chosen because there is plenty of water and coal in the area to supply this plant and its contemplated expansion.

Increasing interest in coal utilization elsewhere in the Mountain States area is shown by other projects such as the following: Open-pit mining at Gillette, Wyo., for steam-electric generating stations at Osage, Rapid City, and other plants of the Black Hills Power & Light Co.; open-pit mining at Sidney, Mont., for a new powerplant built by the Montana-Dakota Utilities Co.; planning for a large steam-electric generating station in the "four corners" area of southeastern Utah to burn local coal; use of the Colstrip mining area east of Billings, Mont., for expanding steam-electric generation by the Montana Power Co.; and acquisition by Reynolds Metal Co. of coal lands in the Lake DeSmet area of Wyoming for future power generation in connection with aluminum reduction.

Pacific Power & Light Co. has an active program of exploration and development, which is not only looking into future fuel supplies and powerplant sites in the Wyoming area, but also has done considerable work in exploring potential coal producing areas in the Centralia, Wash., and the Eden Ridge, Oreg., areas. These sites for steam-electric plants will in the future augment the hydropower supply in the Northwest which will be reaching its limit of economic development.

Electric usage growing

The upward trend in electric usage, plus population growth, largely explains why the Nation's generating capacity has doubled every 7 to 10 years. This rate isn't expected to decline in the near future since electric power expansion is so closely related to the Nation's economy, which leading economists predict will grow substantially in the future. There is a direct relationship between the use of electric energy and the standard of living.

According to a Federal Power Commission report, the Nation's present generating capacity of all electric utilities and private industry is 160,219,000 kilowatts. The Federal Power Commission projects an increase of 147 million kilowatts by 1970 in all plants, and another 144 million kilowatts by 1980, resulting in a total installed capacity of 451 million kilowatts by that date, or about three times the present installed capacity.

Electric industry leaders point out that most of this new generation will probably come from steam-electric plants burning fossil fuels, principally coal, simply because U.S. coal reserves are so extensive, as compared to the other fuel reserves.

The Edison Electric Institute's 1958 report showed the electric utility industry generated 55 percent of its electricity from coal, more than 18 percent from gas, about 6 percent from oil, and nearly 21 percent from hydroplants. Even if these ratios don't change in the future, which I doubt, the increased electric energy requirements during the next decade represent an expanded market for many more tons of coal.

Approximately 41 percent of the Nation's coal reserves are located in the 10 States making up the Missouri Basin region. Yet, it is reported that in 1957 the production of subbituminous and lignitic coal in the basin States was less than 1½ percent of the national solid-fuel total.

This condition indicates the tremendous opportunity existing for expanding coal output in the Missouri Basin region. Wyoming, like her sister States of this basin, will benefit from the enormous expansion in future electric power production.

In 1958, Wyoming mines produced 1,630,000 tons of bituminous, subbituminous and lignitic coal, representing a 23 percent decrease from 1957 output. Back in 1943–45, more than 9 million tons of coal were produced annually. In 1958, approximately 600 men were employed in Wyoming coal fields, compared to about 4,700 in 1943–45. I cite these figures to emphasize the importance of the coal industry in Wyoming's economy. And its prominence becomes even greater when we consider the business generated in utilizing the coal output.

It's entirely possible that Wyoming's coal output can double or triple in the next few years, largely from its use to generate electricity.

For example, the peakload on Pacific Power's Wyoming lines in January 1959 was nearly 109,000 kilowatts, and is expected to be 115,000 kilowatts in January 1960. By 1965 the electric power peak is expected to reach about 285,000 kilowatts, and by 1975 about 675,000 kilowatts. Thus, you can see we expect our peakload between 1960 and 1965 to more than double in 5 years, a rate considerably higher than the national average.

I cite this example to emphasize that there is no doubt in my mind about the tremendous growth yet to come in the use of electric energy in Wyoming, and in the Nation generally.

And I firmly believe that the burning of coal to generate electricity will become an even greater market for coal production in the near future, not only in Wyoming but in other areas where coal is highly competitive with other fossil fuels.

Representative PATMAN. Thank you. Do you have a question, Mr. Widnall?

Representative WIDNALL. No.

Representative PATMAN. You mentioned about low grade ores. What kind of ore do you refer to there?

Mr. HOOVER. We have an abundance of low grade ores, principally iron ore.

Representative PATMAN. Iron ore?

Mr. HOOVER. Yes, sir.

Representative PATMAN. What percent metal?

Mr. HOOVER. I am not sure what the percentage is. I know at the present time, Columbia-Geneva Steel Division of United States Steel is considering the construction of a beneficiating plant near Atlantic City, Wyo. They will transport the upgraded ore from Wyoming to Provo, Utah, their smelter. The beneficiation plant is being built at the site of the ore, and they will upgrade the ore there and move it to their plant at Provo.

Representative PATMAN. Thank you very kindly, sir.

To add to the completeness of the record in respect to subbituminous and low grade coals, I think we might supplement Mr. Hoover's statement by including at this point in the record a chapter from "Mineral Facts and Problems" entitled "Lignite and Peat," by the staff of the Division of Solid Fuels, Bureau of Mines, and a summary page dealing with lignite from the Bureau of Mines report on "Bituminous Coal and Lignite in 1958," released on September 9, 1959.

Operations at underground and strip lignite mines in the United States, 1958, by States[1]

[Excerpt, Mineral Market Summary, "Bituminous Coal and Lignite in 1958," Department of the Interior, Bureau of Mines]

Item	Montana	North Dakota	South Dakota	Total
OPERATIONS AT UNDERGROUND MINES				
Number of mines	5	1		6
Shot from solid ... net tons	15,622	3,049		18,671
Cut by machines ... do				
Total production ... do	15,622	3,049		18,671
Number of cutting machines				
Average output per machine ... net tons				
Underground production cut by machine ... percent				
Average value per ton	$4.27	$4.73		$4.34
Average number of men working daily	20	5		25
Average number of days worked	117	117		117
Number of man-days worked	2,348	586		2,934
Average tons per man per day	6.65	5.20		6.36
OPERATIONS AT STRIP MINES				
Number of strip mines	4	36	1	41
Production ... net tons	77,986	2,310,809	19,571	2,408,366
Average value per ton	$1.95	$2.33	$4	$2.34
Number of shovels and draglines	4	54	3	61
Average number of men working daily	22	322	9	353
Average number of days worked	94	202	266	197
Number of man-days worked	2,078	65,159	2,390	69,627
Average tons per man per day	37.53	35.46	8.19	34.59
TOTAL OPERATIONS AT ALL LIGNITE MINES				
Number of mines	9	37	1	47
Production (net tons):				
Shipped by rail[2]	73,657	1,685,643		1,759,300
Shipped by truck	19,898	326,869	19,371	366,138
Used at mines[3]	53	301,346	200	301,599
Total	93,608	2,313,858	19,571	2,427,037
Average value per ton	$2.34	$2.34	$4	$2.35
Average number of men working daily	42	327	9	378
Average number of days worked	105	201	266	192
Number of man-days worked	4,426	65,745	2,390	72,561
Average tons per man per day	21.15	35.19	8.19	33.45

[1] Exclusive of Texas (lignite).
[2] Includes coal loaded at mines directly into railroad cars and hauled by trucks to railroad sidings.
[3] Includes coal transported from mines to point of use by conveyor belts or trams, used by mine employees, taken by locomotive tenders at tipples, used at mines for power and heat, made into beehive coke at mines, and all other uses at mines.

[Preprint from Bulletin 556, Bureau of Mines]

LIGNITE AND PEAT

A Chapter From Mineral Facts and Problems

(By Staff of Division of Solid Fuels)

The first stage in the metamorphosis of vegetable matter to coal is peat. As it has been for millions of years, peat is still being formed today in swampy regions where mild temperatures favor luxurious plant life. Lignite, in turn, is the first coalified product of peat and, in the United States at least, the lowest rank of combustible matter that is used for burning, gasifying, and coking—the normal large-scale outlets for coal.

SUMMARY

Peat—the first stage in the coalification process—differs from coal in that it consists predominantly of water. Peat, containing about 90 percent water, has only about one-quarter of the peat substance as plant remains, and these vary greatly depending upon the botany of the areas where it is found. On the other hand, lignite contains only about 30 to 40 percent water. Like all material of vegetable origin, peat and lignite contain carbon, hydrogen, oxygen, nitrogen, sulfur, and other elements in small amounts.

Of the 14 billion tons of known reserves of peat in 26 States of the United States, over 10 billion occur in Minnesota, Wisconsin, and Michigan. Lignite deposits have been found only in the Northern Great Plains, the Rocky Mountains, and the gulf and Pacific areas.

Although peat has been used as a fuel in other countries, the abundance of higher rank fuels in the United States has kept peat out of the fuel and energy fields. Instead, it is used primarily for soil improvement, as a conditioner and filler in mixed fertilizers, as mull or litter material for domestic animals, as packing material, and in chemical applications such as filtering and tanning. Montan wax can be extracted from some kinds of peat.

Lignite, obtained primarily in strip-mining operations, can be used for heat and power generation, as an absorbent of liquids from gases, as a source of industrial gas, and to make industrial carbon for decolorizing and refining sugar.

Montan wax can also be derived from lignite. Unlike bituminous coal, lignite does not yield coke upon carbonization but a char that can be used as a briquetted fuel and as activated carbon.

BACKGROUND

ORIGIN AND CLASSIFICATION OF COAL

Peat and coal are classified according to their nature and chemical composition; these in turn depend on the kind of original plant material, its partial decay in the peat swamp, and subsequent metamorphism by geological processes throughout the ages. The following description of the origin and nature of peat and coal is adapated from a Bureau of Mines publication, entitled "Facts About Coal."[1]

Formation of peat and coal

Although coal is commonly thought of as a mineral, it differs from the usual minerals, such as stone and iron ore, because it is of organic origin, meaning that coal was formed from the remains of living things—trees, shrubs, herbs, and vines—that grew millions and millions of years ago during periods of mild, moist climate. During those periods there was heavy growth of trees, ferns, and other plants in swamps and bogs. Century after century the vegetation died and accumulated. Buried to a gradually increasing depth each year by new accumulations, the remains of roots, trunks, branches, and leaves changed gradually to peat, just as decaying vegetable matter is doing today in the Dismal Swamp of Virginia and North Carolina and in smaller swamps and bogs in many areas.

Peat is the first product when organic matter begins to change to coal. In a block of peat one can often see, with the naked eye, woody fragments of stems, roots, and bark. As peat is buried, it is cut off from the oxygen in air, and rapid decay of its organic matter is prevented by slowing bacterial action. The

[1] A selected bibliography of lignite and peat appears at the end of this chapter.

weight of more vegetation falling on the peat helps to compress and solidify it, as does the weight of water when the deposit sinks below a lake or sea, as has often happened. Sometimes mineral sediments have settled from muddy flood waters while vegetable matter was accumulating and formed "partings" or layers of shale in the coal vein. At the end of coal-forming periods swamps remain flooded for a long time; and earthy sediments are deposited in thick beds over the peat, further compressing it and starting "coalification," the coalmaking process.

Coalification is extremely slow when it depends mainly upon pressure generated by overlying rock. For this reason, many coal deposits are still of "low rank," that is, in an early stage of coalification, although they have been buried millions of years. A few deposits, however, are situated where profound movements of the earth's crust occurred during periods of mountain building. This rock movement generated much additional heat and pressure, producing "high rank" coals, such as medium- and low-volatile bituminous coal and anthracite. Sometimes additional heat and pressure came from the movement of molten rock oozing from deep, hot regions of the earth into its outer crust.

TYPES OF PEAT

Peat is extremely varied in nature and composition due to climatic conditions and differences in the types of plants growing in peat-forming areas. The physical form of peat varies greatly, but all raw peat contains 85 to 92 percent water. Its rate of accumulation in an active swamp has been estimated at about 10 feet in 2,500 years. When dry, peat is combustible, burning with a yellow flame during the first part of its complete combustion and with a red glow similar to wood during the latter stage. Although no general agreement exists on the classification of peats according to their botanical characteristics, they may be divided, according to gross botanical composition, into the four following groups:

Sphagnum.—Peat of this type is formed mainly of several species of sphagnum (moss), usually intermixed with small quantities of various plants and shrubs, such as ferns and sedges, orchids, sundews, pitcherplants, and often cranberry. Sphagnum peat is usually loose, spongy, and often layered; it varies from light grayish brown to deep brown in color. It is nearly always strongly acid.

Hypnum and other mosses.—These peats are composed mostly of disintegrated plants of hypnum, often associated with other mosses and with intermingled rootlets of sedges and other flowing plants. They are formed chiefly in areas where the ground is only slightly acid, neutral, or slightly alkaline. The material is brownish or drab, light, spongy, and matted, and often laminated and porous.

Reed sedge.—Deposits of this type are formed mainly in shallow areas around the border of water-filled depressions, of which they gradually take possession, or in boggy meadows. Important constituents of this group are plants of the sedge family, cattail (typha), various grasses, and miscellaneous shore and swamp-loving plants of other families. In their normal development, peats of this type are rather fibrous and somewhat felted or matted; they consist mainly, so far as recognizable vegetable matter goes, of roots and rootlets of the plants mentioned and often contain the rootstocks or stems of the plants. They are light yellowish to reddish, rusty brown, or even blackish.

Shrub-and-tree.—The greater part of the peat of this group consists of material derived from roots, tree trunks, branches, twigs, and bark, in a tangled mass and not highly decomposed, mixed with remains of leaves, ferns, rootlets, and often in a matrix of more finely divided material.

No standards have yet been developed for classifying peat into fuel grades. The Federal Trade Commission established rules for the agricultural classification of peat in January 1950, one of which forbids representing a product as moss peat unless at least 75 percent, on a dry basis, is peat derived from mosses. Some municipal and State governments have set up (agricultural) standards for peat they purchase; and all peat procured by the Federal Government must conform to specifications defined in the Federal Stock Catalog (sec. IV, pt. 5, Q-P 166-3, November 1947).

RANKS OF COAL

The rank or degree of coalification of the higher rank coals is determined by "proximate analysis," a cehmical analysis in which coal is decomposed into four constituents: (1) Water, called moisture; (2) mineral impurity, called ash, left when the coal is completely burned; (3) volatile matter, consisting of gases driven out when coal is heated to certain temperatures; and (4) fixed carbon, the cokelike residue that burns at higher temperatures after volatile matter has been driven off. For the lower rank coals, heating value and caking and weathering properties determine rank. The rank of coal increases as the amount of fixed carbon increases and the amounts of moisture and volatile matter decrease. Moisture and volatile matter were squeezed and distilled from coal during its formation by pressure and heat, thereby raising the proportion of fixed carbon. That this change is great will be seen from the following analyses, in percent, on an ash-free basis, of a typical lignite, the lowest rank of coal, and an anthracite, the highest:

	Lignite	Anthracite
Fixed carbon....percent..	33	92
Volatile matter....do....	26	5
Moisture....do....	41	3
Total percent....	100	100

Table 1 lists the ranks of coal. Lignite (including brown coal and lignite) ranges in appearances from brown to black. It yields a brown powder when ground or when rubbed over a rough, white surface. American lignite as mined contains 30 to 40 percent moisture. When exposed to air, it soon slacks or falls to pieces because of loss of moisture. Although large deposits of lignite exist in the United States, production is not yet important nationally partly because it occurs far from major markets. It is relatively difficult to store, and its heating value is low, making unprocessed lignite uneconomical to ship very far.

TABLE 1.—*Classification of coals by rank*[1]

[F.C.=fixed carbon; V.M.=Volatile matter; B.t.u.=British thermal units]

Class	Group	Limits of fixed carbon or B.t.u., mineral-matter-free basis	Requisite physical properties
I. Anthracite	1. Metaanthracite	Dry F.C., 98 percent or more (dry V.M., 2 percent or less).	Nonagglomerating.[2]
	2. Anthracite	Dry F.C., 92 percent or more and less than 98 percent (dry V.M., 8 percent or less and more than 2 percent).	
	3. Semianthracite	Dry F.C., 86 percent or more and less than 92 percent (dry V.M., 14 percent or less and more than 8 percent).	
II. Bituminous[3]	1. Low-volatile bituminous coal.	Dry F.C., 78 percent or more and less than 86 percent (dry V.M., 22 percent or less and more than 14 percent).	
	2. Medium-volatile bituminous coal.	Dry F.C., 69 percent or more and less than 78 percent (dry V.M., 31 percent or less and more than 22 percent).	
	3. High-volatile A bituminous	Dry F.C., less than 69 percent (dry V.M., more than 31 percent); and moist B.t.u.,[4] 14,000,[5] or more.	
	4. High-volatile B bituminous coal.	Moist B.t.u.,[4] 13,000 or more and less than 14,000.[5]	
	5. High-volatile C bituminous coal.	Moist B.t.u.,[4] 11,000 or more and less than 13,000.[5]	Either agglomerating or nonweathering.[6]
III. Subbituminous	1. Subbituminous A coal.	....do.[4]....	Both weathering and nonagglomerating.
	2. Subbituminous B coal.	Moist B.t.u.,[4] 9,500 or more and less than 11,000.[5]	
	3. Subbituminous C coal.	Moist B.t.u.,[4] 8,300 or more and less than 9,500.[5]	
IV. Lignitic	1. Lignite	Moist B.t.u.,[4] less than 8,300[5]	Consolidated.
	2. Brown coal	....do....	Unconsolidated.

[1] This classification does not include a few coals that have unusual physical and chemical properties and that come within the limits of fixed carbon or B.t.u. of the high-volatile bituminous and subbituminous ranks. All of these coals either contain less than 48 percent dry, mineral-matter-free fixed carbon or have more than 15,500 moist, mineral-matter-free B.t.u.

[2] If agglomerating, classify in low-volatile group of the bituminous class.

[3] It is recognized that there may be noncaking varieties in each group of the bituminous class.

[4] Moist B.t.u. refers to coal containing its natural bed moisture but not including visible water on the surface of the coal.

[5] Coals having 69 percent or more fixed carbon on the dry, mineral-matter-free basis are classified according to fixed carbon, regardless of B.t.u.

[6] There are 3 varieties of coal in the high-volatile C bituminous group; namely, 1, agglomerating and nonweathering; 2, agglomerating and weathering; 3, nonagglomerating and nonweathering.

Subbituminous coal is black; as mined, it looks much like the bituminous coal commonly seen in coalyards. It contains 15 to 30 percent moisture. The range of heating values of subbituminous A coal is the same as that of high-volatile C bituminous coal. Subbituminous coal is entirely noncoking. Like lignite, it weathers upon exposure to air and is subject to spontaneous combustion if not stored properly. Like lignite also, it is used principally in the areas where it is mined.

Bituminous coal is the most abundant and widespread rank of coal in the United States. It is the coal used most commonly for industrial, power, railroad, and heating purposes. Bituminous coals may be coking or noncoking. This property is not based on the rank of the coal but rather on whether it will produce a coke when processed in a coke oven. Nearly all eastern bituminous coals have coking properties but many western bituminous coals are noncoking or free burning.

A coking or caking coal is one that softens and flows when it becomes almost hot enough to take fire. As it is heated further, some degradation occurs, and volatile matter escapes as a gas. When the coal is heated red hot in a sealed oven when there is little or no air, a dull, gray, porous mass—coke—remains after most volatile liquids and gases have been driven off. Because coke consists largely of fixed carbon, coking is often called carbonization.

Noncoking bituminous coal may look like coking coal, and its composition may be similar, but it burns freely without pronounced swelling. Instead of a porous mass, it leaves a char or powdery residue. Noncoking and coking bituminous coals can be used interchangeably for many purposes, such as fuel for powerplants, railroads, and heating and cooking. For some purposes, however, coking coals are required, the principal one being the manufacture of coke for smelting iron ore in blast furnaces. Noncoking coals are preferred for cement and tile burning, for which a high-heating value and a high proportion of volatile matter are desirable.

Most bituminous coals appear black and lustrous in the pile, but close inspection shows a banded structure, with alternate layers of bright, glossy coal and dull, grayish black coal. In some coals this dull material predominates.

Anthracite, sometimes called hard coal, has a brilliant luster and uniform texture. It will not soil objects as does coal of lower ranks. Anthracite has a higher percentage of fixed carbon and a lower percentage of volatile matter than the lower rank coals. It burns slowly with a pale-blue flame, free from smoke. Most anthracite has a somewhat lower heating value than the highest grade bituminous coals, but its lack of soot and the fact that it will burn longer without attention make anthracite an ideal domestic fuel. Most of it is now used for heating and cooking.

CHEMISTRY OF COAL

Coal, like wood and peat, contains carbon, hydrogen, oxygen, nitrogen, sulfur, and other elements in small quantities. The proportions in which the major elements are present differ greatly in different kinds of coal, and the chemistry of coal is quite complicated. For practical purposes, however, coal is analyzed by proximate analysis or sometimes by a more complete test—ultimate analysis—to determine the relative amounts of chemical elements.

Moisture, sulfur, and ash are the undesirable ingredients of coal. Volatile matter and fixed carbon are the most important contributors to the energy produced when coal is burned; and producing energy in the form of heat is the purpose of most uses of coal.

When a scientist wishes to find the heating value of a sample of coal, he weighs an exact quantity of it. He burns this completely in a bomb filled with compressed oxygen and immersed in a carefully measured quantity of water. He takes the temperature of the water at the beginning of the test and again after the burning coal has warmed it. He can then calculate the heating value of the coal, which is commonly expressed in British thermal units a pound. One British thermal unit (abbreviated B.t.u.) is the amount of heat needed to raise the temperature of 1 pound of water 1° F.

FUEL RESERVES

The United States is fortunate in being richly endowed with mineral-fuel resources. It has one-third of the geologically estimated coal and lignite reserves of the world, one-fourth of the proved petroleum reserves, and perhaps one-third of the world's proved natural-gas reserves. The United States also is the greatest producer of solid, liquid, and gaseous mineral fuels. In 1953 this country produced 23 percent of the world output of coal, 50 percent of all petroleum, and probably 90 percent of the natural gas.

To satisfy a large and still increasing demand for liquid fuel, more petroleum deposits must be discovered, more petroleum imported, or, from the standpoint of self-sufficiency, synthetic liquid fuels made from natural gas, coal, or oil shale. Each of these procedures probably will be employed to some degree, depending on economic and national defense conditions.

Additional domestic reserves of petroleum are being found at a rate almost adequate to supply the increasing domestic demand, although the cost of delivery is increasing and importation of oil had grown to 13 percent of consumption by 1953. Development of oil deposits in South America, Canada, and the Middle East are making more oil available for importation to the United States under peacetime conditions and for supplying the growing demand of other countries. The first industrial plant in the United States is beginning to manufacture chemicals and oils from natural gas at Brownsville, Tex. Bureau of Mines research at Rifle, Colo., has demonstrated that liquid fuel can be made from oil shale at comparatively small increases over prices prevailing in recent years. The United States has large reserves of coal and lignite that can be converted to liquid fuel as prices of petroleum rise still further.

COMPARISON OF RESERVES OF MAJOR FUEL SOURCES

Ultimately, coal must be the primary source, not only of solid fuels, but of liquid and gaseous fuels as well, as will be seen from a comparison of coal reserves with those of petroleum, oil shale, and natural gas.

The Federal Geological Survey estimated the remaining coal reserves of the United States, not including Alaska, at 1,900 billion short tons as of January 1, 1953; these estimates include beds down to 14 inches thick for anthracite and bituminous coal and to 2.5 feet thick for subbituminous coal and lignite, and at depths not exceeding 3,000 feet. The estimates are largely geologically inferred and make no allowance for mining losses; moreover, they do not consider that beds less than 2 feet thick are not economically minable by present underground methods. Investigations by the Bureau of Mines and others have shown that, on the average, about 50 percent of the coal is recovered in underground mining. Losses include coal left in pillars in areas around oil and gas wells, under towns, railroads, roads, and streams, in riverbeds, in thin and impure beds, and in isolated areas not readily accessible for mining. For these reasons recoverable coal is considered to be half of the total estimated reserve.

As of December 31, 1953, committees of the American Petroleum Institute and of the American Gas Association estimated the proved reserves of crude oil at 28.94 billion barrels and natural-gas liquids at 5.44 billion barrels, making a total of 34.38 billion barrels of liquid hydrocarbons. The American Gas Association committee estimated the proved reserves of natural gas at 211 trillion cubic feet; the Geological Survey estimated the recoverable oil from shales, averaging not less than 30 gallons oil contend per ton, at 25 billion barrels, and for shale deposits having an average content down to 15 gallons of oil per ton at 500 billion barrels.

These figures cannot be directly compared, because they are not calculated on the same basis. Only proved reserves are given for liquid and gaseous fuels. These are increased each year by new discoveries and extensions of fields and decreased by the year's production. More oil and gas reserves will be proved in the United States; in this respect, these fuels differ from coal and oil shale.

The solid-fuel reserves are based largely on geological observations after limited exploratory drilling, especially in the Western States. No great accuracy is claimed for these estimates, but future exploration is not likely to add much to the solid-fuel reserves. Revisions will probably be downward as more data are obtained in the various coal fields.

Therefore, to compare reserves of fuels, one should express the figures not only in terms of energy content—British thermal units (B.t.u.)—but also indicate whether they refer to proved, measured, or indicated amounts of material recoverable by current methods. Proved reserves of oil and gas meet the last qualification. On the other hand, estimates of recoverable coal are long-term estimates, including considerable inferred and not proved reserves, as well as beds only 14 to 28 inches thick and those 2,000 to 3,000 feet below the surface and thus too expensive to mine at present. The Federal Geological Survey studied its recent reestimation of reserves in 10 States and concluded that one-fourth of the minable reserves would fairly represent the measured and indicated reserves of coal commercially recoverable by current production methods. This amount—237 billion tons—is one-eighth of the total reserves (1,900 billion tons).

The Geological Survey also has cited estimates of authorities on the total inferred reserves of petroleum and natural gas for present and future use and compared these with the minable reserves of coal (including measured, indicated, and inferred) without reference to cost of mining. These two types of estimates are given in table 2 in terms of British thermal units.

Column 1 of this table, showing 5,669 quadrillion B.t.u. for all mineral fuels, gives the measured and indicated reserves of coal now commercially minable, proved reserves of petroleum and natural gas, and estimated reserves of oil from measured and indicated oil-shale deposits averaging not less than 30 gallons of oil per ton.

TABLE 2.—*Estimated recoverable mineral-fuel reserves of the United States, as of Jan. 1, 1953*

Kind of fuel	Reserves (quadrillion B.t.u.)		Percent of total fuel reserves	
	Proved and commercially recoverable [1]	Total potential reserve	Proved and commercially recoverable	Total potential reserve
Coal	5,117	20,469	90.3	84.0
Petroleum, including natural-gas liquids	198	413	3.5	1.7
Natural gas	200	487	3.5	2.0
Bitumen from bituminous sandstone	4	8		
Oil from oil shale	150	3,000	2.7	12.3
Total	5,669	24,377	100.0	100.0

[1] Measured and indicated coal reserves are considered proved.

Column 2, showing 24,377 quadrillion B.t.u., gives the minable (one-half of the total), measured, indicated, and inferred reserves of coal without any deduction for thin or deep beds, the unproved reserves of oil and gas estimated on the basis of favorable geological formations, and the estimated reserves of oil from indicated, measured, and inferred oil-shale deposits averaging not less than 15 gallons of oil per ton.

The long-term estimate of coal reserves (including inferred and difficultly accessible coal) is four times the short-term estimate, the long-term oil and gas estimates are about twice the short-term estimate, and the long-term estimate of oil from oil shale is 20 times the short-term estimate, principally because leaner and much more abundant shales are included. Obviously, coal is the dominant fuel in both estimates. It contributes 90 percent of the total energy in the short-term and 84 percent in the long-term estimate. If coal had been used to satisfy the demand for liquid and gaseous fuels in 1953, over 4 times as much coal would have been used as the 488 million tons produced that year. This example illustrates the tremendous demands that will be made on the reserves of coal, oil shale, fissionable minerals, and other sources of energy as gas and petroleum deposits become depleted. The life of these fuel reserves cannot be estimated because of the many variable factors involved. No one can accurately predict demands, new discoveries, and the effect of further technological developments. Such "guesstimates" as have been made by competent scientists who have studied the question have ranged from 75 to 300 years for fossil-fuel reserves.

Reserves of peat and coal

Peat.—The United States contains extensive reserves of peat in at least 26 States. Table 3 shows the approximate distribution of know reserves by regions and States. Minesota has the largest reserves, followed by Wisconsin, Florida, and Michigan, in that order. The northern region, embracing New England, States bordering the Great Lakes, and Iowa, contains 80 percent of the total deposits of the country. Three States in this region—Minnesota, Wisconsin, and Michigan—contain 75 percent of the estimated deposits. The Atlantic coastal region holds 19 percent, and the Pacific and Gulf Coast States (exclusive of Florida) have less than 1 percent of the total.

TABLE 3.—*Known original reserves of peat in the United States, estimated on an air-dried basis, by region and State*[1]

[Thousand short tons]

Region and State	*Reserves*
Northern region:	
Minnesota	6,835,000
Wisconsin	2,500,000
Michigan	1,000,000
Iowa	22,000
Illinois	10,000
Indiana	13,000
Ohio	50,000
Pennsylvania	1,000
New York	480,000
New Jersey	15,000
New Hampshire	1,000
Vermont	8,000
Massachusetts	12,000
Connecticut	2,000
Rhode Island	1,000
Total	11,050,000
Atlantic coastal region:	
Virginia and North Carolina	700,000
Florida	2,000,000
Other States[2]	2,000
Total	2,702,000
Other regions:	
Gulf coast[3]	2,000
California	72,000
Oregon and Washington	1,000
Total	75,000
Total, all regions	13,827,000

[1] Geological Survey, Coal Resources of the United States, a Progress Report: Circular 293, Oct. 1, 1953, p. 38.
[2] Includes Delaware, Maryland, South Carolina, and Georgia.
[3] Exclusive of Florida.

The Minnesota and Wisconsin deposits have largely resulted from the decomposition of mosses, grasses, sedges, heath shrubs, and trees, and the texture varies from fibrous in the top layer to plastic in the bottom. The peats of Iowa, Illinois, Indiana, Ohio, Pennsylvania, and New Jersey are of similar texture, although usually more fibrous. Sphagnum peat abounds in the deposits of northern Minnesota, Wisconsin, and Maine, and some is also foud in other New England States. Sedges dominate plantlife in the salt marshes of the New England coast. Peat of the Atlantic coast region south of New Jersey contains little sphagnum, as both coniferous and deciduous trees contributed a large proportion of the vegetable matter of this peat. Peat in the Florida Everglades is composed largely of the remains of sawgrass and sedge.

Coal.—Table 4 gives the recoverable reserves of coal as of January 1, 1953. They total 950 billion tons and include bituminous 525, lignitic 232, subbituminous 186, and anthracitic coal 7 billion tons; however, the average heating values of the various ranks of coal decrease from 14,000 B.t.u. for low-volatile bituminous coal to 6,700 B.t.u. for lignite. Therefore, these coals have also been compared in terms of energy obtainable from them by converting the tonnages in column 1 to equivalent tons of bituminous coal of 13,000 B.t.u. per pound. Thus, a reserve of 232 billion tons of lignite equals 119 billion tons of 13,000 B.t.u. bituminous coal in heating value.

TABLE 4.—*Potential recoverable reserves of various ranks of coal as of Jan. 1, 1953*

Rank of coal	Billion net tons (1)	Equivalent billion net tons bituminous coal of 13,000 B.t.u. per pound calorific value (2)	Percent of total coal reserves on B.t.u. basis (3)	Heating values used in conversion, B.t.u. (4)
Anthracitic	7	7	1	12,700
Bituminous	525	545	64	13,500
Subbituminous	186	136	15	9,500
Lignitic	232	119	20	6,700
Total	950	807	100	-------------

Tables 5 and 6 show the distribution, by rank and geographical location, of coal reserves on the basis of equivalent heating value. According to this method of evaluation, about 54 percent of the minable reserves of coal and lignite occur in the Eastern and Interior provinces and 46 percent in the Northern Great Plains, Rocky Mountain, Gulf, and Pacific provinces.

TABLE 5.—*Distribution of recoverable coal reserves in terms of B.t.u. value, by ranks and provinces (weight basis)*

Rank of coal	Billion net tons of equivalent 13,000-B.t.u. coal				
	Anthracitic	Bituminous	Subbituminous	Lignitic	Total
PROVINCE					
Eastern	6.3	223	----------	----------	229
Interior	.1	206	----------	----------	206
Northern Great Plains, Rocky Mountain, Gulf, and Pacific	.4	116	136	119	327
Total	7	545	136	119	807

TABLE 6.—*Distribution of recoverable coal reserves in terms of B.t.u. value, by ranks and provinces (percentage basis)*

Rank of coal	Anthracitic	Bituminous	Subbituminous	Lignitic	Total
PROVINCE					
Eastern	1	27	----------	----------	28
Interior	----------	26	----------	----------	26
Northern Great Plains, Rocky Mountain, Gulf, and Pacific	----------	14	17	15	46
Total	1	67	17	15	100

A great difference in rank exists between eastern and western coals. Virtually all of the Eastern and Interior province coals except anthracite are coking bituminous coals. Coals of the Appalachian region are medium to strongly coking and in 1947 supplied 95 percent of the coal used for making coke. On the other hand, 70 percent of the coals of the Northern Great Plains, Rocky Mountain, Gulf, and Pacific Coast provinces are subbituminous and lignitic. These coals do not coke on heating.

TECHNOLOGY OF LIGNITE AND PEAT INDUSTRIES

Lignite

Mining.—Lignite mining follows, in general, the same principles and practices as bituminous-coal mining. At present, almost all lignite in the United States is produced at strip mines because plentiful deposits are available with relatively shallow cover. The operations (currently carried on in North Dakota, Texas, and California) are: (1) Removal of overburden by means of power shovels, draglines, or bulldozers; (2) excavation of lignite, largely by means of power shovels; and (3) loading and transportation to railroads or nearby consumers for sale as run-of-mine lignite or to tipples equipped with crushing and screening devices for sale as lignite that is graded according to size, ash content, and heating value.

The tonnage of lignite mined underground in the Dakota area is small. Most Texas production is now made by stripping and has recently expanded rapidly so that it nearly equals that of the Dakotas, which is about 3 million tons per year.

Preparation.—Lignite currently mined in North Dakota and Texas has low sulfur and ash content, hence its preparation entails little or no cleaning. When and if lignites containing objectionable amounts of impurities are brought into production, cleaning processes are expected to be similar to those used for anthracite and bituminous coal; however, its high moisture content (30 to 40 percent in American lignites) makes lignite less heavy per unit volume and consequently easier to separate from pyrite, marcasite, etc. (The approximate specific gravity of the different ranks of coal is: Anthracite, 1.62; bituminous coal, 1.37; and lignite, 1.25 to 1.32.)

Present methods of preparation include crushing and screening, drying, carbonizing, and pelleting or briquetting for ultimate use. Although lignite usually requires less preparation than higher rank coals, it presents a storage problem because of oxidation, spontaneous heating, and eventual ignition, particularly in piles of unsegregated sizes of lignite. This danger can be averted by crushing and compacting in place in a pile having small angles at the edges (about 17° to 20° from the horizontal).

Utilization.—Like other ranks of coal, lignite is suffering losses in domestic and industrial heating, where it has been replaced to some extent by more convenient and plentiful supplies of oil and gas. On the other hand, the industrial use of lignite is in its infancy. It is a cheap, plentiful fuel (either as mined or briquetted) for heating and power generation, a source of industrial carbon for decolorizing and purifying solutions (sugar refining), an absorbent of liquids from gases (gasoline from natural gas), and a source of industrial gases. Some lignite deposits yield montan wax. In the United States only small reserves in Arkansas and California yield enough such wax for commercial workability. In recent times the Ione, Calif., deposit has been worked for this purpose on a limited scale. Wax is extracted with solvents and used in polishes, rubber, insulation, inks, greases, coatings, adhesives, explosives, textiles, carbon paper, and hardened wood.

Lignite, like all low-rank coals, gasifies relatively easily and is thus a potential source of synthesis or water gas, containing hydrogen, carbon monoxide, and nitrogen and used for the production of ammonia (fertilizer), methanol and other alcohols, solvents, synthetic liquid fuels, and hydrogen. This gas is necessary for hydrogenation of coal to chemicals and liquid fuels and of oils for margarine and cooking fat.

Unlike the bituminous coals of the eastern United States, lignite does not produce coke. Carbonization yields a char that is relatively soft and is currently used as briquetted fuel in North Dakota and as activated carbon in Texas. The char is a rapid-burning fuel.

Lignite may be dried (from 35 to 40 percent to about 15 percent water) by high-pressure steam to yield lump fuel with a greatly decreased tendency to slack or fall apart with further loss of moisture. There are now no steam-drying operations in the United States.

Industrial exploitation of lignite in the United States—most deposits are in the Dakotas and Montana—has been limited to date, except locally as a fuel, because of two principal factors, the abundance of higher rank coals close to points of usage and a lack of industry and markets in the area of deposits. However, active development is in progress in Texas.

The outstanding potential use of lignite is as upgraded solid and liquid fuels and tar. The fuel produces electric power for making aluminum in Texas, even though that State is an oil- and natural-gas-producing center. In the first phase of processing, lignite is crushed to ¼-inch pieces or smaller and fed to a drying tower where a stream of hot gas (derived from the process itself) carries it upward and causes the moisture to vaporize and disrupt the pieces of lignite in about 40 seconds. The moisture content is thus reduced from 36 to 5 percent or less, and the heat value of the remaining, dry lignite is raised from about 6,800 B.t.u. to 10,800 per pound. Dust is recovered mechanically and can be burned to generate electricity. In a second phase dried, finely divided lignite is fed to a carbonizing tower, maintained at about 900° to 950° F., where it yields oil, tar, and char. The char is separated by means of a cyclone and burned for power. The oil and tar appear, at this stage of development, to have considerable potential value, which, when applied against the total cost of generating power, may make the latter very low. The key to commercial success of this process is development of uses and consequently markets for low-temperature tar and oils.

Peat

Technology.—The greatest progress in technology has been made in those countries where peat necessarily is used for fuel purposes because of lack or high cost of other fuels. Carbonization of peat for making char or charcoal, tar, and liquid byproducts has been studied in many countries, particularly Sweden, Germany, and Canada. In England peat extracts have been found to contain considerable quantities of wax of high melting point—suitable substitutes for low-grade montan wax obtained from German brown coal. Russian reports indicate the possibility of fermenting peat in solution or suspension to alcohol. The Russians are also reported to have developed very efficient combustion equipment for generating electric power from peat. Several large power stations are operating on peat in Ireland and Sweden. In the United States the Minnesota Iron Range Resources and Rehabilitation Commission has worked on the problem of using peat as a fuel for beneficiating low-grade iron ore.

Uses.—The principal use of peat in the United States is for soil improvement. Although some varieties contain a relatively high percentage of nitrogen (3 percent or more), peat is not a good fertilizer because the nitrogen is not readily given up as plant food like the "soluble nitrogen" of artificial fertilizer. Peat contains a large percentage of organic matter (humus), which is an excellent soil conditioner when used in large enough quantities. The second largest use for peat is as a conditioner and filler in mixed fertilizers, for which well-decomposed peat, suitably dried and ground, is ordinarily employed. In mixed fertilizers, peat acts as a carrier for the primary nutrients—nitrogen, phosphoric oxide, and potash—not as an agent for supplying plant food. Fibrous peat is also used as mull or litter material for bedding stock and for stable and poultry yards. Because of its moisture-absorbing qualities, it is used generally for stock bedding. Its deodorizing capacity makes peat useful in barnyards and stables, where it delays decomposition of the nitrogenous and other organic substances deposited on it. Nursery men, gardeners, and others use peat as a packing material for plants, shrubbery, fruit, vegetables, eggs, and fragile materials. Other uses for peat include filtering and deodorizing agents, dyestuffs, and tanning substances.

STATISTICAL DATA

Production, size, and geographical distribution of lignite industry

The production of lignite increased gradually to 3,370,000 tons in 1950 and then declined to 2,851,000 tons in 1953.

North Dakota has become the predominant lignite-producing State, having furnished 98 percent of the output in 1953. Before 1921 Texas was the principal lignite producer, with over 1 million tons annually as late as 1928, from which it declined to 18,169 tons in 1950. (Bureau of Mines statistics on bituminous coal and lignite do not include mines producing less than 1,000 tons per year.) However, Texas production should increase materially in the future to supply the new lignite-powered electric generation plant of the Texas Power & Light Co. at Rockdale.

Contrary to the generally downward trends in bituminous-coal production during the 1920's the 1930's, and following the postwar peak of 1947, the output of lignite in North Dakota has been unique in steadily increasing over the years. Of the various factors responsible for this trend, the most important one has probably been heavily increased production by strip mining and continued improvements in methods of utilization. Although total production in North Dakota has more than doubled between 1926 and 1953 (1,370,000 to 2,802,000 tons) the number of employees has been cut in half, and the number of mines has been reduced by two-thirds. On the other hand, production per man-day has increased from 6.56 tons in 1926 to 25.70 in 1953. The more rapid acceleration that began in 1940, when output per man-day was still as low as 8.57 tons, has continued through 1953. The average value of North Dakota lignite, f.o.b. mines, has more than doubled between 1940 and 1953 (from $1.17 to $2.36 per ton).

The tremendous swing to strip mining and the differences in average value per ton at the mine and in productivity per man-day as between underground and strip mining are indicated by the following data for 1953:

	Montana	North Dakota	South Dakota	Total
Underground mines:				
Production .... net tons	22,148	161,438	....	183,586
Number of mines	4	6	....	10
Average number of men working daily	16	95	....	111
Average production per man per day .... tons	7.67	8.13	....	8.07
Average value per ton	$3.80	$2.40	....	$2.57
Strip mines:				
Production .... net tons	2,655	2,641,120	23,671	2,667,446
Number of mines	2	40	2	44
Average number of men working daily	5	486	14	505
Average production per man per day .... tons	6.88	29.61	8.61	28.89
Average value per ton	$3.53	$2.36	$3.47	$2.37
Total all mines:				
Production .... net tons	24,803	2,802,558	23,671	2,851,032
Number of mines	6	46	2	54
Average number of men working daily	21	581	14	616
Average production per man per day .... tons	7.58	25.70	8.61	24.78
Average value per ton	$3.77	$2.36	$3.47	$2.38

Of particular interest are production data from Mercer, Ward, Burke, and Divide Counties, N. Dak., where output per man-day has reached averages of approximately 23, 27, 33, and 36 tons, respectively, and value f.o.b. mines in 1953 ranged from $2.29 to $2.59 per ton. Also, information from Bowman County, where output per man-day was over 43 tons in 1953 and value per ton f.o.b. mines was $1.73, is worthy of note.

The principal competitive source of energy in North Dakota is oil. No hydroelectric power is available nor is the cost of such power likely to be competitive with lignite-generated power for large-scale use. Although natural gas has not been a strong factor until recently, its potentials are considerable unless checked by increasing price trends.

The principal factors that have retarded the use of lignite are low B.t.u. values, problems of degradation and storage, and transportation costs. The combination of high freight rates (which provide a limitation to the movement eastward of North Dakota lignite) and a quality lower than that of bituminous coal moving into the upper Midwest markets from Central and Eastern coal fields has confined the general market for North Dakota lignite to a rather restricted area. Advancements in technology with respect to upgrading, increased efficiency at the consumer level, and development of alternatives to expensive transportation will be very important to the future of the lignite industry.

Production, size, and geographical distribution of peat industry

Production of peat in the United States averaged about 200,000 short tons annually in 1951–53. Compared with the average production in 1947–49, this figure represents a 54-percent gain. Production increased fastest on the west coast, particularly in Washington, where output advanced twentyfold in the past 5 years. Over half of production in 1953 consisted of peat humus, 37 percent of reed or sedge peat, and the remainder of moss peat.

Peat has been used as a fuel for centuries, notably in the Soviet Union, Germany, Sweden, Ireland, Denmark, and Holland. In the United States, however, its use as fuel has been negligible because of ample supplies of superior fuels at reasonable costs. In this country peat is used almost exclusively for agricultural and horticultural purposes.

In 1953 commercial production of peat was reported to the Bureau of Mines by 68 producers in 18 States; however, the output from these operations does not represent the total utilization of peat in the United States. Some municipalities operate peat plants for their own needs (to improve the soils of lawns and parks), and many owners of land containing peat use it for growing crops. The area of peat and muck soils under cultivation is not known but probably amounts to thousands of acres. Such use of peat is an important factor in its economic utilization.

The value of domestically produced peat, f.o.b. plants, totaled $1,617,947 in 1953. The value of an almost equal quantity of imported material was $7,333,749. Data on employment, wages and salaries, value of buildings, machinery and equipment, and other economic factors relating to the peat industry has not been published since the 1939 Census of Mineral Industries. Because of the growth of the peat industry since that time, this information is outdated; however, the results of a census of mineral industries covering 1954 will be available in the near future.

The peat industry is widely scattered over the United States. Washington led all States in peat production and in the number of active operations in 1953. Its producers supplied about one-sixth of the national output. Ohio, Florida, Michigan, and New Jersey produced half of the total domestic production. Other States where significant tonnages of peat were produced are Iowa, California, Pennsylvania, Connecticut, Indiana, and Colorado.

CONSUMPTION AND PRICES

Lignite

The decline in lignite production and consumption in Texas was due, of course, to the huge indigenous supplies of oil and natural gas; however, now that the large plant of the Texas Power & Light Co. at Rockdale is expected to use dried lignite for power generation, consumption of Texas lignite should increase substantially.

Consumption has increased in the North Central States because of reduced cost of production (heavy increase in strip mining) combined with adaption of lignite to use in railroads, steady growth of demand for electric power in the region, and lesser availability of alternate sources of energy than in other geographic areas.

Consumption of lignite for generating electric energy amounted to 1,509,282 tons in 1953, according to the Federal Power Commission. This use took 53 percent of total production. Consumption by States was: North Dakota, 1,097,777 tons; Minnesota, 237,105 tons; and South Dakota, 174,490 tons.

Peat

In 1953 the consumption of peat exceeded 400,000 short tons for the first time. This tonnage was nearly five times greater than in prewar years. The latest information available indicates that approximately 59 percent of the total quantity consumed in the United States was used for soil improvement, 24 percent for a conditioner and filler in mixed fertilizers, 15 percent for poultry litter and stable bedding, and 2 percent for all other purposes, such as packing material for plants, shrubbery, fruit, vegetables, and eggs.

In 1953 the average value of moss peat was $11.87 per ton, reed or sedge type $8.82, and humus $6.65. The average price per ton of all types increased slightly to $8.34. Peat sold for soil improvement is cheapest on the average, while peat for "other uses" is highest. In the latter group some peat that is marketed in small packages for household plants averages as much as $50 per ton.

FOREIGN TRADE

Imports of peat in 1953 reached an alltime high and approximated 200,000 short tons, a quantity nearly equal to domestic production. The total dollar value, however, was over four times that of the domestic product. All imported material was moss peat and, according to classifications set up by the United States Department of Commerce, was divided into two grades: (1) Poultry and stable and (2) fertilizer. The quantity of poultry and stable grade decreased slightly in 1953, whereas that of fertilizer grade increased by 35,777 tons (25 percent). The latter grade is usually of a higher quality, and the average unit value is correspondingly higher. The principal sources of imports are Germany (58 percent), Canada (more than 33 percent), Netherlands, and Ireland. Exports of American peat are virtually nil.

Outlook

LIGNITE

The future of lignite will depend considerably on the extent to which oil and natural gas become available in North Dakota and adjacent areas. Relative price levels of the respective fuels, including bituminous coal, will be the principal determinant in the industrial market and to some extent in domestic consumption, although factors of convenience have a strong effect upon domestic consumption.

Whereas domestic consumption of North Dakota lignite stayed ahead of industrial use until 1946, industrial use since then has increased steadily. With higher production of thermal power and steady rise in the availability of competitive fuels, industrial markets hold the key to any appreciable advancement in the production and use of lignite.

In addition to being limited in growth by high transportation costs, low B.t.u. values, degradation in storage and transit, and competition of oil and natural gas, the lignite industry in the North Central States is restricted by the fact that the region is primarily agricultural. The present consuming area for lignite extends about 300 miles east and southeast from the lignite deposits. The eastern market extends to the area where the cost of lignite is equaled by that of eastern coals delivered at the northern lake ports; and the southeastern to where costs are equal to that of coal barged up the Mississippi River, principally from Illinois and Kentucky. North and west of the lignite deposits, availability of higher rank coals and lack of population have prevented development of markets for lignite.

Two important areas that may be within economic reach of the North Central lignite deposits after development of cheaper transportation methods are Minneapolis-St. Paul and the northern Minnesota iron-range country. In the iron ranges large amounts of electric power will be required in the near future for processing low-grade taconite ore that may soon undergo increased utilization. The present delivered cost of fuels now used in these two areas is slightly over twice the cost of lignite at the mine.

Pipeline transportation of coal and long-distance transmission of power generated at the mine are future possibilities for increased lignite production.

PEAT

Although peat will not be able to compete in the near future with oil, natural gas, or coal for fuel purposes or as a chemical raw material, the use of peat for agricultural and horticultural purposes should increase. The demand for stock-bedding or litter purposes doubtless will also increase when the superior absorbing qualities of peat become known more generally.

Problems

Certain lignite deposits in Texas contain partings that will make some type of cleaning necessary, unless selective mining methods are used. Research on this problem is needed. Transportation and storage of lignite, particularly dried lignite or char, pose real problems owing to their tendency to heat because of their high reactivity. As yet these problems have been only partly solved.

Because of its high moisture content, lignite can be very substantially upgraded in value by drying. However, drying at atmospheric pressure with hot gas or superheated steam has to date given severe size degradation. This is of little consequence for some applications but is a problem if sized domestic or stoker fuel is desired or certain types of gasification processes are contemplated. Drying with a high-pressure steam or briquetting of dried lignite are partial solutions to the size-degradation problem, but available processes are relatively expensive.

Lignite can be carbonized, yielding a reactive char and potentially valuable liquid and gaseous product; however, the yields of these products vary markedly with the different lignites. Much research along these lines is required. The economics of carbonization will depend upon the demand and price obtainable for the liquids produced. Research is required on the characteristics of these liquids.

Gasification of lignite presents the possibility of an outlet for large tonnages of lignite. Research on methods of gasification specifically suited for this fuel is required.

BIBLIOGRAPHY

ORIGIN, CLASSIFICATION, AND RESERVES OF PEAT AND COAL

1. American Gas Association, "Reports on Proved Reserves of Crude Oil, Natural-Gas Liquids, and Natural Gas," American Gas Association, volume No. 8, 1953, page 3.
2. Averitt, P., Berryhill, L. R., and Taylor, D. A., "Coal Resources of the United States (a Progress Report, October 1, 1953)." Geological Survey Circular 293, 1953, pages 1 and 40.
3. McCabe, L. C., "World Sources and Consumption of Energy," United Nations Educational Scientific, and Cultural Organization. NS–75, June 11, 1951, pages 9–18.
4. Sherman, A., and MacMurphy, A. B., "Facts About Coal." 1950, 26 pages.
5. Young, W. H., Anderson, R. L., Hall, E. M., and Hunter, T. W., "Bituminous Coal and Lignite in 1952." Bureau of Mines Mineral Market Summary 2339, 1954, page 5.

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6. Allen, R. R., and Parry, V. F., "Storage of Low-Rank Coals." Bureau of Mines Report of Investigations 5034, 1954, 31 pages.
7. Bureau of Mines, "Bituminous Coal and Lignite in 1953." Mineral Market Summary 2339, 1954, 156 pages.
8. ——— ———, Minerals Yearbook, "Bituminous Coal and Lignite," chapter. Annual publication.
9. Bureau of Mines staff, Grand Forks, N. Dak., "Technology of Lignitic Coals—Part I." Bureau of Mines Information Circular 7691, 1954, 142 pages.
10. ——— ———, "Technology of Lignitic Coals—Part II." Bureau of Mines Information Circular 7692, 1954, 120 pages.
11. Parry, V. F., "Low Temperature Carbonization of Coal and Lignite for Industrial Uses." American Institute of Chemical Engineering, December 1953, 32 pages.
12. Parry, V. F., and Wagner, E. O., "Drying Fine Coal in the Entrained and Fluidized State." Mining Engineer Transcript, volume 187, September 1950, 10 pages.
13. Parry, V. F., Goodman, J. B., and Wagner, E. O., "Drying Low-Rank Coals in the Entrained and Fluidized State." Mining Engineer, volume 184, No. 4, April 1949, pages 89–98.
14. World Power Conference, "Low-Temperature Carbonization of Lignite for a 240,000-kilowatt Steam-Electric Powerplant." Brazil, July 1954, 15 pages.

PEAT

15. Anderson, M. S., Blake, S. F., and Mehring, A. L., "Peat and Muck in Agriculture." U.S. Department of Agriculture Circular 888, October 1951, 31 pages.
16. Bureau of Mines, Minerals Yearbook. "Peat" chapter. Annual publication.
17. Cronin, W., and Lang, J. F., "Peat-Fired Power Stations," Jour. Inst. Fuel, volume 27, November 1954, pages 545–555.
18. Odell, W. W., and Hood, O. P., "Possibilities for the Commercial Utilization of Peat." Bureau of Mines Bulletin 253, 1926, 160 pages.
19. Plummer, Clayton E., "Report of Progress in Peat Development." Office of commissioner, iron range resources and rehabilitation, St. Paul, Minn., 1949, 142 pages.
20. Scottish Peat Committee. "Peat as a Fuel and a Source of Chemicals" (extracts, Edinburgh, 1954). Chemical and Process Engineering, volume 35, No. 6, June 1954, pages 173–175.
21. Soper, E. K., and Osbon, C. C. "The Occurrence and Uses of Peat in the United States." Geological Survey Bulletin 728, 1922, 207 pages.

Representative PATMAN. Tomorrow we have a program with four witnesses: Mr. Walter H. Zinn, president, General Nuclear Engineering Corp.; Mr. Philip Mullenbach, vice president, Growth Research, Inc.; Mr. Gordon A. Weller, executive vice president, Uranium Institute of America; and Mr. George O. G. Lof, consultant, research associate, University of Wisconsin.

Without objection, the committee will stand in recess until tomorrow at 10 o'clock.

(Thereupon at 12 noon a recess was taken until Friday, October 16, 1959, at 10 a.m.)

ENERGY RESOURCES AND TECHNOLOGY

FRIDAY, OCTOBER 16, 1959

CONGRESS OF THE UNITED STATES,
SUBCOMMITTEE ON AUTOMATION AND
ENERGY RESOURCES OF THE
JOINT ECONOMIC COMMITTEE,
Washington, D.C.

The subcommittee met at 10 a.m., pursuant to recess, in the Old Supreme Court Chamber, the Capitol, Hon. Wright Patman (chairman of subcommittee and vice chairman of the committee) presiding.

Present: Representatives Patman and Widnall.

Representative PATMAN. The committee will please come to order.

Mr. Zinn is our first witness. Mr. Zinn, who is president of the General Nuclear Engineering Corp., was for more than 10 years Director of the Argonne National Laboratory. His expertness in the subject of nuclear power is attested by the fact that the organization with which he is associated has been commissioned by the U.S. Atomic Energy Commission to prepare a quarterly review of reactor development to assist the interested organizations in keeping abreast of new results in reactor technology for civilian application.

Mr. Zinn, we are glad to have you, sir. You may proceed in your own way.

STATEMENT OF DR. WALTER H. ZINN, VICE PRESIDENT, COMBUSTION ENGINEERING, INC.

Mr. ZINN. My name is Walter H. Zinn. I am vice president of Combustion Engineering, Inc., and I am president of General Nuclear Engineering, which is a subsidiary of Combustion.

The present problems of nuclear power perhaps can be reviewed best under four topics. These are (*a*) fission fuels as an energy resource, (*b*) cost of nuclear power from fission reactors, (*c*) safety of fission reactors, and (*d*) other sources of nuclear energy. Each one of these topics is extensive, and in this statement only a few highlights on each topic can be given.

A. FISSION FUELS AS AN ENERGY RESOURCE

A great deal of money is being invested in research and development on the technology of the use of fissionable materials for the generation of electricity and other energy uses. Also, a considerable sum is being spent for developmental plants which, by themselves, are not economically competitive but are thought to be the forerunners of a future technology and are being built to advance the technology and to gain experience. This expense is justified only if the contribution of fissionable fuels to the total energy resource can be shown to be substantial. Two factors must be considered in making such an estimate: The first is the amount of fissionable fuel recoverable from the earth at a reasonable cost, and the second, the efficiency with which this fuel is used by the nuclear reactors which constitute the heat source for the nuclear powerplant.

It is a well known fact that uranium in the form in which it is mined contains only seven-tenths of 1 percent of U^{235} and that our nuclear reactors are designed to burn not only the U^{235} but a certain amount of plutonium, which is generated in the reactors from the U^{238} which makes up the bulk of the natural uranium. Because of this regenerative feature, nuclear reactors of various designs differ very considerably in the amount of energy which is produced and made available from each ton of natural uranium. We now know enough about the technology of burning uranium in nuclear reactors to make reasonably sound estimates of the utilization of uranium which can be expected. It is not my purpose here to review the various reactor types or to indicate their relative effectiveness in the utilization of the basic raw material, but rather to indicate in general terms where we stand in this matter. I should, at this point, emphasize that our major immediate problem is to achieve nuclear powerplants which produce kilowatt-hours at a cost competitive to the cost of producing kilowatt-hours from coal-burning plants. It is felt that once this point has been achieved, the industry will evolve those reactors which are necessary to improve the utilization of uranium.

A typical power reactor in the United States is moderated and cooled with ordinary water and the fuel is uranium dioxide enclosed in a metallic jacket. Such reactors are fueled with uranium in which the U^{235} content has been increased in a diffusion plant to a value ranging from 1.5 to 3 percent U^{235}, depending upon whether the fuel-element cladding is of a low neutron-absorption metal, such as zirconium, or a high neutron-absorption metal, such as stainless steel. The amount of energy which is dervied from the fuel charge depends directly on the life of the fuel in the reactor. Extending this life is one of the main objectives of an extensive research and development program, and primarily is done to reduce the fuel cost. The main ingredient in the fuel cost is the expense of fabricating the uranium into suitable fuel elements; and, obviously, the greater the amount of energy which can be extracted from a fabricated set of fuel elements, the lower the contribution of such fabrication cost to the total fuel cost. In this part of my discussion, we are concerned only with the amount of energy such a reactor can be made to extract from a ton of natural uranium. The fuel discharged from such a reactor contains U^{235} which has not been burned and a certain amount of plutonium which has been generated by the capture of neutrons in U^{238}. Nuclear power stations built or being built generally envisage that the plutonium will be sold to the U.S. Government at prices ranging from $30 per gram to $12 per gram and that the unburned U^{235} will be returned, along with the remaining U^{238}, to a diffusion plant to be re-enriched and re-used. This type of operation can be expected to yield approximately 5,000 megawatt-days of thermal energy per ton of natural uranium. (1) In this estimate, allowance is made for the U^{235} which necessarily is discarded in the enrichment process.

With respect to fuel utilization, the performance can be considerably improved by retaining the plutonium which is contained in the discharged fuel elements and recycling this plutonium to the reactor. This means that the plutonim must be mixed with uranium of the proper enrichment and fuel elements fabricated and reinserted into the reactor. With such plutonium recycle, the utilization of the natural uranium will be increased by a factor of 4—namely, to 20,000 megawatt-days of thermal energy per ton of natural uranium. It should be noted that this type of operation is only in the research and development stage in the United States. The principal problem has to do with the development of fuel elements containing the recycled plutonium and which will have an adequate burnup life in the reactor. Finally, reactors can be devised in which the amount of plutonium discharged from the reactor exceeds the amount of U^{235} or plutonium which is charged to the reactor. These are the so-called breeder reactors. While a technical demonstration of the breeding process has been made, a practical demonstration of a breeder reactor cycle for a powerplant has not yet been accomplished. There is good reason to believe that with a breeder reactor, which must include plutonium recycle, a utilization of at least 250,000 megawatt-days of thermal energy per ton of natural uranium can be achieved.

To summarize, our present power reactors produce 5,000 megawatt-days of thermal energy per ton of natural uranium. We have expectations that with further research and development this can be raised to 20,000 megawatt-days of thermal energy per ton of uranium, and we see the possibility through the use of breeder reactors of obtaining a utilization which is more than 250,000 megawatt-days per ton.

The next question concerns the relation of such energy yields to the available supplies of uranium. The figures released by the USAEC indicate that the probable low-cost reserves in the United States total about 220,000 tons of U_3O_8, (2) and that future exploration will raise this to approximately 580,000 tons. Five to seven million tons are estimated to be available in the United States at a recovery cost four or five times greater than the cost of the low-cost reserves. In addition to uranium, thorium may be used in reactors which operate in a manner similar to the plutonium recycle reactors or the breeder reactors. The reserves of thorium in the United States are small, but the world reserves of thorium approximate one-tenth the uranium reserves.

We may ask the question, "How long will the U.S. reserves of uranium support a uranium-fueled power industry?" To answer the question, it is necessary to estimate the extent to which uranium fuel will come into use, and, in my opinion, there is at present no basis for making such an estimate. We have had too little experience with nuclear powerplants to properly assess their desirability on economical or operational grounds. Our first lot of nuclear powerplants is just coming into operation, and we will need experience with them as well improvements in cost before valid estimates of the future use are possible.

Hence, it is only possible to make an arbitrary estimate. I assume that in 1980, 20 percent of all electrical generation will be by fission reactors. I believe this is an optimistic assumption. Current estimates indicate that the total electrical energy produced in 1980 in the United States will be 1,800 by 10^9 kilowatt-hours. (3) At 20 percent, the nuclear share will be 360 by 10^9 kilowatt-hours. This would require about 250 reactor powerplants, each generating 200,000 kilowatts of electricity. All of the plants built thus far or planned for construction in the near future add up to about six such plants. Using reactors which produce 5,000 megawatt-days per ton and assuming a 30 percent efficiency of conversion of thermal energy to electrical energy—an efficiency already achived in some power reactors—the annual consumption of natural uranium would be 10,000 tons. At this rate and with this elementary technology, the low-cost reserves of the United States would suffice for about 50 years.

Assuming that all of the reactors are operated to produce 20,000 megawatt-days per ton, the annual consumption would be 2,500 tons of natural uranium. Our low-cost reserves alone would last some 200 years. If reactors are developed which produce 20,000 megawatt-days per ton, we can seriously consider using the high-cost reserves because the contribution to the fuel cost of the uranium would be only 0.6 mill per kilowatt-hour. This cannot be considered to be an obstacle, and therefore the high-cost reserves should be included in an estimate of the total energy capability of fission fuels.

The development of breeder reactors would make a very large extension in the available energy reserve in uranium. There does not seem to be any insurmountable technical problems in attaining the high utilization indicated by the breeder reactors so that their successful development, while it may be a considerable time away, cannot be classed as speculative. The conclusion which we come to is that presently developed reactors with plutonium recycle could carry a substantial portion of the electric-generating load for several centuries, and there is a good chance that the breeder reactor would make a further sizable extension in this time. With respect to time scale, we should set a goal of having a demonstrated successful plutonium recycle fuel system or a demonstrated breeder fuel cycle in about 20 years. Fission fuels remaining in our reserve after that time and using the indicated technology would certainly supply our energy needs for a time measured in centuries.

B. COST OF NUCLEAR POWER FROM FISSION REACTORS

Nuclear powerplants in operation or under construction in the United States are not expected to produce electrical energy at a cost competitive with plants using fossil fuels. It would appear that the best nuclear plants now under construction will have generating costs ranging from 10 to 14 mills per kilowatt-hour. The cost of generating electricity from fossil fuels varies widely throughout the country, but an average figure would be 7.4 mills per kilowatt-hour. Recent studies of a number of the nuclear power reactors which have received the greatest amount of development indicate that if constructed in a size as large as 300 megawatts, the cost of power generation would be 9 mills per kilowatt-hour. This figure breaks down to 5.1 mills per kilowatt-hour for capital charges, 3.4 mills per kilowatt-hour for fuel costs, and 0.5 mill per kilowatt-hour for operation and maintenance expenses. It would appear, therefore, that there is a gap of 1.6 mills which has to be closed before nuclear power plants can hope to be competitive. Even here, we must qualify the nuclear case by noting that lease of enriched uranium from the Government at 4 percent and the sale of plutonium to the Government at $12 per gram is part of the cost picture. For smaller nuclear powerplants, the gap would be larger since the effect of size on the unit-generating cost varies more steeply for the nuclear plant than for the fossil-fuel plant. Fossil-fuel plants are being built in sizes larger than 200 electrical megawatts, and because of the size effect just mentioned, it is clear that nuclear powerplants also have to be built in large sizes to have a chance of becoming competitive. What are the prospects of eliminating the 1.6 mills per kilowatt-hour handicap which now applies to nuclear powerplants? A good argument can be made for a decrease in capital cost just because of experience in building nuclear plants. If it is assumed that the capital cost for a next generation large plant can be reduced by 12 percent, a saving of 0.6 mill per kilowatt-hour is made. The fuel cycle offers even better opportunities for cost reduction. The quantity of fuel that has been fabricated to date and the experience with such fuel is so limited that the fabrication costs are expected to be high, and are high. It is estimated that if the fabrication cost could be reduced from its present value of $140 per kilogram of uranium to $100 per kilogram of uranium, a saving of 0.5 mill per kilowatt-hour would result.

Fuel costs generally are predicated on an average exposure of 10,000 MWD/T of the uranium placed in the reactor. Experimental evidence is accumulating that this is a valid figure and that there is a very good chance that it can be increased—perhaps doubled. An average exposure of 20,000 MWD/T of uranium would produce a savings in fuel cost of 0.8 mill per kilowatt-hour. These three reductions, together, are enough to close the gap and to make nuclear power competitive in some places. Other savings are possible. Most of the present nuclear powerplant designs do not produce superheated steam for the turbine. A considerable amount of development work, however, is underway to devise schemes of enabling the reactor to produce such superheated steam. The function of superheating, of course, is to increase the efficiency of the conversion of the reactor heat to electrical energy. It is possible that such superheating might produce an additional reduction in cost as much as 1 mill per kilowatt-hour. Development projects are underway to increase the compactness, to decrease the hardware needed for control, and to simplify the design and reduce the expense associated with safety measures for reactors. One can only conclude that the prospects are good that the next generation of large-size plants will be competitive in some areas of the United States. Since these large-size power plants are not as yet in the blueprint stage, and since it takes 4 years time to construct a powerplant, we cannot expect an actual demonstration of competitive nuclear power before 1965 or 1966. The actual time may be delayed beyond this point because the present U.S. program envisages the construction of a number of prototype plants incorporating the latest technical improvements as the next phase in the development of nuclear power plants. It is entirely possible that the construction of large-scale plants will be delayed until the prototype plants can be built and operated, in which case we should not expect competitive power from such large plants before 1970. Since there is no urgent need for nuclear power in the United States, the time scale indicated, while disappointing to the nuclear power industry, does not represent any difficulty as far as the supply and cost of electrical energy is concerned.

C. SAFETY OF FISSION REACTORS

Nuclear reactors are being constructed in this country with a full awareness of the potential hazards involved. The approach generally has been to use engineeging techniques to reduce all conceivable hazards to an acceptable level. For this purpose, the Atomic Energy Commission has established an Advisory Committee on Reactor Safeguards, has established a staff of safety specialists, has set up inspection procedures, and has initiated and funded a research and development program. Designers of nuclear reactors and manufacturers of components have used a conservative approach to problems of safety, and there is no doubt that in many cases the plants have been overdesigned with a resultant increase in cost. As the research and development program proceeds, we are beginning to see areas where our designs have made allowances for events which cannot happen and have made provisions to deal with temperatures and pressures which, in fact, cannot be generated. The research and development program is beginning to yield results, and in almost all cases the experiments show that the actual consequences of malfunction or of operator error will be substantially less than what was assumed when there was no experience or experiments for guidance. A great deal remains to be done along these lines. Not only should the program of research and development be continued and expanded, but it can be expected that the operation of additional nuclear powerplants will give useful information on the safety question. We are optimistic that the safety of nuclear powerplants can be further increased and that there will be a reduction in the expenses associated with containment and other special safety provisions.

D. OTHER SOURCES OF NUCLEAR ENERGY

From time to time, suggestions have been made that contained nuclear explosions can be used for the generation of power. The idea is to explode small fission bombs in a properly chosen rock formation, and, subsequently, use the heat generated for the generation of power. There are many aspects of this problem which remain unexplored, including the economics of such an operation. Even if the economics were proved to be favorable, there would remain the problems of international consequences of bomb detonations and the problem of finding suitability disposed sites for such operations. My opinion is that at this time we do not know enough about such an operation to give it consideration as a method for producing useful energy.

The generation of useful power from the fusion of light elements is the subject of a research program which is receiving a great deal of attention in the United States and other countries. The possibility of tapping the very large reservoir of energy potentially available in the heavy water of the oceans was first publicly broached at the Geneva Conference in 1955. At the 1958 Geneva Conference, equipment from a number of countries, especially the United States, was shown in operation. These experiments indicated that there was some possibility of obtaining the very high temperatures, at least 20 million degrees, required for a fusion reaction. It was also generally agreed at the Geneva Conference that the research phase of the problem would be extensive and that no early development of useful power from thermonuclear reactions was to be expected. In the past year there has been no announced change in the situation. There has been verification of the fact that some of the experiments have generated very high temperatures, but the various instabilities which so far prohibt a satisfactorily sustained fusion reaction have not been overcome. Perhaps the situation can best be summed up by a quotation from a recent speech by Sir John Cockroft, the leader of the British nuclear power development program. (4) Dr. Cockroft stated that "We will have to understand much more about the properties of plasma before we can hope to suppress this misbehaviour, and begin to design thermonuclear reactors. We should also remember that our magnetic bottles of the future will have to withstand plasma pressures of up to 100 atmospheres and that we need 6 inches of steel to contain such pressures in fission reactors; so thermonuclear power will not be without its design problems. I think therefore that my previous guess that thermonuclear power is at least 20 years away is still valid."

REFERENCES

1. Power Reactor Technology, vol. 2, No. 3, June 1959, U.S. Atomic Energy Commission.
2. Resources of Nuclear Fuel for Atomic Power, A/Conf. 15/P/1921, Second United Nations International Conference on the Peaceful Uses of Atomic Energy, Geneva, September 1958.
3. Estimated Future Power Requirements of the United States, By Regions, 1954–80, FPC–29, October 1955.
4. International Atomic Energy Agency, General Discussion, September 22, 1959.

Representative PATMAN. Thank you, sir.

I would like to ask you how does the rate of development of atomic power in this country comparable with, say, that in Great Britain or Russia?

Mr. ZINN. Well, I believe that our rate of development compared to Great Britain is substantially greater. It is spread over a substantially larger area of possibilities. In one particular area, namely, the gas cooled reactor, the British rate of development has been greater than ours and may remain so. On balance, I would say our rate has been greater than Great Britain.

As far as comparison with Russia is concerned, it is pretty difficult to tell. I think the only clue we have is to compare the Russian technology as it was revealed at the 1958 conference with what was revealed at the 1955 conference. Then you must admit that their rate of development is quite rapid. In the 1955 conference they had apparently no technology to deal with zirconium of the kind we use in reactors. In the 1958 conference they showed fully manufactured fuel elements using such zirconium.

Representative PATMAN. If that rate of increase has continued from 1955 to 1958 and up to now, how would it compare with our own development?

Mr. ZINN. I would not want to hazard a guess. I would assume that the Soviet development has the same problems that the British and we have. The British progress is being delayed at the moment, I believe, by doubts that the capital cost of their plants will come down sufficiently. This is one of our big worries. I suspect the Russians would have the same worry.

Representative PATMAN. Thank you very much, Mr. Zinn. We appreciate your testimony.

The next witness is Mr. Philip Mullenbach.

Mr. Mullenbach is vice president, Growth Research, Inc.; consultant, Nuclear Energy Study, Twentieth Century Fund, New York.

We are glad to have you, and you may proceed in your own way, Mr. Mullenbach.

STATEMENT OF PHILIP MULLENBACH, VICE PRESIDENT, GROWTH RESEARCH, INC., CHICAGO, ILL.; AND CONSULTANT, NUCLEAR ENERGY STUDY, THE TWENTIETH CENTURY FUND, NEW YORK, N.Y.

Mr. MULLENBACH. Thank you, Mr. Chairman. I am pleased to appear again before the committee. I recall with pleasure discussing Federal expenditures for nuclear energy and economic growth in 1957. The data and views presented then as well as today are based largely on an economic study of nuclear power policies that I am now completing for the Twentieth Century Fund.

The primary purpose of my remarks is to review with the committee the available estimates of uranium reserves and prospective requirements over the next couple of decades.[1] A secondary purpose, covered in my closing comments, is to examine the future price prospects for conventional fuels in the light of the divergent private and public policies that are influencing them. In brief, it is my conclusion that if present policies for conventional fuel maintain their present direction, higher real prices of primary energy may be the result, despite the ample domestic reserves described in earlier sessions of these hearings. Competitive nuclear energy may help in the formation of public policies that contribute to lower rather than higher real prices, but it cannot be decisive.

RESERVES OF URANIUM

The U.S. reserves of uranium are now well established, their development having been the close cooperative effort of industry and the Atomic Energy Commission over more than 15 years. "Economically recoverable reserves," defined here as uranium oxide (U_3O_8) that can be mined and concentrated at $10 or less per pound, are indicated and inferred to total almost 250,000 short tons as of July 1, 1959. As seen in table 1, these reserves are large, although somewhat greater tonnages are reported for Canada and South Africa. However, the AEC estimates that known and inferred reserves may well be doubled by allowing for the extension of existing ore zones and the probable discovery of new ore bodies in present or adjacent mineralized districts. Hence, free world reserves of economically recoverable uranium are set at about 2 million tons and could well be far greater.

[1] Thorium reserves and requirements are not examined because the techniques for utilizing thorium and the fissionable material U^{233} are less advanced than for U^{235} and plutonium.

TABLE 1.—*Free world economically recoverable reserves and annual production of uranium*

[Short tons of U_3O_8]

	Reserves	Annual production, 1958
United States	250,000	18,000
Canada	380,000	15,000
South Africa	370,000	6,000
France, Australia, Belgian Congo, and Portugal	100,000	3,000
Additions to reserves:		
By extension of existing ore zones	400,000	
By new ore bodies in present or adjacent districts	500,000	
Total	2,000,000	42,000

Source: Robert D. Nininger, 5th Annual Conference, Atomic Industrial Forum, Washington, D.C., Nov. 10, 1958; Jesse C. Johnson, Wyoming Mining Association, Riverton, Wyo., Apr. 17, 1959, and AEC release B-156, Sept. 9, 1959.

PRODUCTION RATES AND RESERVE ESTIMATES

Production of uranium in the United States has risen rapidly, reaching 18,000 tons in 1958, and now exceeds that of the other two major producers in the free world. Total free world production capability is at least 42,000 tons. At these rates of output, the known economically recoverable reserves would appear to have a limited useful life; only 14 years for the United States against 25 years for the free world as a whole. However, this is an unwise and undiscriminating comparison. It seriously understates the resources position of these countries by failure to consider, first, the reasonably anticipated extensions of economically recoverable ore already mentioned; second, the progressive additions to inferred reserves as production and development proceed; and, third, the vast quantities of uranium contained in higher cost ores that do not justify beneficiation while low-cost reserves are still abundant. For example, if we consider the higher cost uranium contained in phosphates, shale, and lignite, the present inferred reserves might be increased 10 times. Furthermore, the comparison ignores the enormous quantities of uranium that it would be technically possible to recover from granite and common rock.[2]

One of the first conclusions we come to is that the committee's basic question, whether reserves are "adequate," should center first on the magnitude of low-cost reserves and then how efficiently these can be used to meet emerging nuclear energy requirements for productive purposes.

COMPARATIVE ENERGY VALUE OF URANIUM RESERVES

The heat we can get out of our uranium reserves depends primarily on the success of nuclear fuel and reactor technology, both still in the developmental stage. In simple terms, the value of uranium as a fuel will depend on how efficiently it can be burned in nuclear reac-

[2] H. Brown and L. T. Silver, "The Possibilities of Securing Long-Range Supplies of Uranium, Thorium, and Other Substances From Igneous Rocks," 1st Geneva Conference, 1955, vol. 8, p. 129.

tors. We are all familiar now with what an incredibly large amount of energy may theoretically be produced by the complete fission of a very small amount of uranium (or plutonium). For example, the burning of 1 gram produces heat equivalent to that of 3 tons of coal and in addition provides neutrons that can produce about as much more fissionable material as has been burned. But as a practical matter, making nuclear fuel as cheap a source of heat as it might be is proving extremely difficult. Instead of complete burnup, assumed in our example, present technology permits only between 0.6 and 1.2 percent of the material to be utilized, but hopes for highly advanced technology indicates 20- to 40-percent utilization may become feasible.

The importance of technology in determining the energy value of uranium reserves and production is seen in table 2. It is constructed on three states of technology: present, near term, and highly advanced degrees of utilization. At current uranium production rates, 18,000 tons, the use of uranium for reactor fuel can become large, compared with total annual energy consumption in the United States, only on achieving further advances in technology. Using total 1958 energy consumption as a benchmark, we can see that "present" technology, at "high" 1.2-percent utilization, would mean that about one-third of the total annual requirement could be met by current uranim production rates. On the other hand, if the degree of utilization can be increased greatly by the recycle of byproduct fuel and ultimately by breeding, then the heat equivalent of the current production rate becomes very large compared to total energy consumption. Similarly, the energy value of uranium reserves depends far more on technical progress than on the tonnage represented by the reserve estimates themselves.

TABLE 2.—*Energy equivalent of U.S. uranium reserves, and annual production*

	Assumed utilization (percent)	Megawatt-days per ton	Heat value measured in B.t.u.$\times 10^{15}$	
			Known reserves (250,000 short tons)	Production, 1958 (18,000 short tons)
	(1)	(2)	(3)	(4)
1. Present technology—low utilization	0.3	2,500	51	3.7
	.6	5,000	102	7.4
	1.2	10,000	205	14.8
2. Near-term technology—with fuel recycle	1.8	15,000	308	22.1
	2.4	20,000	425	29.5
	3.0	25,000	525	36.9
3. Highly advanced technology—"breeding"	20.0	165,000	3,440	246.0
	30.0	250,000	5,150	369.0
	40.0	330,000	6,880	492.0

NOTE.—(*a*) 1 megawatt-day=82×10^{6} B.t.u.
(*b*) In 1958 total U.S. commercial energy consumption was 41×10^{15} B.t.u.—a convenient benchmark for comparison.

Further insight into the energy value of uranium may be achieved by comparing the reserves of uranium with the reserves of the conventional fuels (see table 3). At 1.2 percent utilization the uranium reserves represent only a fraction of the heat value of oil or natural gas. Further advances in nuclear technology are a necessity if uranium in low-cost reserves is to become of the same energy stature as conventional energy sources.

TABLE 3.—*Rough comparison of heat equivalent of U.S. reserves of uranium with coal, oil, and natural gas*

	Estimate of economically recoverable reserves	Heat equivalent, B.t.u.×10[15]
Coal (bituminous)	237 billion short tons	6,209
Petroleum and liquid hydrocarbons	170 billion barrels	986
Natural gas	850 trillion cubic feet	935
Uranium	250,000 short tons (U_3O_8)	
Present technology (1.2 percent utilization)		205
Near term (2.4 percent)		405
Highly advanced (30 percent)		5,150

Source: For coal, oil, and natural gas, the McKinney Panel, Joint Committee on Atomic Energy, vol. 2, 1956.

URANIUM REQUIREMENTS AND THE ROLE OF NUCLEAR ENERGY

We need now to consider the prospective demand for natural uranium, as this is indicated by a number of projections of nuclear energy's role during the next few decades. Let us assume, as was done in the pioneering National Planning Association's 1958 study, that competitive nuclear power is achieved in the United States by about 1965 and that thereafter the cost of generating nuclear power is progressively reduced, by 1980 reaching almost the lowest level of steam-generated power in the United States.[3] Together with other reasonable assumptions, the NPA concluded that nuclear energy might contribute as much as 9 percent of total U.S. energy consumption in 1980 (see table 4). In 1980 this share would represent roughly 7×10^{15} B.t.u., or one-half the heat equivalent of the current rate of uranium production, assuming the present state of reactor technology—1.2 percent utilization. This suggests, rather crudely certainly, that the probable rate of growth in nuclear energy over the next 20 years will be far less than fuel technology and the production rate of uranium should permit.

TABLE 4.—*Role of nuclear energy in U.S. energy consumption, 1980*

[Percent]

	1955	1980		Market given up
		Without nuclear energy	With nuclear energy	
Petroleum	41	45	42	6.6
Natural gas	27	24	23	3.0
Coal	29	28	24	13.6
Hydro	3	3	3	2.0
Nuclear energy			9	
Total	100	100	100	

Source: Based on Perry D. Teitelbaum, "Nuclear Energy in the U.S. Fuel Economy," National Planning Association, 1958.

Many other projections of nuclear energy capacity are higher than those of NPA (see table 4A). Together they illustrate the inherent difficulties of prejecting growth of the industry as well as the uranium inventory and consumption requirements associated with that growth.

[3] P. D. Teitelbaum, "Nuclear Energy in the U.S. Fuel Economy, 1955–1980," National Planning Association, Washington, D.C., 1958, pp. 47–54.

Few experts have attempted to project uranium needs. In 1955 the staff of AEC made a series of hypothetical calculations to underline the difficulties.[4] Their uranium estimates for the year 1975 fell in the very wide range of 11,000 to 41,000 tons. At the time these estimates were presented to the McKinney Panel in 1955, the AEC staff indicated "the greatest probability" was for a uranium requirement in the range of 5,000 to 20,000 tons. Unfortunately, since the AEC has released no new estimates of uranium requirements. The principal estimates recently have been by staff of the Canadian Atomic Energy Commission and of the Oak Ridge National Laboratory. The three sets of estimates are given in table 5, the most recent estimate (by Lane) being the lowest and probably most realistic.[5] This shows a a uranium requirement of only 2,400 tons on 1970 and 12,000 in 1980—both far below current production capability in the United States.

TABLE 4–A.—*Projections of nuclear power capacity in the United States, 1965–80*

Source	Nuclear capacity-year end (millions of kilowatts)				Percent of total generation	
	1965	1970	1975	1980	1975	1980
AEC staff (1954):						
Case 1	-------	-------	21.0	-------	10.0	-------
Case 2	-------	-------	5.0	-------	2.0	-------
McKinney Panel (1956):						
Series I (optimistic)	4.0	12.3	48.0	137.0	11.0	23
Series II (pessimistic)	2.9	7.2	22.6	54.3	7.5	15
Davis-Roddis, AEC (1957)	4.0	22.6	88.9	227.2	18.0	32
National Planning Association (1958)	1.3	8.5	28.0	61.5	8.0	15
Lane (ORNL–1959)	-------	11.0	-------	78.0	(1)	(1)

1 Not available.

Source: AEC Semiannual Report to Congress, July 1954, McKinney Panel Report, January 1956, NICB, 5th Conference on Atomic Energy, March 1957, NPA, "Nuclear Energy in the U.S. Fuel Economy," 1958 (P. D. Teitelbaum), Lane, "Annual Review of Nuclear Science," 1959 (in press).

TABLE 5.—*Estimated natural uranium requirements—U.S. civilian nuclear energy plants*

[Short tons of U_3O_8]

Year	AEC staff (1955)		AECL Canadian (1959)	Lane-ORNL (1959)
	Optimistic	Conservative		
1960	1,310	350	1,150	(1)
1965	2,550	685	3,850	(1)
1970	22,100	5,925	9,000	2,400
1975	41,000	11,000	(1)	(1)
1980	(1)	(1)	(1)	12,000

1 Not available.

Source: McKinney Panel Report, 1955; Atomic Energy of Canada, "Uranium in the Western World," AECL No. 858 (S. W. Clarkson); Lane, "Annual Review of Nuclear Science, 1959" (in press).

These are civilian requirements for nuclear power and make no allowance for continuing military requirements. Military requirements are unknowable and cannot be discussed for reasons of national security. However, published information indicates that military requirements are not a constant and may vary widely, as do civilian

4 McKinney Panel, vol. 2, pp. 113–125, Joint Committee on Atomic Energy, January 1956.

5 James A. Lane, "Economics of Nuclear Power," to appear in the forthcoming Annual Review of Nuclear Science, 1959. (I am indebted to Mr. Lane for his having made available to me a preliminary draft of this Review article.)

requirements, for technical reasons among others. For example, the operation of the gaseous diffusion plants that produce enriched uranium primarily for weapon purposes, and the materials production reactors that provide weapon-grade plutonium, can be changed in ways that would considerably alter the natural uranium requirements for military purposes. Furthermore, new expanding fuel requirements for ship propulsion purposes may be expected to reduce somewhat the preponderant role of materials required for nuclear weapons.[6]

Aside from the conjectural rate of growth in civilian nuclear reactor capacity, the main sources of variation in civilian uranium requirements ar ein fuel technology and reactor design. By way of illustration, we can see that reactor technology is pursuing two main lines, here and in foreign countries—nuclear reactors that are designed for natural uranium as fuel and those that utilize slightly enriched uranium (1 to 2 percent) of U^{235}. Both lines of effort are aimed at securing high burnup of fuel. To the degree they are successful, reactor technologists will thereby reduce the need for new uranium. Furthermore, if it should become economically possible to reprocess enriched uranium fuel after it has been irradiated in the reactor, then the requirement for new uranium would be somewhat less than if natural uranium were the fuel.

There are many other ways in which the use of uranium supply may be extended—even though supplies are not a problem. For example, so-called depleted uranium, in which the percent of fissionable U^{235} has been reduced below the normal 0.7, may be used as fertile material for the synthesis of plutonium, in turn, useful as reactor fuel. The so-called recycling of nuclear fuel could substantially reduce the requirement for natural uranium. Plutonium could become an important alternative to U^{235} within the next 10 years, provided economical techniques for separating and fabricating this highly toxic material can be developed. (That plutonium could be an important nuclear fuel within a decade is suggested by table 6 giving AEC estimates of byproduct plutonium coming from prospective power reactors fueled with enriched uranium.)

TABLE 6.—*AEC estimates of plutonium output of nuclear powerplants fueled with enriched uranium supplied by United States*

Fiscal year	Cumulative output of plutonium, in kilograms	
	Domestic reactors	Foreign reactors
1962	200	50
1963	500	200
1964	900	600
1965	1,300	1,500
1966	1,700	2,700
1967	2,400	4,200
1968	3,300	6,400

Source: Hearings before Subcommittee on Legislation, Joint Committee on Atomic Energy, 86th Cong., 1st sess., AEC authorizing legislation fiscal year 1960, p. 680.

[6] However, the thermal energy requirements of a nuclear-powered Navy and Air Force would, in 1980, be the equivalent of only one-eighth that of nuclear electric power generation. (Teitelbaum, op. cit., p. 54.)

More important than any of these technical developments would be the achievement of "breeding," that is, in the common use of the term, the process of producing more nuclear fuel in a reactor than is burned up during the same interval. Such breeding may become possible in reactors using plutonium as fuel, as well as in recators using the uranium isotope, U^{233}, produced from thorium. Because major advances like these are unlikely to have great effect on natural uranium requirements during the next decade, hence it is easier to project shortrun aggregate requirements, to 1970, than it is for a longer period. Canadian estimates of free world maximum requirements and supplies to 1970—ignoring the technical advances we have just mentioned—show that even with a heavy allowance for military requirements and for natural uranium reactors, a substantial world surplus of natural uranium seems a certainty for many years. (See table 7.)

TABLE 7.—*Rough supply-demand projection for uranium in the free world*

[Short tons, U_3O_8]

	1960	1965	1970
Demand:			
Nuclear power	4,500	15,000	30,000
Military	21,000	21,000	11,000
Other applications	1,500	3,000	6,000
Total	27,000	39,000	47,000
Production	42,700	42,800	47,000
Surplus supply	15,700	3,800	----------

Source: S. W. Clarkson "Uranium in the Western World," Atomic Energy of Canada, Ltd., AECL No. 858, July 1959, p. 44.

U.S. URANIUM PRODUCTION CAPACITY

The AEC's raw materials program has been outstandingly successful in expanding the mining and concentration of uranium, here and abroad. The primary problem now, owing to the failure of civilian nuclear power to emerge as soon as had been expected, is how best to limit further procurement. In fiscal year 1959 AEC procured 15,160 tons of U^{308} from domestic sources, against 18,170 tons from foreign. At the beginning of the program, in 1948, almost all the procurement was from foreign countries. AEC's plan for retrenchment consists of terminating purchases abroad as present contracts run out, in 1962 and somewhat later. (See table 8.) In the United States, a market is assured until 1966, though current prices may not prevail. Because the effect of this policy is to use domestic rather than foreign reserves, we should ask how the maintenance of current production rates may deplete our inferred reserves, now totaling about 250,000 tons. Also, we should ask what this policy may mean for future prices of uranium, here and abroad.

The depletion of domestic reserves, if high production is maintained, should be inconsequential for many years. Annual additions to reserves year after year have greatly exceeded the annual rate of procurement. (See tables 8 and 9.) This is a good sign, suggesting that a production rate of 15,000 to 18,000 tons could be sustained much longer than the bare 14 to 17 years misleadingly indicated by present inferred reserves of economically recoverable uranium. Because civilian requirements for uranium are growing so slowly, the adequacy of reserves for this purpose alone may remain an academic question for several year—but not indefinitely.[7]

TABLE 8.—*AEC procurement of uranium and projection of commitments*

[Short tons of U_3O_8—annual rates]

Fiscal years	Domestic	Foreign	Total
Actual: [1]			
1943–47 (average)	360	2,540	2,900
1948–51 (average)	295	2,430	2,725
1952–55 (average)	1,350	2,945	4,295
1956	4,200	6,240	10,440
1957	7,580	8,580	16,160
1958	10,250	16,130	26,380
1959	15,160	18,170	33,330
Projected (purchase commitments): [2]			
1960	17,300	18,615	35,915
1961	18,500	17,930	36,430
1962	18,200	15,770	33,970
1963	18,000	6,200	24,200
1964	17,500	4,135	21,635
1965	17,500	2,535	20,035
1966	17,300	1,465	18,675
1967 (1st half)	8,100	435	8,535

[1] AEC release, B-166, Sept. 23, 1959.
[2] Address by Jesse C. Johnson, AEC, Apr. 17, 1959.

TABLE 9.—*Growth of U.S. uranium ore reserves—Measured, indicated, and inferred*

Year end	Ore (millions of short tons)	Uranium content-tons of U_3O_8 (approximate) [1]
1947	1.0	2,800
1951	2.0	5,600
1952	3.0	8,400
1953	5.0	14,000
1954	10.0	28,000
1955	27.0	75,500
1956	63.0	176,000
1957	78.0	218,000
1958	82.5	240,000
1959 (July 1)	88.9	249,000

[1] Based on 0.28 percent U_3O_8 content.

Sources: Remarks of Jesse C. Johnson, Riverton, Wyo., Apr. 17, 1959 (AEC release S-11-59), and AEC release B-156, Sept. 9, 1959.

A further reason for accepting the principle of using domestic reserves is economic: domestic output is less costly than foreign—it is from much richer ore—and its price has been declining during the last several years. (See table 10.) Still lower prices seem in prospect, here and abroad. Foreign and domestic concentrating mills will soon be fully amortized. Moreover, substantial excess capacity will appear among foreign producers as AEC procurement diminishes. Because a more or less "free" market in natural uranium is emerging, we may reasonably expect that in a few years price parity between

[7] For example, some reactor scientists have expressed great concern that the low-cost reserves of uranium may be wasted on civilian power reactors having only low utilization of nuclear fuel. They have urged the speedy development of breeding so that the useful energy value of the low-cost reserves could be greatly extended. In particular, consult the writings of Alvin M. Weinberg, for example, "Geneva, 1958: Some Thoughts on Reactors," Bulletin of Atomic Scientists, March 1959, p. 132.

domestic and foreign uranium will occur, and possibly at a level below \$8 per pound. (Among all the fuels, uranium seems to be the only one that during the next decade or more will be assuredly lower in real price terms than at present.)

TABLE 9.—*Growth of U.S. uranium ore reserves—Measured, indicated, and inferred*

Year end	Ore, millions of short tons	Uranium content—tons of U_3O_8 (approximate [1])	Year end	Ore, millions of short tons	Uranium content—tons of U_3O_8 (approximate [1])
1947	1.0	2,800	1955	27.0	75,500
1951	2.0	5,600	1956	63.0	176,000
1952	3.0	8,400	1957	78.0	218,000
1953	5.0	14,000	1958	82.5	240,000
1954	10.0	28,000	1959 (July 1)	88.9	249,000

[1] Based on 0.28 percent U_3O_8 content.

Sources: Remarks of Jesse C. Johnson, Riverton, Wyo., Apr. 17, 1959 (AEC Release S-11-59), and AEC Release B-156, Sept. 9, 1959.

TABLE 10.—*AEC expenditures and average prices paid for uranium*

Fiscal year	United States	Canada	Overseas	Total
	Cost (millions)			
1956	\$101.3	\$136.9		\$238.2
1957	161.3	72.6	122.6	356.6
1958	196.0	204.1	156.5	556.6
1959	280.0	288.5	111.0	679.5
1960	310.8	293.1	108.8	712.6
	Unit price (per pound)			
1956	11.96	10.94		11.35
1957	10.64	10.78	11.78	11.03
1958	9.57	10.77	11.76	10.55
1959	9.24	10.83	11.91	10.25
1960	8.88	10.57	11.97	9.92

Source: House Subcommittee on Appropriations, for fiscal year 1958, fiscal year 1959, and fiscal year 1960 data for fiscal year 1956 and fiscal year 1957 from Annual Financial Report, U.S. Atomic Energy Commission (1957 and 1958).

Whether uranium in the 1960's stabilizes at \$8, or perhaps even less, is important to uranium producers and those reactor designers who rely on natural uranium fuel. It is of less direct consequence to U.S. reactor designers and manufacturers who are pursuing the enriched uranium route to competitive nuclear power. For an enriched uranium reactor the component cost of natural uranium is not large, but for a natural uranium reactor it is.[8] Therefore, the economic and political attractiveness of natural uranium reactors will be improved by lower uranium prices. The superior technical performance of enriched uranium reactors, which is generally accepted by reactor experts, will therefore have to be still further improved. In this setting of declining, primary energy prices, it may be well

[8] At \$10 per pound the U_3O_8 cost component is less than 15 percent of the cost of representative types of slightly enriched uranium fuel elements, compared to roughly 35 percent in nautral uranium fuel elements.

to ask, rather critically perhaps, what the real price prospects are for conventional fuels.

FUEL PRICES AND FUEL POLICIES

In these hearings great attention has been given to the physical reserves of conventional fuels, somewhat less attention to their prospective costs of production and probably too little to their real prices or the private and public policies that are influencing them. This is unfortunate, for the central questions of energy concern relative prices and real price trends. Yet there is great reluctance apparently to discuss these matters in straightforward fashion and against the background of world energy supplies, prices, and future requirements. For example, general agreements seems to have been reached among energy experts that domestic reserves and the resource base of conventional fuels are so great that increasing average costs of production are unlikely in the foreseeable future. The inference one is expected to draw is that fuel prices are also unlikely to rise. Now, in my judgment, this inference requires just as careful examination as the questions of reserves or costs of production. It may be valid, on examination of the data, to reach such a conclusion, but there are so many weaknesses in the chain of reasoning that one must not be so confident of the outcome. The strict economics of fuel supplies and demand do support the proposition that real prices in the United States should not rise, and in fact should decline in the next couple of decades—but the major private and public energy policies we are following now do not seem to support a very high probability of this actually occurring.

Let me outline why it seems reasonable to consider with care the possibility of increasing average prices of primary energy over the next couple of decades—despite ample reserves at apparently constant costs. At the outset consider the probable energy "mix" in 1980—petroleum contributing about 42 percent of total consumption, coal and natural gas each about 24 percent and the small remainder being divided between nuclear energy and hydro. (The specific percentages, it will be seen can be altered considerably without changing the argument). This distribution, in which petroleum and natural gas represent two-thirds of the total energy balance sheet, is indispensable for weighting the price prospects of each energy source.

Hydroelectric power and nuclear energy will be qualitatively important, if not quantitatively. Nuclear energy during this period will be of marginal importance, entering primarily through electricity generated in the high fuel cost areas.[9] For hydro, a small contributor, the low-cost sites will soon be exploited and costs of additions along developed rivers have begun to rise. Indeed, industrial consumers of electricity as a raw material are looking to the low-cost coal regions for power supply.

Let us turn to petroleum and its products—more than two-fifths of the total—and by far the Nation's principal energy source. Today, the prices of U.S. crude petroleum and products are being protected from lower cost sources in foreign countries by a combination of re-

[9] For example, by 1980 almost two-thirds of all nuclear power capacity is expected to be in the Northeastern and North Central States.

strictive policies—controlled output by proration exercised at the State level, and mandatory import quotas at the national level. So long as these economically restrictive policies stand—and the national security arguments for quotas cannot be ignored—domestic prices are being propped up and the reasonable expectation of lower prices for petroleum is thwarted. Despite the special tax incentive in the form of the 27½ percent depletion allowance, and despite the magnitude of crude reserves, real prices domestically are unlikely to decline. Substantially lower crude oil prices could be expected if drastically different private and public policies prevailed—policies that would provide a far better balance between real national security considerations and the economic benefits of lower cost petroleum available in the free world.[10]

Natural gas has had a unique position in the Nation's energy economy because it has been "underpriced" compared to coal and oil in almost all parts of the country. Since the end of the war natural gas prices have risen rapidly at the source and are headed toward parity with other fuels on a delivered basis. Public regulation of natural gas prices by Federal and State agencies has slowed but not arrested the persistent rise in field prices. Since consumption of natural gas has been rising more rapidly than that of coal or oil, even against rising prices, a reversion to lower natural gas prices is not credible in the foreseeable future. Despite plentiful reserves and despite partial regulation of prices, natural gas seems certain to continue rising in price until parity is reached—still likely to be several years away.[11]

Finally, we come to coal, contributing about one-fourth of total energy consumption. Coal, of course, is considered by energy experts as the great hope for restraining, or putting a ceiling on any upward drift in the future prices of its alternatives—natural gas and oil. Reserves, we have seen, are exceedingly great and theoretically, should permit future production almost indefinitely at constant average costs—or better. We might accept this optimistic view with greater confidence if we could be assured on certain rather critical points. First, examination of the 50-year trend of bituminous coal prices (mine-mouth) indicated that a 1½ percent rate of increase (compound) has occurred. Second, the influence of coal as an alternative to oil or natural gas has been confined to coal producing regions of the country—it is not nationwide. Third, over the next two decades the consumption of coal is expected almost to double. Production rates can certainly be increased this much and more in light of known reserves, but the major quantity-consumers of coal—particularly the electric utilities—are rightly concerned whether a doubling (or trebling) of production rates can in fact be achieved without involving higher real prices. (Long-term power contracts of the utilities, for example, carefully allow for escalation of fuel prices.) Finally, imported fuel oil is no longer fully effective, under current policies, in

[10] The vulnerability of the free world to possible interruption of Middle East petroleum output is lessened by increasing production capacity in Canada and Venezuela and by the current successful development of North African discoveries. Still greater assurance of supply flexibility would require a number of carefully designed measures, among others, to stockpile, to build more supertankers, to develop sources in new regions, and to develop lagging methods of recovering oil from shale and tar sands.

[11] In 1958 the national average price paid for natural gas by electric utilities was 24 percent below that paid for coal; in the "coal-consuming States" it was 8 percent lower. In 1958 the average price paid for gas was 42 percent higher than in 1952, while oil was 9 percent higher.

restraining delivered coal prices in regional markets (New England and Florida) distant from coal mines.

We have "boxed the compass" in rather quick fashion, but we can see that, under present policies, the real price prospects for primary energy sources cannot be judged solely by evaluation of reserves or assumed production costs. Considering the predominance of oil and natural gas in energy consumption—both of which have recently been rising in real price terms—and considering the historic rise in real prices of coal, we cannot assume that ample reserves will in fact permit the economy to avoid higher primary energy prices.

Representative PATMAN. Thank you. We appreciate your testimony, and I know it will be helpful to the members of this committee.

Mr. Widnall has a question.

Representative WIDNALL. Mr. Mullenbach, do you believe that a less restrictive Government policy would speed the development and use of nuclear energy and lower its capital costs?

Mr. MULLENBACH. I would have to ask you what you mean by restrictive policy.

Representative WIDNALL. Well, at the present time, you can only go into nuclear energy, as I understand it, through Government contracts in that the Government controls the uranium. If you want to patent anything in connection with it, there is a long period that you have to go through. I believe some contracts are pending for a 6-month period at the present time before they are approved.

Mr. MULLENBACH. I am not aware of such limitations.

Representative PATMAN. It is possible that the next witness can give enlightenment on that.

Representative WIDNALL. As I understand the present picture, it is not conducive for private sources doing their best for research and development in order to hasten nuclear energy. They are dependent on the Government itself doing it, where everything is controlled by the Government and licensed by the Government.

Mr. MULLENBACH. I think this is putting too strict an interpretation on the Government policy at the present time. It seems to me that what is occurring is that the AEC is very diligently trying to encourage private enterprise to develop nuclear power. It is doing it at very great cost, and I think the restrictions of a legal nature contained in the act are minor as compared with the technical problems being encountered both in Government laboratories and private laboratories. So, considering the line of your question, I would say that the restrictions that are imposed by AEC, or by the Atomic Energy Act, on the development of nuclear power are small and unimportant as compared with the real task of overcoming the technical problems and bringing nuclear power costs down to a competitive level.

Representative WIDNALL. I would like to have something clarified in my own mind, and I think some others feel the same way about it. We had understood that the original development was tightly controlled for national security reasons, and the output of uranium was completely controlled in that the Government wanted to stockpile uranium and could not afford to let it go out of the hands of the Government for security reasons. I wonder, now that our ample supply is indicated, whether or not a loosening of controls to some extent might hasten development and further use of the uranium supply.

Mr. MULLENBACH. Well, as Dr. Zinn's testimony and mine have tried to emphasize, we don't have any problem of uranium supply. We have ample supplies of it. It is not being restricted in its utilization by AEC. AEC would be glad to have additional users of uranium come into this market. The problem is that we have not been able to develop nuclear reactors that can burn the fuel economically. The restrictions on the national uranium supply are not important. They are not what are hindering the development of competitive nuclear power.

Representative WIDNALL. Maybe I am not posing my question properly; I am merely probing, trying to clarify something for myself. We know that when there is a monopoly of any kind there is a tendency to stifle competition and a tendency to shut off things that might be new and that might be creative. This happens with private industry and it could also happen with government. It happens as between the armed services, in their bidding for the attention of the public and for the development of certain things. I am more than curious as to whether or not there is anything in our present policy that might be restrictive in the development and use of uranium as a fuel.

Mr. MULLENBACH. I think almost all the stops have been pulled, practically speaking. AEC and industry together are doing just about all they possibly can—with the exception of AEC building full scale demonstration plants. I think one would say that the basic issue is where the primary initiative for nuclear power development stands. I would say that there should be far greater initiative on the part of AEC in developing nuclear power than has been true in the last few years.

Representative WIDNALL. That is all. Thank you very much.

Representative PATMAN. Thank you very much, sir.

Mr. MULLENBACH. I am grateful for the opportunity of appearing before the subcommittee. Thank you.

Representative PATMAN. The next witness is Mr. Gordon A. Weller, executive vice president, Uranium Institute of America.

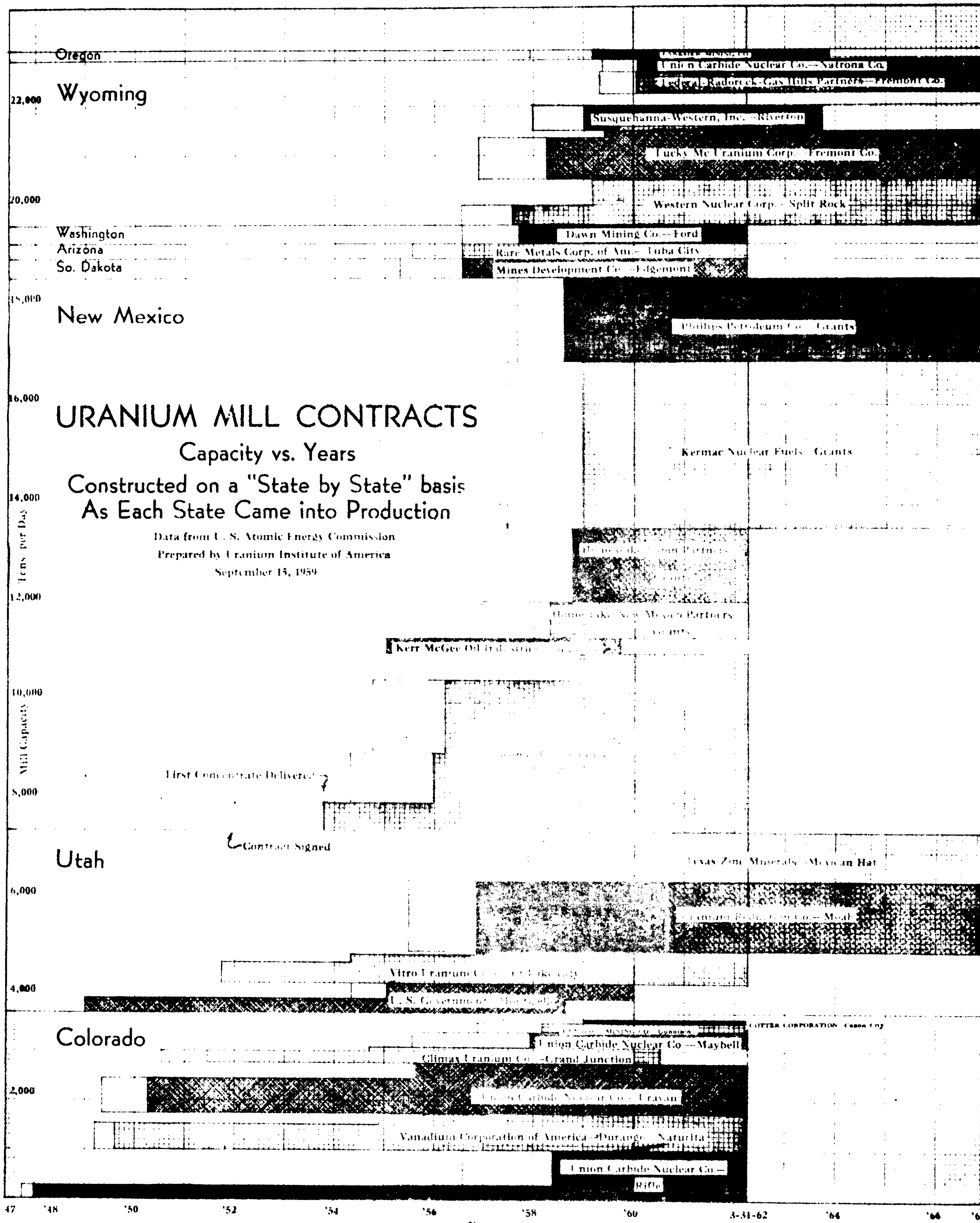
You may proceed, Mr. Weller, as you desire.

STATEMENT OF GORDON A. WELLER, EXECUTIVE VICE PRESIDENT, URANIUM INSTITUTE OF AMERICA

Mr. WELLER. Thank you, sir.

I am Gordon A. Weller, executive vice president of the Uranium Institute of America. Our principal organization offices are located at Grand Junction, Colo. We are incorporated under the laws of the District of Columbia.

Many hundreds of millions of dollars have been spent in the development of uranium reserves and processing facilities to satisfy the requirements of the atomic energy program of the U.S. Government. An industry has developed in eight Western States that now produces annually an important mineral product valued at $300 million. All phases of the industry are subject to the usual taxes for local, State, and National governments.



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STATUS OF THE DOMESTIC INDUSTRY

Production of uranium concentrates in the United States today is seven times greater than 5 years ago: 2,140 tons of U_3O_8 were produced in fiscal year 1955 compared with 15,180 tons in fiscal year 1959. Uranium reserves have increased by a much greater factor. Reserves today, amounting to approximately 90 millions tons of commercial ore, are 18 times greater than they were at the beginning of 1955.

On July 1, 1959, the U.S. Government had purchased 125,980 tons of uranium oxide since the inception of the atomic energy program in 1943. Almost two-thirds of this material, 80,760 tons, came from foreign countries and 45,220 tons have been produced from the domestic industry.

Prices paid for uranium concentrate from domestic producers are from $1 to $4.75 less per pound of U_3O_8 than those paid to foreign producers. The latest figures indicate that $10.77 was the average price paid to Canadian producers under the U.S. procurement program; $11.75 was the average price paid for uranium from oversea sources. The American Government is forcing American producers of uranium concentrates to accept $8 or less as the price for uranium concentrates in all domestic contract negotiations. Some contract prices, negotiated even 2 years ago, are below $7.

In the late 1940's and early 1950's the Congress developed deep concern as to our supply of uranium. In 1952, the Joint Committee on Atomic Energy expressed this concern in the following forceful words:

> * * * if war should come some years hence and if the United States did not then possess as many atomic weapons * * * as would have been desirable, there could be no valid exoneration of either the military or higher authority in terms of uranium shortage.

Under this impetus, conditions were created that caused thousands of prospectors and miners to swarm to the Colorado Plateau in a concerted search for uranium. Yet, oddly enough, the American Government today denies that it issued any assurance that it would buy more than token quantities of only specific types of ore from the independent miner.

Mr. Chairman, I submit for inclusion in the record a chart showing the development of uranium mill contracts for 25 privately owned and operated mills and one federally owned plant. The American Government maintains that the assurances for markets for independent producers are contained in these contracts. Yet the American Government has kept the complete terms of every one of these contracts secret, maintaining that it does not have the authority to divulge the terms.

The contracts have been developed on a piecemeal basis, which to a degree is understandable because of the primitive state of the art of finding, producing, and processing uranium ore. Undoubtedly, conditions changed, warranting changes in the terms of contracts negotiated.

But Mr. Chairman, is the American Government unprepared to defend the actions that it took under those conditions? Now that all security restrictions have been removed from the raw materials program, is the independent producer still to be denied an understanding of the exact nature of his market assurance?

We read that the American Government is currently exploring arrangements for the exchange of information on the peaceful uses of atomic energy with the Soviet Republic, and yet the American Government is denying the discoverers of the fuel that makes our atomic energy program possible, the knowledge of the agreements by which their product finds a market.

AMERICAN GOVERNMENT PURCHASE WITHDRAWAL TO DOMESTIC INDUSTRY

On May 24, 1956, the American Government gave assurance to the uranium industry that there would be an adequate market for all uranium produced in the United States at a price of $8 per pound of U_3O_8 in quantities up to 500 tons per year from any one mining operation or mining property. This advice was issued by press release and by public officials in addresses before the industry.

At that time the principal activity of the industry was located in western Colorado and eastern Utah, plus the large mill operated by Anaconda at Grants. In addition, mills were in operation at Shiprock, N. Mex.; Edgemont, S. Dak.; and Tuba City, Ariz.

Companies negotiating contracts for the sale of uranium concentrates after this time were required to prove substantial deposits of uranium in order to qualify for contracts that would justify the construction and amortization of mills. Contracts which were negotiated in 1957 and 1958 were required to "prove up" 10 years supply of ore for the capacity of the mill requested.

On November 24, 1958, the American Government withdrew its 1956 commitment to the industry and issued a regulation in the Federal Register, stipulating that markets would be provided for ore which had been discovered as of November 24, 1958.

Inasmuch as the earlier mills established in the areas to which we have referred were not required to give proof of reserves in the regions tributary to them, this new regulation in effect foreclosed the market on millions of tons of potentially good uranium ore.

We were advised that this action was necessary because of limitations which the Bureau of Budget had placed upon the uranium procurement program.

Mr. Chairman, several months after this withdrawal of important markets was issued the industry, the American Government committed itself to the purchase of an additional 8,724,000 pounds of uranium concentrate from the Canadian uranium industry.

AMERICAN GOVERNMENT PURCHASE EXTENSIONS WITH CANADIAN INDUSTRY

According to facts which were developed by Mr. Robert W. Burnick, business editor of the Salt Lake Tribune and published in that newspaper on June 19, 1959, the American Government agreed to pay a price of $8 a pound in U.S. currency for 4,225,000 pounds of uranium concentrate. This market was to be distributed among three Canadian companies as follows:

	Pounds
Algom	2,436,000
Pronto	1,508,000
Bicroft	260,000

An additional commitment was made by the American Government for the purchase of Canadian uranium produced from the Gunnar Mines, Ltd. to extend of 4,500,000 pounds at a price of $8.75 per pound, U.S. currency.

This total purchase extension to the Canadian industry amounted to 8,724,000 pounds of U_3O_8 at a total cost of $73.1 million.

It is interesting to note that no press release was ever issued on this transaction. The official representing the American Government in these transactions, however, gave the following explanation to Mr. Burnick upon his request:

> I should like to emphasize that execution of the particular contracts involved was in the nature of a formal and detailed reflection of long established understandings between the U.S. Commission and Canada. For your information, most of the negotiations with respect to the pricing arrangements for these extensions had been completed about a year ago.

Mr. Chairman, this quotation was published on June 19, 1959. A year previous would have been June of 1958. Almost 6 months before that time, or 18 months before Mr. Burnick's column, the same official appeared before a meeting in Albuquerque, N. Mex., and presented the following facts concerning the relationship of the American Government with the Canadian uranium industry.

> Now, in 1955, early in 1955, we could see the uranium production going up, we could see more profitable development in the United States, and before the Ambrosia Lake was discovered, we agreed with Canada for a cutoff on any additional purchases from Canada. That was in the spring of 1955 and announced in Canada about July, and all contracts that had been made with Canada were on the same basis, and proposals that were presented before March 31, of 1956.

The same official went on to say:

> Now, about a year or more ago, the British were interested in getting some additional uranium for their program from Canada. Canada was in a position to expand its uranium production to meet the British requirement. The matter was discussed with us. In view of our increased domestic production, it seemed desirable not to increase uranium production facilities further, and we (the Commission) made an arrangement whereby the British could buy uranium from Canada. The Commission would release material that it had under firm contract. In other words, we reduced our commitment to Canada, thereby permitting Canada to sell to the United Kingdom, which gave us then an opportunity for a larger share of the domestic requirement for our domestic producers, and I think that is generally the situation on the foreign production.

An examination of the two statements which I have given to you would force one to the conclusion that someone has been renovating old and dusty obligations which in December of 1957 had been set aside, but which were dusted off and brought back into use in the early months of this year in order to extend the U.S. commitments to Canada to the extent of $73 million.

CONCLUSION

Mr. Chairman, it is regrettable that your committee should be burdened with problems of this nature. From the facts which have been presented to you this morning, one must conclude that the uranium segment of our U.S. energy resources has developed to a very satisfactory state in the overall analysis.

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Miners in the uranium industry are typically Western people. They dislike the type of dependence in which they are now placed with respect to the U.S. Government. At the same time, they deeply resent arbitrary and abusive treatment, and we have to submit that uranium purchase withdrawals to the domestic industry in face of purchase extensions to the Canadian industry is both abusive and arbitrary.

In this presentation, I have purposefully substituted the words, "American Government" for the "Atomic Energy Commission." I have done this because I want to emphasize that the actions which we here protest are actions which reflect unfavorably upon our Government for which we set the highest of standards.

The uranium industry is happy to join the family of energy resources of the United States. We are extremely pleased to observe and we applaud the very substantial advancements which are being made in the applications of uranium for peaceful uses, particularly in the field of production of electric power from nuclear reactors, under the guidance of such outstanding scientists as Dr. Walter Zinn, who has preceded me.

Producers of oil, gas, coal, and oil shale are all good neighbors of the uranium industry in the West. We even claim considerable interest in Dr. Löf's sun, and we regard both the doctor and the sun as beneficial parts of the Western environment.

It is important that all of these elements of our domestic economy learn to live together and to compete with one another in a manner that will be productive for the Nation and profitable for the enterprises involved. To accommodate such objectives, it is important that we recognize both the benefits and the flaws of Government-sponsored programs.

We believe that much benefit has been gained under the program of the Atomic Energy Commission. We submit that the main dividends to be reaped by all of America are in the years immediately ahead of us now, but many important decisions are yet to be made which will require the forthright give and take and the willingness of the people in our Federal Government to make adequate accommodations and corrections of programs which may unwittingly involve abuses to a given segment of our economy.

For this reason we are genuinely hopeful that an accelerated program of research for the coal industry along the lines of H.R. 6596 might be adopted and thereby relieve the coal industry of its presently depressed circumstances.

Irradiation of coal in nuclear reactors to produce coal-in-oil suspensions has made possible, experimentally, greater power in diesel engines. This is an excellent example of how research can achieve benefits for coal and oil through atomic energy. We can visualize the use of atom-produced process heat (at temperatures heretofore impractical and in oxygen-free systems previously too costly) for the conversion of coal, oil, and their derivatives to a wide range of useful synthetic fuels and products.

These are applications which to us suggest that the energy resources might more truly be cooperators rather than competitors in the years to come. But it will only come about by the recognition that the American Government must assume its proper role in this age of great technical potentiality.

Certainly, the secrecy must be eliminated as it has typified the character of contracts with the uranium milling industry. Certainly, negotiations must be made openly with proper opportunity of affected elements of the economy to be heard.

Mr. Chairman, we cannot deny that the Government has tied itself to scientific research in a manner from which it cannot retreat. Our international position as well as the promise of the important gains to our economy and standard of living prevent any other course.

The atomic-energy program has afforded our Nation the opportunity to make a full-scale experiment in such Government participation. We urge that a full-scale congressional review of that program and of the uranium procurement program would net considerable benefit to all concerned.

Thank you, Mr. Chairman, for permitting this presentation in behalf of the uranium industry.

Representative PATMAN. I would like to ask you how the small producers are getting along. You know, Congress has concerned itself with the problem of small business for a long period of time and we, naturally, in hearings of this type, ask how the small man is getting along. About how many members do you have in your association?

Mr. WELLER. We have approximately 200 members—companies.

Representative PATMAN. And how many of your members are what would be in the category of small business?

Mr. WELLER. The Uranium Institute is made up of both milling companies and independent producers. Some of those independent producers are of substantial size; some of them are of very small size. Also, our membership includes people who may have no property under production at the present time but are hopeful that production will develop in the future.

Representative PATMAN. How is the small man faring in the uranium business?

Mr. WELLER. I think that the small man is in the most insecure position of any of the elements in the uranium industry at the present time. The reason for this is, as indicated briefly in the statement, market assurances were only given the industry, in any sort of positive fashion for token quantities of uranium to be sold and of only specific types of ore. The balance of the ore finds its market by virtue of the provisions in milling contracts. We understand various mills are authorized to buy varying percentages of uranium from independent producers. The terms of these contracts, however, are not made available to the independent producer, so he is at the mercy of a situation which he does not understand.

It also is possible for mills on the basis of the economics of the moment to, at a moment's notice, deny any further market to any particular producer.

I think Mr. Mullenbach's discussion as to the reduction of price in uranium has been very productive, but it is interesting to note that with the $8 price and the lower than $8 price, which we now have in the uranium procurement program, has created a peculiar situation in which rock which is ore to a miner may not be ore to a mill.

You understand, in the mining industry we only consider rock which has enough mineral values to produce a profit over the cost of its production as ore. A producer can produce ore from a mine economically down to 0.20 of 1 percent U_3O_8. It was visualized in 1956 at the time the post-1962 program was announced that that $8 price would permit 0.20 percent grade to be produced and milled economically. The inflationary aspects of the mills today have caused mills to require 30/100th and even 40/100th of 1 percent ore as a minimum grade.

So while a price schedule exists that permits a miner to produce ore at lower grades, he can't find a market for it because mills can't afford to mill it at the present price for concentrates. Actually we are permitting mines to be caved in with 20/100th and 25/100th of 1 percent ore still in the ground which will be lost to us for all time. I think at the moment our reserve picture is very favorable, but I can't see the justification for the loss of important values in uranium through a price schedule which is actually precluding markets of some of these lower grades but still economic ore.

Representative PATMAN. You brought up several points that I expect to explore more fully. I will not pursue the question further at this time. Your statement, however, does raise several questions in my mind. Many of them should be investigated.

Mr. Widnall.

Representative WIDNALL. Doesn't what you are saying sum itself up that you would like to see a real Government floor by way of subsidy for the entire industry?

Mr. WELLER. I don't like the term "subsidy," Mr. Widnall, because we feel that there is a real economic benefit to come from the uranium to be produced. There is no artificial padding of the price.

Representative WIDNALL. The Government price is certainly an artificial price where it is set at one figure for domestic producers and another figure for Canadian producers and another figure for oversea producers.

Mr. WELLER. That is true.

Representative WIDNALL. It is not based on a competitive bid-and-asked situation.

Mr. WELLER. On the basis of that premise, would you restate your question?

Representative WIDNALL. Well, I am just wondering whether you feel that there should be a Government floor or a Government base in connection with the uranium industry in order to protect the so-called small producer.

Mr. WELLER. Yes, sir; I think it is necessary to provide a Government base. Actually the cost of uranium with respect to the kilowatt-hour produced through nuclear power reactors is a very small part. In other words, it is a matter of a few percent of the total cost of the kilowatt-hour coming from the uranium produced in concentrate form.

Representative WIDNALL. Wouldn't that in the end lead to the type of situation we have in the farm surpluses, where you are creating more and more of a stockpile and not using them?

Mr. WELLER. We have other purchase controls on the uranium industry at the present time being exercised.

Representative WIDNALL. I understand that. But if you are going to enlarge the purchase price to make it as good as possible for the small producer, inevitably you will end up with the demand that so much more be bought by the Government to support the activities.

Mr. WELLER. No, sir, no more ore will be mined than can be milled, and the milling capacity is controlled by Government contract. Therefore, we do not ask for more market than is now afforded by existing mills.

We simply ask for an understanding of the market. There is a situation in the industry which the Commission permitted to develop wherein the miller is the buyer of the uranium ore. The mill is also a competitor with the ore producer because of mining properties owned and operated by the mill. He can, by exercise of buying policies, preclude the market from the independent producers, and therefore cause the properties involved to be sacrified and they can be picked up by other companies, or possibly the milling companies. This is an unfortunate situation. I think that even the milling companies themselves feel many times that this is an improper arrangement.

Representative WIDNALL. Do you have any comparative figures on the cost of operation for the Government plant as against the private plants?

Mr. WELLER. The Government plant is reasonably comparative. There are many difficulties involved in operating a Government plant that don't attend the operation of a private plant, in the way of justification procedures and cost accounting, which cause the Government plant to operate on a higher paper figure level. The Government plant was used as a yardstick for the industry for the Commission to arrive at some of the prices for uranium concentrate.

Representative WIDNALL. Has your institute arrived at any position as to whether or not you feel the time has passed for the operation of a Government plant?

Mr. WELLER. The Government plant is important to the industry from the standpoint of its geographic location, because after 1962 the ore producer is going to have to pay for the haulage of his ore to a market. From the standpoint of the Government competing with private industry, we don't endorse this program. We see no reason for the Government to continue to operate the plant. There does appear to be adequate milling capacity for the proved reserves in the general region of the Monticello plant. When I say "the general region" I am talking about the Four Corners area. The other competitive mills are perhaps 60 or 70 miles away from the Monticello, and if this one problem of cost of haulage could be overcome we would see no reason for the need for continued operation of that plant.

There are potential reserves which are yet in early stages of development that now appear to be of such an extent as to justify the continued operation of the Monticello mill. The most reasonable solution appears to be the operation of this plant by a private company to accommodate those new reserves plus those independent properties geographically located as being tributary to the Monticello mill.

Representative WIDNALL. Are all of the firms shown on that chart of yours members of the institute?

Mr. WELLER. No, sir.

Representative WIDNALL. Are most of them?

Mr. WELLER. Of the milling companies, there are, at the present time, three members in the institute.

Representative WIDNALL. The ones shown on the chart are the largest producers, are they?

Mr. WELLER. Are you talking about producers of ore or of concentrate? All producers of concentrate are shown on the chart. I would say that 25 percent of the production of ore comes from independent producers at the present time.

Representative PATMAN. What percent?

Mr. WELLER. Twenty-five percent of all ore comes from independent producers. This percentage is decreasing continually under the present restrictive AEC policy.

Representative WIDNALL. That is all.

Representative PATMAN. Thank you very much, sir.

Mr. WELLER. Thank you, sir.

Representative PATMAN. Our next witness is Mr. George O. Löf, consultant, Resources for the Future, Inc.; research associate, University of Wisconsin.

Mr. Löf, we are glad to have you. You may proceed in your own way.

STATEMENT OF GEORGE O. G. LÖF, CONSULTING ENGINEER, RESEARCH ASSOCIATE, RESOURCES FOR THE FUTURE, INC., AND THE UNIVERSITY OF WISCONSIN

Mr. LÖF. Thank you, Mr. Chairman. My name is George O. G. Löf. I am a consulting engineer, and hold research staff positions at Resources for the Future, Inc., and at the University of Wisconsin.

By way of further personal identification with this topic, I would like to state that I have been engaged in solar research and development for 15 years, in association with several universities and industrial firms.

I have prepared a written statement, copies of which are available here, and I should like to read the statement.

Representative PATMAN. You may also insert such additional material as you believe is germane to your discussion.

Mr. LÖF. Thank you.

I would like to offer, for the record only, a portion of a paper on the economics of solar energy utilization by Dr. J. A. Duffie, of the University of Wisconsin, and myself, published in the April 1959 issue of the Canadian Journal of Chemical Engineering.

Representative PATMAN. Without objection, it may be inserted.

(The material referred to is at the conclusion of Dr. Löf's statement. See p. 315.)

Mr. LÖF. It is significant, I believe, that this committee has arranged the program so that the statement on solar energy concludes these hearings. In all probability, it will be the last form of energy to enter the economy in substantial proportion. It is also the greatest source of the earth's energy and the one which will eventually replace all fuels.

In contrast with the valuable statistical material presented to this committee by most of the other participants, my statement is primarily descripive. This is necessarily so, because appreciable solar energy utilization has not yet commenced, and estimates of near-future usage can be little better than speculations. Nuclear energy shares some of these difficulties. Even though there are several commercial nuclear power installations which provide cost data for projections of future use, such estimates are uncertain. So the problem of making confident quantitative appraisals of the rate at which solar energy is introduced in the economy does not yet have a good solution.

Until the last few years, the practical use of solar energy was seldom considered more than the visionary idea of a few "basement inventors." I think this committee's decision to include its discussion in these hearings best testifies to its technological and economic advance from this dubious category. And although I suspect that scientists and engineers working in this field, like myself, may sometimes still be thought visionary, we are beginning to find ourselves in good company, as in these hearings.

Most technical developments in their early stages have their ardent advocates and gloomy prophets. Solar energy is no exception. This committee could have invited a much greater optimist as to the rate and magnitude of solar energy application, and I am sure that a more conservative view than mine could also be obtained. My hope is that these remarks, insofar as the future use of solar energy is concerned, will prove to represent the views of a realist.

CHARACTERISTICS OF SOLAR ENERGY AND ITS CONVERSION

Before examining its economic aspects let us consider this energy source itself. In sharp contrast with practically all of our conventional sources, solar energy is of immense quantity, universal availability, very low concentration, and extreme variability. Its magnitude can be readily appreciated by recognizing that this daily U.S. energy supply of 70 trillion horsepower-hours is about 1,700 times as great as all of our present uses for energy. Or, in more easily visualized quantities, a Texas oil well on a quarter section of land would have to produce crude oil at a perpetual rate of 2,500 barrels per day to have an energy output equal to the sunshine falling on that piece of ground.

Although solar energy is universally received, its quantity varies from place to place. Typical annual average radiation intensities in very sunny climates are around 2,000 B.t.u. per day per square foot of ground area whereas a mean value for the entire United States is approximately 1,500. These figures also illustrate one of the two mxajor problems in the utilization of solar energy. To make solar energy usable, some sort of surface must be provided to intercept the radiation and convert it to another form such as heat, electricity, or chemical compounds. Conventional energy exchange surfaces, such as the tubes in a boiler furnace, may transfer heat at hourly rates of 100,000 B.t.u. per square foot of area; solar energy, however, has a maximum intensity of only about 350 B.t.u. per square foot per hour. This means that very large surfaces must be used for the recovery of appreciable quantities of energy.

Possibly the greatest problem in solar energy utilization is its intermittent nature. Not only is there the regular variability from day to night and season to season, but there is fluctuation due to cloudiness. The use of solar energy must therefore depend on there being (1) no need for continuous energy supply, or (2) supplementary energy use, or (3) some form of solar energy storage.

Solar energy can readily be converted to heat, and it can be converted to electric energy either directly as in the well-known solar battery or indirectly in some form of heat engine. It can also be converted to chemical energy by use of living and nonliving systems. Although far the greatest use of solar energy is in agriculture, this application is omitted here, because the economic factors and uses for the products are outside the energy field.

Conversion to heat can be accomplished by either of two simple processes. The diagram (fig. 1) shows these in schematic form. Hot air, hot water, steam, and other fluids can be supplied from a flat plate solar collector, comprising one or more transparent glass or plastic surfaces above an insulated blackened metal sheet. By absorption of solar radiation, the black surface is heated, even to several hundred degrees if desired; a fluid passed through tubes or channels in contact with the hot surface can thus be heated. Depending on many factors, the efficiency of solar energy recovery as heat in fluids, say at 150 F. to 250 F., may range from 50 to 60 percent down to 25 or 35 percent.

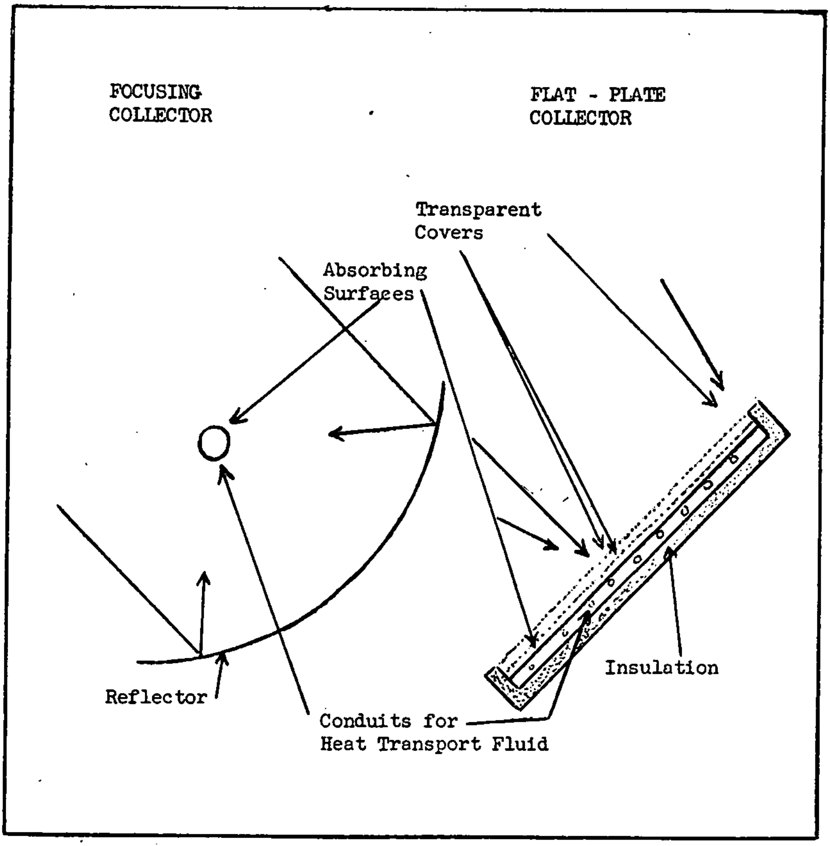

Figure 1 - Schematic sections of focusing and flat-plate solar collectors. The focusing collector operates only on direct, or beam, radiation. The flat-plate collector operates on direct and diffuse radiation, and does not have to be moveable.

A focusing reflector of the same exposed area collects roughly the same amount of solar energy, but by concentrating it on a small receiver, much higher temperatures can be achieved at comparable efficiencies. This unit must be arranged to follow the apparent movement of the sun, and it can function only in perfectly clear weather. Heat at hundreds or even several thousand degrees can be delivered by circulating a gas or liquid through a suitable heat exchanger or boiler at the focus.

The production of electric energy from heat obtained from solar radiation by either of these processes can be accomplished by conventional methods, employing expansion engines of reciprocating or turbine types. Steam from focusing or flat solar collectors can be used directly, or if some other medium is being heated in the solar unit, steam can be obtained by heat exchange. At the comparatively low operating temperature of the flat collectors, however, heat-to-power efficiency is poor, and the overall solar-to-power conversion efficiency may not be over 5 percent. In the focusing system, higher temperatures make it possible to achieve heat-to-power efficiencies comparable to those in commercial power plants, and overall solar-to-power conversions of 20 percent could be realized.

Direct conversion of solar radiation to electricity is also possible. The silicon cell, so effectively employed as a power source in our new satellites, utilizes an electronic property of matter, delivering 10 to 15 percent of the solar radiation as electric energy. Concentrated solar energy can also be used efficiently as the heat source for the recently developed thermionic and thermoelectric conversion elements. Other, presently less efficient, methods employing chemical reactions may ultimately prove useful.

Although high efficiency is important in solar energy conversion, it is for a different reason than in conventional fuel use. The minimizing of fuel costs is the primary objective of efficiency improvement in the use of fuel, but if the raw energy is free, as is solar energy, this incentive is absent. However, it is the size of solar collector surface and the amortization of its initial cost which are so heavily dependent on overall solar utilization efficiency.

A final technical note concerns solar energy storage. Solar heat can be stored at moderate temperatures in the form of hot water, heated solids, and in chemical compounds. The cost of facilities for 24-hour storage is not a large fraction of the cost of the solar collection equipment. Long-term storage for smoothing season-to-season and even day-to-day fluctuation in solar radiation is, however, much more expensive. High-temperature heat storage for subsequent electricity generation can be accomplished in similar manner, but at still higher cost. Another technique for solar power storage is the use of surplus daytime electric output for pumping water to a higher level, for subsequent fall through hydroelectric generation facilities during sunless periods.

From this brief description of the principal solar energy utilization methods, it may be observed that there are no great technical obstacles to the use of this energy source. The technology is comparatively simple, and although major improvements and new discoveries will undoubtedly take place, wide application of solar energy would appear to depend much more on economic developments than on scientific advances. In other words, the reduction in cost of solar energy conversion equipment, through design changes, material substitutions, mass production, and the rise in costs of conventional energy are the primary requisites for extensive utilization of the sun's energy.

POSITION OF SOLAR AND CONVENTIONAL ENERGY SOURCES IN THE ECONOMY

In examining the economics of solar energy, it is helpful first to consider the types of businesses concerned with conventional energy supplies. The firms and individuals that have income from energy may be divided into three groups: First, there are the owners and producers of the raw energy source. These comprise the organizations which own and mine coal and uranium deposits and those who own and sell petroleum and natural gas. Secondly, there are the organizations which convert the raw energy sources to other forms and sell the resulting energy. These include petroleum refiners who manufacture motor fuel, and utility companies which produce and sell electricity. And thirdly, there are the suppliers of materials and equipment which are used by the producers, converters, and ultimate users of energy. Included here are the manufacturers of automobiles, electric-generating equipment, steam boilers, household furnaces and air conditioners, cookstoves, and the many materials which go into the fabrication of such equipment.

Let us now see how solar energy fits into this industrial pattern. It is immediately seen that there is no counterpart of the owner and producer of raw fuel energy. Every landowner is, in effect, a sun owner, in proportion to his acreage. It therefore appears that solar energy use will not involve industrial activity in the raw energy owner and producer segment of the economy.

Next, in converting solar energy to forms which are salable, the purchase of adequate land and the construction of solar heat recovery equipment will put a power company in a position in solar energy entirely analogous to that which it now occupies by its use of fuels for the same purpose. And as explained shortly, the individual consumer of energy will also become a converter, at least in some applications such as space heating and cooling.

The third category of equipment supply will be as important to industry in the manufacture of solar energy conversion facilities as it now is for conventional sources. The conversion of solar radiation to heat or to work requires equipment analogous to that presently being used in the conversion of other sources. Thus, the heating of houses requires solar heat exchangers, heat-storage units, and control systems; these in turn require metals, glass, plastics, chemicals, and so on. Direct conversion of solar energy to electricity will require semiconductor, alternator, and transformer equipment.

There are no owners of solar energy so its use cannot be expected to receive the sort of promotion that natural gas does, for example. Thus, one incentive for solar energy development is lacking. In the category of converters and sellers of energy, there is a corresponding lack of incentive to develop solar energy because now there are ample, and in most cases, cheap supplies of fuel and waterpower for conversion. An alternate basic supply is not yet needed, and the time when it may be needed in the United States is too distant to justify research and development expenditures by these organizations. To great extent, the same might be said of nuclear energy, but here there is a heavy Government subsidy to the developers of this source, absent in the case of solar energy.

Only the manufacturers of materials and equipment for use by the individual converter of solar energy are therefore likely to participate in near-term economic benefits, and the rate of development of this resource will be largely dependent on their efforts. Research and development will be carried forward by these firms at rates dependent on the expected sales potential of the products. Inasmuch as heat and electricity from a solar source are no different than these energies derived from conventional fuels, the substitution of solar energy is dependent primarily on economic factors. Except in special situations, the ultimate energy derived from solar radiation must be competitive for suppliers of conversion materials and equipment to sell their products. The rate of solar development by equipment and materials suppliers thus depends on their ability to develop and produce such goods at costs which will make the converted energy competitive with that from conventional sources.

But if the public utilities are not going to be using solar energy for many years to come, the buyers of this equipment will be limited to the individual energy users—the homeowner, businessman, industrial firm, and the farmer. These people have solar energy available to them, they can purchase the equipment to convert this energy to useful forms, and they can then utilize the heat, electricity, or other products derived therefrom. Ultimately, the commercial power supplier will also be an equipment customer.

EQUIPMENT FOR SOLAR ENERGY USE

The dependence of solar energy development on materials and equipment makes it convenient to place further discussion in a framework of present and potential participation by manufacturing industry. There is another reason for orienting the subject matter this way. Aat least within the next few decades, solar energy cannot be expected to furnish an appreciable fraction of the energy needs of the country. One percent in the year 2000 would appear to be an optimistic estimate. But the importance of solar energy to the equipment manufacturers might be much larger than apparent from this small percentage. By way of analogy, dry cells, telephones, and radios are insignificant in the overall energy use picture, but their manufacture is an important segment of industry. Solar energy conversion equipment such a solar cells for communications, cooking and refrigeration units (probably for export), house heating and cooling systems, water distillers, and even toys and novelties, would not loom large in the energy statistics, but could occupy significant positions in manufacturing industry.

SOLAR CONVERSION EQUIPMENT NOW COMMERCIALLY AVAILABLE

Solar energy equipment now being manufactured and sold falls into four groups: water heaters, solar-electric converters or solar batteries, cookers, and toys and novelties. These products are made by numerous manufacturers who, in turn, utilize metals, glass, plastics, paints, fabrics, and many other materials from their suppliers. Except for the solar water heaters, these products are really not intended for supply of energy at competitive costs. Instead, they serve certain special needs.

The manufacture of domestic solar water heaters in Florida has been going on for several decades. Comprising simply a glass-covered, blackened metal sheet in contact with tubing through which water circulates to an insulated storage tank, a 50-square-foot unit on a house roof in southern Florida, can supply enough warm water for average family. A survey shows no less than a dozen manufacturers of this equipment and that about 25,000 solar water heaters are used in this area. Recent developments in heat transfer surfaces, and transparent plastic films may stimulate this market, although the recent arrival of natural gas will provide stronger competition.

Almost at the other extreme of size and precision are the solar cells being manufactured for use in radios, clocks, toys, hearing aids, and communication equipment. When a very pure crystal of silicon is sliced into thin wafers which are then "doped" with traces of certain other elements, an electric current is produced when the wafer is exposed to sunlight. Since the wafers have an area less than a square inch, many would be required for delivery of much motive power, but energy for communications and other small power needs can be obtained from relatively few irradiated cells. A solar radio, for example, needs only half a dozen. Most of the satellites this country has launched have radio equipment powered by these solar converters.

At present prices of silicon metal and solar cells, generating capacity would cost over $50,000 per kilowatt, compared with operated plant costs below $200. But there are possibilities for cost reductions, such as by use of focusing reflectors to concentrate considerable solar energy onto comparatively few solar cells, and by use of cheaper methods for preparing the silicon surface. But even if this remains an expensive source of electric energy, there will be many new uses for small electrical outputs at these costs. Electricity in space may well be produced primarily by converters of this type, and their extensive use in communication equipment appears possible.

In the third group of products, portable solar cookers are beginning to enter the market for outdoor recreation equipment. At least three different styles are being commercially made at the present time. Typical of these is a folding solar barbecue grill which focuses nearly a kilowatt of solar power on the cooking surface by means of a flexible fabric-plastic reflector supported on a modified umbrella frame.

Still another group of solar-operated devices are in the toy and novelty markets. Although of trivial consequence now, this group of products will become larger as solar energy applications increase. Two current examples are a solar cigarette lighter and a child's rotating solar pinwheel.

ADDITIONAL PRODUCTS WITH EARLY COMMERCIALIZATION PROSPECTS

There are three types of solar-operated equipment in the development or testing stages which may become commercial products within the next few years. It appears that their first important application will be in other countries where domestic sources of energy are scarce and expensive. These items are a domestic food cooker, a solar-operated food refrigerator, and a small solar distillation unit for demineralizing highly saline water.

Reflecting-type solar cookers of rigid plastic with metalized linings have received field trials in rural Mexico and in a few other countries where the supply of cooking fuel has become critical. Potentially cheap, these units show promise for substantial sale and use in parts of Mexico, Central and South America, southern Asia, the Middle East, and north Africa. Simple food refrigerators intended for use by peoples in these same regions are being developed for use in combination with solar cookers. By means of an intermittent absorption cycle, several pounds of refrigerant and absorbent in a two-chambered metal container can keep a small insulated icebox cold for 24 hours. The unit must be regenerated once a day by solar heating for about 2 hours. At a price potentially below $25, the market for such a unit might be in the many millions.

A third need in the arid, unindustrialized regions of the world is safe drinking water for people and for domestic animals. In many areas, highly saline ground water is available but practically unusable. Other regions, some with high population, are right on the seacoast, but lack fresh water even for absolute minimum requirements during certain seasons. Low-cost water distillation equipment would find ready application in these countries, provided that operating energy is available. By evaporation from shallow basins directly heated by the sun, and condensation on sloping glass or plastic covers, distilled water can be produced from sea water in a sunny climate at a daily rate of approximately one-tenth gallon per square foot of basin. Several designs are now being tested by the U.S. Department of the Interior at a pilot plant in Florida. As they are simplified and costs reduced, small installations should begin to appear in areas where water supply is a most critical problem. Prefabricated, plastic-covered units of a few gallons daily capacity will probably soon be available, particularly for export.

MAJOR FUTURE MARKETS FOR SOLAR ENERGY EQUIPMENT

By far the largest American market for solar energy equipment, at least during the present century, will be in residential heating and cooling systems. One-fourth of the Nation's energy consumption is for space heating, and the steady growth of air conditioning is placing increased demands on electric power facilities. Substitution of solar energy for these other sources, even if initially only in the sunniest regions of the country, will require large quantities of solar heating and cooling equipment.

Residential solar heating is still in the development stage. At least five buildings in the United States are now partially solar heated and others are in the planning stage. Several different systems are being used. The MIT house in Lexington, Mass., employs hot water in a manner similar to the Florida water heaters previously described, but on a larger scale. A house in Denver utilizes solar heated air and heat storage in a bin of loose rock. Supplementary heat is supplied to these buildings by conventional furnace equipment, or, as in two other installations, by a heat pump. The solar heated buildings in Massachusetts, Colorado, Arizona, and New Mexico are yielding valuable information on equipment performance, architectural design, convenience, economy, and public acceptance. All these factors, and others, are important in solar heating development.

In areas where domestic fuel is cheap, solar heating will probably not be important in the near future. Elsewhere, particularly where domestic fuel costs have been rising and where sunshine is plentiful, there should be commercial applications within a decade. Economics are not now favorable for construction of individual solar heating systems, but factory production of solar heating equipment could soon make costs competitive with fuels in many areas.

Development of solar-powered air-conditioning equipment is considerably behind solar space heating. No full-scale units are yet in operation. But the appealing aspects of maximum energy availability coincident with maximum cooling demand, seasonally and even almost hourly, along with the rapid growth of domestic air conditioning, are stimulating research in this field. Most attractive are absorption refrigeration systems operated by hot water, hot air, or steam supplied from roof-mounted solar heat exchangers used also for winter heating. The technical problems are more formidable than those of the heating system, but the favorable annual load factor on solar equipment operating most of the year is a strong development incentive.

It is very difficult to estimate the potential market for solar heating and cooling equipment. But even assuming as little as 10 to 15 percent of new residential construction being provided with solar heating and/or cooling systems in two to three decades, the annual market for perhaps 300,000 units could gross over half a billion dollars for the manufacturers of this equipment, and their material suppliers.

In an overall view of the potential of residential heating and cooling with solar energy, the following factors are of particular importance: (1) These uses represent a sizable segment of the national energy demand; (2) the cost of heating and cooling with conventional energy is likely to continue its rise; and (3) the quantity of solar energy available in winter and summer in most areas of the country is adequate for most of the house heating and cooling requirements.

Because of technical as well as economic limitations, several important applications of solar energy appear to be still further into the future. Commercial electricity from solar energy, for example, appears to be limited primarily by costs, at least insofar as present known methods for conversion are concerned. The efficient capture and storage of solar energy by means of reversible chemical reactions, on the other hand, has not yet been achieved because of technical problems.

The usual approach to electricity from solar energy is through operation of an engine by means of steam produced at the focus of a concentrating solar reflector. These reflectors have various shapes such as paraboloids, parabolic cylinders, and circular cylinders. The high cost of these reflecting surfaces, necessarily movable to follow the sun, coupled with the low efficiency of steam engines operating at only moderate pressures, would make the fixed cost of even a large installation, per kilowatt-hour generated, much greater than the cost of electricity from large powerplants in the United States.

There are two other approaches that appear more promising. One is the production of steam or other vapor in flat plate solar heat exchangers similar to the units used for house heating, and its subsequent expansion in an engine. But major reductions in equipment costs will have to be made before this source of electricity could begin to complete with modern powerplants. Again, however, in parts of the world where fuel is very expensive, small electric generating plants operated in this manner should become important at a much earlier date, possibly within the next decade. As fuel costs rise elsewhere, including the nuclear sources, solar electricity should gradually become predominant.

The other general method by which large scale electric power might be produced from solar energy is by direct conversion with semiconductor materials, such as employed in silicon cells, and by use of thermoelectric or thermionic generators heated by concentrated solar energy. Economies in materials, manufacture, and utilization will certainly reduce the cost of these components, but it is too early to forecast the minimum levels that can be reached.

Predictions of the eventual entry of the public utilities into the production and sale of solar electricity are based on considerations of only the presently known practical sources of energy. If successful and reasonably economical power can be achieved from the nuclear fusion reaction, based on hydrogen, deuterium or lithium, commercial solar electricity might be delayed many centuries. Certainly no one is able to make such distant projections, so the best we can do is to outline the expected situation if factors preclude application of this vast source of energy.

No discussion of solar energy would be complete without mention of the remarkable capabilities of the solar furnace. With very precise focusing reflectors ranging in size from a few feet in diameter to the 35-foot French solar furnace, these systems can produce temperatures in excess of 5,500° F. The newest solar furnace is the 28-foot concentrator at the Quartermaster Research and Engineering Center in Massachusetts. Although these units have some unique research and development uses, their cost now prohibits application as industrial production equipment. Another long-range prospect, therefore, is for solar furnaces of perhaps more economical design being used in the next century for high temperature metallurgical and ceramic processes. Solar variability is of course a disadvantage, but choice of furnace sites could minimize unplanned shutdowns.

One of the most intriguing potentialities of solar energy is in the combined energy absorption and storage by means of photochemical reactions. For example, water can be decomposed into hydrogen and oxygen by the absorption of energy in the ultraviolet portion of the solar spectrum. These gases can be stored for subsequent combustion and power generation. Certain other reactions could possibly be utilized whereby absorption of energy would cause a change in one direction which could be reversed when desired to liberate the absorbed energy as heat or more ideally, as electricity. Limited progress has been made along all of these lines, but as yet, only small fractions of 1 percent efficiency in converting solar to chemical energy have been achieved. If a substantial technical "break-through" should occur, the whole economic picture of large scale solar energy utilization could be affected.

CONCLUSION

In the long view, solar energy potentially has all the applications of conventional energy sources. However, there are fewer incentives for development of this new supply, the principal interest being limited to manufacturers of materials and equipment for energy conversion.

Several solar operated devices are already being marketed. By means of these, the individual user is converting solar energy to heat and small amounts of electricity. These applications are specialized, and not significant in terms of energy quantities. Within the next decade, several solar-operated products for domestic use in the energy-scarce regions of the world should become important. These include cookers, refrigerators, water distillers, and small electric power generators. This market may become of major importance, and one not to be ignored by American industry. It is suggested that American goodwill abroad, particularly in the underdeveloped countries, could be enhanced by making such conveniences available to low-income segments of the population.

Salt-water distillation by means of solar energy may soon become competitive with other demineralization methods, and small units as well as some large plants should be in practical use abroad well within a decade. Some use in the United States may also develop in this period. It must be recognized, however, that the water from any known demineralization process is going to be costly in comparison with natural fresh water, and that use of these methods will be limited to rather special situations in the foreseeable future.

The most nearly competitive large application of solar energy in the United States is in the heating and cooling of dwellings and other buildings. This is also the most attractive future market for solar conversion equipment and the largest potential use of solar energy in this country during the next several decades. Current developments, particularly in the direction of cost reduction, should lead to some commercialization within a decade.

Unless there is a remarkable discovery in the conversion of solar energy to electricity, this application cannot be expected to become a significant factor in the U.S. energy supply until conventional energy costs increase severalfold—possibly in the next century. Prior use will undoubtedly occur in areas of the world having less abundant fuels. Ultimately, power companies here and abroad will become the principal direct users of solar energy and convert it to electricity for public consumption.

As a concluding remark, I should add that in many potential space applications, solar energy seems to have no peer, and its development in this connection should be spectacular.

Thank you, Mr. Chairman.

Representative PATMAN. I should ask you if the Government is giving any assistance by subsidies or otherwise to the development of solar energy?

Mr. LÖF. Not at the present time, Mr. Chairman.

A bill was introduced in the last session by Senator Bible and Congressman Hosmer for such legislation, but I believe no action was taken. I believe, however, it is going to be introduced again in the next session.

Representative PATMAN. It occurs to me that in view of our particular interest in the Latin American countries and our recent creation of the Inter-American Bank, that some of these suggestions you have here would be applicable to that situation in which we want to create and cultivate as much goodwill in those countries. Do you not think the development of solar energy would be particularly applicable to the southern area?

Mr. LÖF. Yes, the solar environment there is good. The economic environment I feel is also good, because many of these countries are energy poor. This energy poverty extends clear down to the individual user for cooking and other domestic purposes. It seems to me that as an instrument of goodwill, and also as a means for development of solar energy in a way such that benefits ultimately would come back to the United States, those efforts would be to our great advantage.

Representative PATMAN. Thank you.

Mr. Widnall?

Representative WIDNALL. Mr. Löf, I enjoyed your statement very much. It is certainly quite enlightening.

You mention the solar furnace at the Quartermaster Research Center in Massachusetts. Wouldn't that be a Government project or Government aid in that direction?

Mr. LÖF. Yes, indeed. You are right. This is a research tool being used by the Quartermaster Corps for high temperature studies. But I would not look upon it as an effort particularly to develop solar energy. It is simply a useful device for securing very high temperatures with a large heat input. It is being used, incidentally, to simulate the effects of atomic bomb blasts so that the effects of heat flash on materials can be easily determined. It also has some other uses there.

Representative WIDNALL. To the best of your knowledge, that is the only Government project in the field at the present time?

Mr. LÖF. There is, of course, the solar distillation of sea water experiment in Florida being conducted by the Interior Department. This is one of many processes being investigated. Then there is a proposal for an Air Force solar furnace of much larger size than the quartermaster furnace. This is still in the discussion stage.

Representative WIDNALL. Thank you very much.

SOLAR ENERGY ECONOMICS

(By J. A. Duffie[1] and G. O. G. Löf[2])

The use of solar energy, in most applications, is dependent primarily on economic considerations; solar energy can become an important energy source when the costs of its use become competitive with the costs of energy from other sources. The basic and usually most costly item of equipment for solar energy utilization is the collector, or solar heat exchanger, and the amortization of the first cost of this and associated equipment is the major cost of solar energy. In this paper, the probable economic feasibility of several solar applications is assessed by using the costs of energy from present sources as a basis for estimating upper limits on the first cost of solar heat exchangers and their associated equipment. For example, for space heating in temperate climates, heat exchanger costs would have to be in the range of $1–$6 for solar heating to be competitive; this appears to be within an attainable range.

[1] Director, solar energy laboratory, University of Wisconsin, Madison, Wis.
[2] University of Wisconsin and chemical engineering consultant, Denver, Colo.; research associate Resources for the Future, Inc. Based on a paper presented at the joint A.I.Ch.E.-C.I.C. Chemical Engineering Conference, Montreal, Quebec, Apr. 20–23, 1958.

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Solar energy in most applications is not now competitive with energy from other sources and, until it is, widespread use cannot be expected. The costs of collecting and using solar energy include the major items of amortization of first cost, direct operating costs, and realistic maintenance costs. There have been little quantitative data available on these costs for most of the promising applications. Economic studies can serve to indicate the more promising applications, where research and development studies may be fruitful.

The first cost of a system for utilizing solar energy, for any of the purposes indicated, includes (*a*) the collector system with its pumps, ducts, piping, etc.; (*b*) the storage system, if required; (*c*) the "energy-utilizing" unit; and (*d*) the necessary auxiliaries such as control systems and instruments. These first costs should be amortized over periods which realistically represent the expected life of the equipment. Direct operating costs should include power costs for such purposes as pumping heat transport fluids and labor for operation. Maintenance expense includes costs of cleaning and repair of collector systems, glass or reflector cleaning and replacement, servicing of plumbing or duct work, and maintenance of storage units, engines, coolers, and auxiliaries.

Where continuous output or continuous availability of output of a process is required, in most temperate climatic zones it appears to be economically impractical to provide sufficient collector area and storage capacity to operate processes exclusively on solar energy. Auxiliary energy sources must be provided to carry the load during prolonged nonsunny periods. As with most processes, the major economic consideration is the minimization of the total cost of the product of the process. Thus, if fuel is the major cost factor in a conventional system and if the costs of the product of the solar-operated system are lower than the corresponding fuel costs on the conventional system, total costs can be reduced by use of the solar-operated system. For example, in a house heating system in areas where central heating is required, a conventional furnace is needed; if the total cost of heat delivered from a solar heating system is lower than the fuel saved by it, the overall cost of heating can be reduced by use of the solar heating system.

COSTS OF ENERGY FOR SEVERAL APPLICATIONS

The availability and costs of energy from various sources over the world are widely variable, and the possibilities for economic utilization of solar energy are correspondingly variable. The competitive position of solar radiation as an energy resource for many applications may be expected to improve with time, as advances in the new fields of solar technology make its use less expensive and as the costs of energy from other sources rise. The economics of solar energy utilization are also dependent on the development of local resources. The competitive position of solar energy thus varies with location, nature of the application, and time, and generalizations on the relative costs of energy from solar radiation and other sources are difficult to make. In this discussion, the probable economic feasibility of several solar applications is assessed by using the range of costs of energy from present sources as a basis for estimating upper limits on the first costs of the solar-operated systems.

Table 1 shows the range of costs of energy for three applications which are of potential interest as solar processes.

TABLE 1.—*Estimated costs of energy for several applications at selected locations*

Location	Type and capacity	Cost	Notes and references
SPACE HEATING			
1. Central United States	10^5 B.t.u. per hour oil burner	\$1.50 per 10^6 B.t.u.	Fuel oil at 15 cents per gallon, fuel cost only.
2. Western United States	10^5 B.t.u. per hour LPG system	\$2 per 10^6 B.t.u.	Propane at 17 cents per gallon, fuel cost only.
3. Denver	Natural gas	\$0.75 per 10^6 B.t.u.	Fuel cost only.
SPACE COOLING			
1. South United States	2–5 tons compression	5 to 8 cents per ton-hour	Electric power at 2 to 4 cents per kilowatt-hour, C.O.P.=2.5, 20 percent load factor, equipment cost included at 10 percent per year.
2. South United States	do	2.5 to 6 cents per ton-hour	Fuel cost only, at \$0.75 to \$2.00 per 10^6 B.t.u.
		5.5 to 9 cents per ton-hour	Same, with equipment cost included as in No. 1.
3. Cairo, Egypt	do	12 cents per ton-hour	Electric power at 7.5 cents per kilowatt-hour fixed cost, 40 percent load factor.
4. Dakar, West Africa	do	25 cents per ton-hour	Electric power at 17 cents per kilowatt-hour, 10 percent per year fixed cost, 40 percent load factor.
POWER			
1. United States of America	Industrial large capacity	1 cent per kilowatt-hour	Power generated at large central thermal power stations or hydroelectric stations.
2. United States of America	Small central powerplant	3 cents per kilowatt-hour	Power from a 10,000-kilowatt central power station.
3. Rural United States	Auxiliary generator	4 to 8 cents per kilowatt-hour	Power from small gasoline generator plants of 2- to 3-kilowatt capacity.
4. Cairo, Egypt		7.5 cents per kilowatt-hour	Residential lighting rate.
5. Dakar, West Africa		17 cents per kilowatt-hour	Residential rate.
6. Rural India	Animal power	15 to 30 cents per kilowatt-hour	Power for lifting irrigation water, estimated in terms of electrical equivalent.

Solar and conventional processes are compared by estimating the maximum cost chargeable to a solar-operated process in order for it to compete with conventional energy sources. The comparison is simplified by two assumptions. First, even though solar intensity is widely variable over the earth's surface, the climates where solar energy is most likely to be widely used do not have greatly differing annual solar energy reception. Second, although various designs and applications involve solar collection efficiencies which vary considerably, research on materials and thermal properties of collectors should lead to improvements in design and selection of systems which permit average efficiencies of conversion of solar radiation to sensible or latent heat in a working fluid to reach about 60 percent. This figure is used in the following analysis, except where another choice is dictated by the special nature of the application. Attainment of this efficiency is contingent on further engineering advances in collector design and operation.

In solar energy applications discussed here, only the fixed costs, including amortization of the solar equipment, are considered. Since there is no information available in the literature on maintenance or operating costs for any solar operated systems, they have not been included. Ultimately these costs must be minimized by satisfactory design.

Some of the assumptions made in estimating the allowable costs of solar units are in part arbitrary, and the estimates are considerably affected thereby; this is particularly true of the assumptions of useful life of the equipment. Where there is reasonable indication of the useful service life of a solar unit, this has been taken as the basis for amortization cost, or the amortization rate has been taken equal to a typical rate for the energy source replaced. No account is taken of the availability of capital for investment in the solar-operated systems.

In contrast to many items of process equipment, the cost per unit of capacity for a system of flat plate solar heat exchangers, if made up of a number of factory-produced units, would be nearly independent of the capacity of the system. Thus, in the estimates following, the costs are considered on the basis of a square foot of collector without regard to the total capacity of the system. The assumption that cost is independent of capacity for a focusing collector is less valid because of variabiliy of requirements for moving and positioning the reflector, wind loading, and other factors.

SPACE HEATING

Space heating is an application of solar energy which is of interest because (*a*) the temperatures required are low enough (100° to 150° F.) to permit the use of flat-plate collectors, (*b*) the solar energy incident on a dwelling during the winter in most temperate climates is more than the energy needed for comfort heating, (*c*) there is no requirement for conversion of thermal to other forms of energy, and (*d*) comfort heating is a major user of conventional fuels.

Space heating costs in the United States are to a large extent dependent on the proximity of the user to fuel supplies. In table 1 the approximate costs of 1 million B.t.u. net heat delivery to a residence from inexpensive natural gas (based on rates in Denver, Colo.), propane "bottled gas" (typical western U.S. price) and fuel oil (typical national price) are listed. In estimating space heating costs, a combustion efficiency of 80 percent has been assumed, and only fuel costs have been considered as the fixed costs of the conventional (auxiliary) equipment are not reduced by the solar heat supply. In the United States, typical costs of fuel for residential space heating generally range from 75 cents to $2 per million B.t.u. delivered. In other areas, costs may be several times as great.

With heat collection by 1 square foot of a flat-plate solar heat exchanger at a rate of 150,000–300,000 B.t.u. per annual heating season (variable with the length of the heating season), the value of the output per square foot of exchanger would range from 11 to 60 cents, based on a value of delivered heat of $0.75 to $2 per mililon B.t.u. At a fixed cost of 10 percent per year, an expenditure of $1.10 to $6 per square foot could be justified for the collector and associated equipment. The flat-plate heat exchangers suitable for house heating applications can be fabricated from materials such as glass, sheet metal, and insulation; costs of these materials in most proposed designs total less than $1 per square foot of collector. However, the labor costs for fabrication of the solar collectors for the few solar houses built to date have been many times the material costs.

For a practical solar heating system, heat storage must also be provided. This may be in the form of a liquid (hot water), solid (crushed rock), or a change-of-state material. With a heat storage capacity equivalent to a day's solar collector delivery capacity, the cost of heat storage equipment should be much less than that of the solar collector. Auxiliary equipment such as fans, ducts, piping and control instruments, where required in addition to the conventional system, will add further investment to the system. However, it appears that collectors and associated equipment can be built, in quantity, for costs within the range of $1 to $6 per square foot, and development of solar space heating systems appears attractive.

SPACE COOLING

Research on solar space cooling is suggested by the generally good correlation between energy supply and cooling demand, as areas of high solar incidence usually have uncomfortable summer temperatures. Technical feasibility is assured by the fact that heat-operated absorption refrigeration units require temperatures well within the range of working temperatures of solar heat exchangers. Comfort cooling by solar energy can be associated with a solar heating system, and if used for both purposes, the allowable cost of the solar heat exchanger would be greater than for either of the separate purposes because of its useful energy collection over a greater part of the year.

In evaluating the potential economics of solar cooling, costs of energy for conventional refrigeration systems have been presented in table 1 as cents per ton-hour of refrigeration, (i. e., cost per 12,000 B.t.u. of cooling). The compression system has been evaluated in terms of total fixed and operating cost with a use factor of 20 percent. For absorption systems, in which heat could be supplied to the refrigerant generator either by solar or conventional means, it is of interest to make two comparisons: the fuel cost only can be compared with the cost of heat from a solar collector, or the total costs of both fuel and equipment can be compared. Operating costs for air conditioning vary greatly with location as shown in the examples selected, which were chosen primarily for their comparatively high solar availability, and also their wide energy cost range.

Table 1 shows typical U.S. costs in the range of 5 to 9 cents per ton-hour of refrigeration, applicable to small compression or absorption units of 2 to 5 tons refrigeration capacity. In a heat-operated system the cost of fuel would usually lie in the range of 3 to 6 cents per ton-hour equivalent to $36 to $72 worth of fuel per year of 1,200 operating hours. If solar heat is substituted for fuel in an absorption system about 150 square feet of solar collector would be necessary to provide sufficient heat for replacing each ton of cooling capacity. Considering use of solar energy only for cooling, at 10 percent annual fixed cost, $2.50 to $5 could be paid per square foot of solar collector and the necessary storage facilities. These costs are in an approachable range. Substitution of solar energy for the usual heat source in a conventional cooler will require some modification in cooler design, particularly if flat-plate collectors are used, because of the variable nature of the solar energy supply.

Replacement of an entire compression cooling system by a solar-operated absorption-type cooler requires consideration of air-conditioner costs as well as solar heat exchanger costs. At total conventional costs of 5 to 8 cents per ton-hour of refrigeration, there would be an investment of approximately $4 to $7 allowable per square foot of solar collector and associated air-conditioning equipment. If the costs of an air-conditioning unit operable with solar heat are reducible to those of a conventional unit, $100–$200 per ton of refrigerated capacity, the allowable cost of the solar collector would be reduced to the range of $3 to $6 per square foot.

Two other factors improve the prospects of solar cooling. In many installations, particularly in temperate climates, space heating will also be accomplished by use of the solar collector; this increases by a substantial amount the allowable investment in the solar collector, storage unit, and other common facilities. Secondly, in other parts of the world where energy is more expensive than in the United States, the economic situation is more attractive for the solar operated cooling system. In Dakar, for example, the cost of electricity for air-conditioner operation is 10 times as great as in the United States. This permits a substantial increase in allowable investment in solar cooling facilities. In many such areas space cooling is now used to a very limited extent. As the purchasing power of the peoples in these countries rises, however, and the modern conveniences enjoyed in industrialized countries come into increasing demand, solar air conditioning should achieve substantial application.

SOLAR POWER

Generation of power from solar energy, in the form of mechanical work, has been accomplished on a limited scale by the production of steam or other vapor in a boiler heated by a solar collector and the expansion of this fluid in a reciprocating engine. Electricity has been generated by coupling a generator to this type of engine, or by converting sunlight directly to electrical energy in a silicon semiconductor cell or "solar battery." These applications have been either experimental or specialized, and not based on the economics of substantial energy supply.

Costs of power from several selected types of power installations shown in table 1 range from 1 to 30 cents per kilowatt-hour. Most residential consumers of electricity in the United States and Canada pay 2 to 3 cents per kilowatt-hour for power from central plants. Power from some small central installations is more expensive, ranging up to 3.5 cents per kilowatt-hour, and that from gasoline or diesel-powered generator sets used on nonelectrified farms for pumping irrigation water, etc., costs in the range of 4 to 8 cents per kilowatt-hour. In some foreign locations much higher costs prevail, even in central stations. In estimating these costs, it was necessary in some cases to assume load factors and fuel costs; the best available data and reasonable assumptions of load factors and useful life of equipment were employed. In most of the small installations fuel is the major item of cost.

For a solar powerplant consisting of a focusing collector or a flat-plate solar exchanger producing steam for use in an expansion engine the maximum plausible efficiency from steam (100 pounds per square inch) to electricity in small units appears to be about 15 percent. With a focusing collector having a 60-percent solar collection efficiency, about 15 square feet of solar collection surface would be required for the daily generation of 1 kilowatt-hour. Over the total cost range of electric power shown in table 1, from 1 to 30 cents, and at a total annual fixed cost of 15 percent of the original investment, the allowable expenditure for solar collector, powerplant equipment, and all auxiliary facilities would range from $24 to $720 for the 15 square feet of collector and associated equipment necessary to develop 1 kilowatt-hour per day. Per square foot of solar receiving surface, these figures become $1.60 and $48, respectively; or for an average delivery of 1 kilowatt for 10 hours daily, $240 to $7,200 are the maximum allowable costs for the 150-square-foot collector and associated powerplant.

Small steam engines, if manufactured in quantity, should be obtainable for less than $50 per kilowatt capacity, and electric generators should be in the $50 range. At $100 for these items, the allowable investment in solar heat exchange units would be $140 to $7,100. Thus, in areas of high power costs (e.g., rural India and parts of North Africa), the allowable investment in a solar boiler and associated equipment is high enough to make solar power of potential economic interest. With these high allowable investments per square foot of solar reflector or flat-plate exchanger, the prospects appear promising; however, there are no small prime movers presently available that will operate at an efficiency near 15 percent on 100 pounds per square inch steam, nor are there focusing collectors of reasonable cost which will produce this steam at 60-percent efficiency. A further deterrent in these areas may be lack of capital to make the initial investments required for the solar power systems.

Since solar power is not continuous and electrical storage appears to be prohibitively costly, auxiliary energy supply would have to be provided where continuous power is essential. The load factor on the auxiliary facilities would be reduced by the solar powerplant, and, in effect, only a portion of the fuel cost reduction in the competing (standby) electric power station should be credited to the solar powerplant. In some applications, such as pumping irrigation water, auxiliary energy would not be required and the economic comparison involves the total alternative original investments and operating costs.

For large central powerplants, Hottel has made economic studies of the use of flat-plate collectors and low pressure turbines and has concluded that the costs are potentially in the range of two to three times the current costs of power from conventional fuels in the United States.

OTHER PROCESSES

There are several additional uses of solar energy which merit consideration. Among these are applications in nonindustrialized areas where sociological considerations may be as important as the economic factors; solar cookers and food coolers are examples. If solar cookers can be made cheaply enough and if the requirements for their operation can be made consistent with the eating and living habits of the users, they could be used by millions of people who are now using wood or other primitive fuels. In northern Mexico, for example, fuel for cooking is a major item of expenditure for many low-income families, and reduction in the use of wood could improve their economic situation as well as decrease the rate of deforestation. Small, inexpensive refrigerators, operated by solar energy or other heat sources, could provide facilities for food preservation not now existent in many of these areas.

Salt water demineralization by solar distillation could provide potable water in arid regions where solar radiation is high. At a distilled water cost of $2 per 1,000 gallons (based on costs in several large fuel-operated evaporation plants) and at a typical daily productivity of one-tenth gallon of potable water per square foot of solar distillation plant, about 75 cents is the maximum allowance for investment in each square foot of solar distiller and accompanying auxiliary equipment if annual fixed and operating costs are 10 percent. With the lower cost of capital used for public works, annual fixed costs could be somewhat lower and the total allowable investment might be increased to $1 or $1.25 per square foot. Large scale construction methods and the use of cheap materials such as bituminous coatings, glass, and some plastic films may permit construction in this cost range. The problem is difficult, however, and exceptional economies in design, construction, and operation must be developed if solar distillation is to compete with fuel-operated demineralizers.

In comparison with the usual costs of natural fresh water, the projected prices for solar-distilled water are very high. However, the need for demineralized saline water is expanding, and in favorable locations, solar distillation of saline water has the potential of becoming economically attractive where potable water must be available for human consumption.

SUMMARY

The foregoing appraisal of several energy applications from the standpoint of their competitive position with respect to conventional sources of energy shows the possibilities and limitations of these applications. In each case chosen, solar energy appears to have promise in some areas and some scales of use. Other applications may be similarly considered.

Representative PATMAN. Each witness has been given permission to extend his remarks and insert any germane material.

We also have for inclusion in the record four additional items:

(1) A statement from the Independent Natural Gas Producers Association;

(2) A letter, together with four articles and speeches, by Commissioner William R. Connole, Vice Chairman, Federal Power Commission which have been called to our attention:

"Energy, Its Use and Abuse," Independent Natural Gas Association of America, September 1957,

"Future Prospects for International Pipelines," Journal of the Pipeline Division Proceedings of the American Society of Civil Engineers, June 1958.

"Role of Regulation in Developing the Transportation and Use of Liquefied Methane," Conference on Natural Gas and Oil Problems, Federal Bar Association, March 1959, and

"Take One Giant Step," National Coal Association Annual Convention, June 1959.

(3) A statement from the consulting firm of Boni, Watkins, Jason & Co., Inc.; and

(4) Letter from Richard J. Gonzalez, Humble Oil & Refining Co., Houston, Tex., dated October 21, 1959.

Without objection, they will be inserted in the record at this point.

(The statements referred to follow:)

STATEMENT ON BEHALF OF INDEPENDENT NATURAL GAS ASSOCIATION OF AMERICA, WASHINGTON, D.C.

This statement is directed to the subject matter of the coal interests' proposals for a "national fuels policy." Its submission was prompted by your subcommittee's announcement which disclosed that those interests would participate in these hearings. We called on your staff to offer a witness or statement and it was suggested that a written statement would be preferable.

In order to file this statement before the hearings closed, it was necessary in this preparation largely to anticipate the nature of the testimony which those interests would present. To the extent any reference herein to claims or arguments advanced by the coal interests do not precisely fit this record, the references are to claims and representations made by those interests on this subject matter before other committees and published speeches and statements.

Coal proposals are not in the national interest

This association desires the record to show that the proposals urged by the coal interests as a "national fuels policy" are in our opinion inimical to the best interests of the Nation and the principles which have made it strong.

There were introduced late in the last session and are now pending in this Congress numerous concurrent resolutions to create a Joint Committee on a National Fuels Policy. The resolution was favorably reported in the Senate by the Interior Committee without hearings, and was referred to the Senate Committee on Rules and Administration. In the House the resolution was referred to the Rules Committee where it was tabled.

A bill providing for an independent Federal coal research program was recently vetoed. Early attempts at this and other legislation have sought to have written into law some principles designed at placing restraints on the other competitive fuels.

The proposals for a national fuels policy mentioned above contain provisions that, in effect, require predetermined answers for what we are asked to accept as a factfinding study. These include assumptions—

(*a*) That some fuels are in danger of approaching the limit of reserves.

(*b*) That we have no national fuel policy.

(*c*) That its absence has caused uneconomic exploitation of, and wasteful competition between, limited energy resources.

(*d*) That our Government must undertake the maintenance of our basic fuel industries.

These are the criteria which represent the impartial and objective study which the coal representatives urge with such eloquent articulateness. It is significant that none of the witnesses (including representatives of public bodies and independent research organizations), in this hearing who preceded the coal witnesses made any suggestion for the need of such a program. In fact, the nature of their testimony completely and in some cases quite pointedly refutes the arguments of the coal interests.

These current proposals are centered in the National Coal Policy Conference which was represented before this subcommittee by its president. That conference is a coalition of coal operators, labor unions, coal-carrying railroads, and some equipment manufacturers and electricity generating companies. Their preliminary aim is directed at gas and oil used as industrial fuel. Their ultimate aim is to strengthen their position for all competitive markets and uses. These aims are clearly set forth in their published statements and proceedings, and in the published statements of the groups which comprise this coalition. Their so-called national fuels policy has as a principal purpose the curtailment and prohibition of the use of natural-gas.

They recently launched a most ambitious and massive program concentrating on the national fuels policy theme under which they have repeatedly sought Government intervention to obtain competitive advantage. For more than 20 years these interests have sought by every means available either to prevent the introduction of natural gas service into new market areas or to prohibit its use for industrial purposes, or to require the prices to be increased so high that fuel consumers will be forced to turn to coal. In short, the major purpose of their program has been based on the theory of denying or prohibiting fuel which competes with coal from being used for certain purposes and denying the American consumer the right to choose between available fuels at competitive prices.

We do not believe that such a program has any place within a free enterprise system. We understand free enterprise to encompass the right of all who live within it to offer whatever they have created—whether products, services, or skills—to other individuals, who are just as free to take them or pass them up.

Gas industry has never opposed research nor fair inquiry

The natural gas industry has never interposed opposition to any proper Government research nor fair inquiry into any business activity for legitimate purposes of Government or the best interests of the Nation. We will not, however, passively submit to the development of a program conceived and instigated for the purpose of artificially restricting our business for the benefit of our competitors and at the expense of fuel consumers.

Fuel and energy requirements of our country are matters of particular concern and interest to all branches of our Government and are legitimate areas for Government study. However, we do not think that legislative or executive inquiries should be circumscribed by predetermined guidelines and preconceived objectives which are contrary to our national policy to foster competition.

The facts concerning every phase of each of our fuels industries, including production, uses, consumption, prices, revenues, earnings, reserves, etc., are regularly collected and published by private and Government sources. These facts with respect to the natural gas industry, nearly every phase of which is completely regulated by a public agency, are always open for public inspection. Our fuel reserves are under constant Government scrutiny and study and have been repeatedly considered by congressional committees.

They also seek to amend the Natural Gas Act for coal industry's benefit

For many years the coal interests have sought to amend the Natural Gas A
in such a way as to impose restrictive criteria upon the Federal Power Comm
sion in the exercise of its regulatory responsibilities.
The coal interests claim the Federal Power C...
agencies have no guides or standards by wh... when the Natural Gas Act was passed
tion to other fuels and that regu... ...ate phases of the natural gas industry in the
quilt basis. ...ne public interest is the congressionally established
The congressi... ... controls every regulatory action and decision by the FPC. While
in 1938 w... sometime disagree with the FPC regarding aspects in the application of
public in... ...erriding principle, we are particularly concerned that it not be changed
criteria ...
we m...ecting the coal interests.
thi... representatives of coal, railroad, and related labor unions, petitioned to inter-
vene and oppose one of the first applications filed for an extension of facilities
after the Natural Gas Act was passed in 1938. Since that time they have consistently opposed every major extension of natural gas service. They have participated in nearly every natural gas case and have fully and repeatedly presented their evidence, arguments, and claims. They have not only had their "day in court," they have had almost every day for 19 years.

Their repeated claim is that natural gas should be conserved for superior uses and that its use for industrial purposes is inferior and below cost and is subsidized by the prices charged household consumers. These claims have no foundation in fact. The terms "superior" and "inferior" have in our opinion been loosely and incorrectly applied to fuels. These relative terms can be properly determined only by the value which the consumer places on a fuel for his specific purpose. They are directly related to the free choice of the consumer and to consumer preference.

Natural gas is sold to industrial users (1) directly by producers of gas in or adjacent to the gasfields, (2) by pipeline companies directly to consumers, and (3) by distribution systems who purchase all their supply of gas from pipeline companies.

Pipeline systems, and the distribution systems they serve, are designed and constructed primarily to meet the fluctuating and seasonal requirements of the household and commercial customers. These systems represent a very high capital investment in relation to annual revenues. Aside from the gas itself, the costs of providing all classes of service are for the most part fixed and go on irrespective of the amount of gas being transported. One of the major items of fixed expense is depreciation. If only household and commercial service is delivered from the systems, the rates to those customers would be required to be high enough to return the full amount of fixed costs. On the other hand, to the extent that the industrial gas price exceeds the cost of the gas purchased and related out-of-pocket costs, the industrial sales make a contribution and benefit to the other customers. In some instances the contribution made by industrial sales to the costs of the pipeline have represented the difference between an economically feasible project or extension to new areas and one which would not otherwise have been possible. A reliable estimate of the dollar effect of the contribution made by industrial gas sales to other classes of customers for the year 1956 was on the order of $525 million.

The "ills" of the coal industry

The coal interests have long and loudly shed bitter tears at their loss of revenues and production. They claim coal is a "sick" industry.

We do not wish to belittle or to make light of even a temporarily depressed condition of a major industry, but we very seriously question both whether the reasons advanced for its ills will bear the light of scrutiny and the validity of some of the cures for those ills which are advanced. Their repeatedly expressed desi[illegible] ect natural gas consumers is not substantiated by their repeated leg[illegible] l regulatory proposals aimed at raising gas prices or prohibiting its use.

Spokesm[illegible] for the coal industry to a large extent blame coal's depressed condition [illegible] what they term "unfair" competition from natural gas which they claim has taken their traditional markets. Statistics regarding coal production, consumption, prices, major uses, etc., show some significant trends and shifts other than those reflecting decline in annual production which has been stressed by the coal interests. For instance, they show that until about the middle 1940's the class I railroads had been one of the largest consumers [illegible] coal. Since that time the use of coal by railroads has practically disappeared [illegible]en by those whose revenues are substantially derived from coal hauling.

The railroad market shrank from 109 million tons in 1947 to only 3.7 million [illegible]s in 1958. The decline in the use of coal by railroads is recognized as the [illegible] market change in the history of the coal industry. More than tions on the use of natural gas. They cla[illegible] [illegible] by railroads and the railroad revenue loss of revenues. This is little short of amazin[illegible] [illegible] other commodity. Yet some of economies and modernization by railroads in substituting [illegible] to propose and seek restric- the steamer. We do think it little short of fantastic that the railro[illegible] for railroads' deny a similar freedom of choice of fuels to other consumers. [illegible]n the fuel [illegible]gine for [illegible]ants to

Using national statistics sometimes yields fallacious interpretations

The coal interests make much of the fact that the percentage of our total markets supplied by that industry continue to decline while the percentage supplied by natural gas and petroleum continue to grow. They utilize these national relative percentage factors as an argument for the Government to step in and restrict the use of natural gas and oil.

From an industry's viewpoint these relative national percentages may sometimes have importance but from a national interest standpoint the percentage of the total fuels market occupied by a single fuel is of no significance. Such statistics are subject to different and sometimes quite fallacious interpretations.

For instance, it is not inconceivable that the coal industry may expand its current production rate two or even three or more times within the foreseeable future and still maintain a declining percentage of the total energy market.

In market shifts the coal industry has found rising demand from the electric utilities for coal to fire boilers to turn generators for electricity. Electric utilities have more than doubled their consumption of coal since World War II. This increase has been more than 400 percent since the Natural Gas Act was passed in 1938, despite phenomenal increases in the efficiency of electric generating plants. Of great deal more significance, however, is the tonnage increase. The use of coal for this purpose has increased from 38.1 million tons in 1938 to 155.7 million tons in 1958. The experts, both within and without the coal industry, say that by 1975–80 electric utilities will be able to use more coal tonnage than all current coal production.

In spite of the past growth in use of coal for electricity generation—in spite of the predictions for future growth—one of the foremost objectives of the coal interests legislative proposals is to limit and curtail the use of natural gas and oil for this purpose. They have insisted that this is one of the natural markets for coal and they will insist and will have "what is (theirs) by right."

They use statistics to support their claim that coal has lost a large percentage of this market. Again the statistics widely used and widely quoted are national figures which are quite misleading. Their own industry has traditionally classed 12 States as noncoal consuming, among which are the largest natural gas producing States where coal has never been used to any extent for any purpose. Over 60 percent of the total volume of natural gas used for fuel in electric generation is used in 9 of the 12 non-coal-consuming States. In those States where it is economical to use coal its total percentage of the electricity market is very nearly as great as it was 20 years earlier while its tonnage increase for this use is as dramatic as has been the decline in railroad use. Neither relative percentages nor tonnage increase takes into account the substantial amounts of coal used for generating plants of industrial establishments.

We have a national fuels policy

We have a national policy concerning fuels. It is the same policy which has made this a strong nation in every respect. It may be summed up as our policy of allowing free competition between the different forms of fuel and encouraging research to overcome the disadvantages of so-called inferior fuels.

If as a nation we depart from such a policy for expediency or convenience of one fuel industry, it may create a disastrous imbalance and disruption in our economy. We are in a period of population and industrial growth and expansion which will require tremendously increased quantities of energy. We are going to need all the energy, from whatever source, that we can get. This energy will come from conventional as well as new sources. The consumers will be best served so long as their fuel requirements continue to be supplied them on a competitive basis. Intense competition in the energy field is entirely consistent with our private enterprise philosophy.

The subject of interfuel competition is exceedingly complex. The conventional fuels, coal, oil, and natural gas, are competitive or potentially competitive for many known and some to be developed uses. The comparative newcomer, atomic energy, is entering the field. Electric energy is becoming a strong contender in some of the uses presently dominated by conventional fuels.

One of the coal witnesses pointed to the tremendous increase which will be required for electric generation and said that bituminous coal will gradually enlarge its proportion of that market. This is as it should be so long as it is accomplished under competitive conditions. We agree with Dr. Gonzalez' statement that unless the system of interfuel competition that has worked so efficiently in the past is upset by Government intervention, adjustments in the use of alternative available fuels will continue to occur gradually and to the benefit of consumers in response to changing economic conditions.

It is impossible to predict definitely what the competitive energy and fuel situation will be for generations to come. Fuel consumption trends have followed shifting patterns with changed conditions. Interfuel competition does not adhere to fixed relationships where alternatives are made available which offer varying appeals in price and quality. Market relationships between coal, oil, and gas have changed over the years, as have also the competitive relationships between different grades and sources of coal.

The theory of a national fuels policy, of equating conservation to end use control, of ascribing "inferior" and "superior" uses to energy resources presents a complex and technical maze of infinite difficulties. The competitive characteristics of our economy would be destroyed if the policy of the Government were to try and maintain for each competing energy an equivalent competitive position.

Respectfully submitted.

JOHN A. FERGUSON,
Executive Director, Independent Natural Gas Association of America.

FEDERAL POWER COMMISSION,
OFFICE OF COMMISSIONER,
Washington, October 22, 1959.

Hon. WRIGHT PATMAN,
Joint Economic Committee, U.S. Congress,
Washington, D.C.

DEAR MR. PATMAN: I have been interested in following the hearings which your committee has been conducting on energy resources and of course am familiar with the material which the Federal Power Commission has furnished to the committee through Commissioner Kline and Messrs. Kallina and Adams.

It occurs to me that you might be interested in including in the record as well some other materials which are closely related to the committee's interest and enclose copies of these for your information.

Very truly yours,

WILLIAM R. CONNOLE,
Vice Chairman.

Enclosures:
"Energy, Its Use and Abuse."
"Future Prospects for International Pipelines."
"Role of Regulation in Developing the Transportation and Use of Liquefied Methane."
"Take a Giant Step."

ENERGY, ITS USE AND ABUSE

(By William R. Connole, Federal Power Commissioner, before the Independent Natural Gas Association of America, September 10, 1957, Houston, Tex.)

The ages of man are known by the principal materials that supported them: the stone age, the bronze age, the iron age. By this token, our age will be known to future epochs as the age of steel. For our vast technology the result of pure science applied to daily tasks is largely dependent upon that material.

Yet we who live within our age would have it known as the era of fossil fuel energy, the driving force of our complicated steel machines. Indeed, the future archeologist would properly so regard it if he were not confined to material exidence of our society. As he probed into the sources of that energy, remarking the foundations of tumbled power dams, ancient generating stations, old mines, and the vestiges of oil and gas wells, he would conclude that fossil fuel energy must have been the most important dynamic element in our industrial life.

Indeed, the importance of energy, and therefore of energy sources and energy resources, can hardly be overemphasized. It is about the problems of maintaining the sources of that energy and about the consequent policy implications that I should like to direct your attention for a few moments.

Fortunately, we can see a mounting concern for the dynamics of our energy supply. Maintaining the supply of the energy resources which we voraciously yet casually consume has been attracting more and well-merited attention. We have long been concerned for the scarcity and cost of energy. Recent concern, however, is for the continuity of these vital elements as well.

The spendthrift nurses his last remaining dollar bill with many times the loving care devoted to his first "C" note. In the same fashion, contemporary America begins to display signs of prudent concern for tomorrow's energy supply. We feel the bottom of our fossil fuel pocket. We are stunned by the thought of an end to this formerly inexhaustible store.

When the Sault Ste. Marie Canal was completed in 1855, Henry Clay could say the utility of those wilderness works was beyond human imagination to conceive. Generations gave little thought to the decrease of bountiful endowment of forests, coal, petroleum, and natural gas. They saw no bottom to that resource pocket, no end to the rich store of fossil fuel supplies.

Nor has the time come to take a deeply pessimistic view of the matter. Yet whatever affects our energy supplies concerns us vitally. The time is here when every American must concern himself to secure a valid measure of the degree in which these irreplaceable stores must be conservatively used. Especially so for Americans who, as do you gentlemen, work daily with our greatest energy source—the fossil fuels.

Admiral Rickover of the U.S. Navy and Atomic Energy Commission has effectively described the critical importance of those fuels. He expressed himself so clearly that his thought cannot be improved by paraphrase. Let me read the admiral's own words;

"We live in what historians may some day call the fossil fuel age. Today, coal, oil, and natural gas supply 93 percent of the world's energy; water power accounts for only 1 percent; and the labor of men and domestic animals the remaining 6 percent. This is a startling reversal of corresponding figures for 1850—only a century ago. Then fossil fuels supplied 5 percent of the world's energy, and men and animals 94 percent. Five-sixths of all the coal, oil, and gas consumed since the beginning of the fossil fuel age has been burned up in the last 55 years.

* * * * * * *

"* * * All the fossil fuels used before 1900 would not last 5 years at today's rates of consumption.

"Nowhere are these rates higher and growing faster than in the United States. Our country, with only 6 percent of the world's population, uses one-third of the world's total energy input; this proportion would be even greater except that we use energy more efficiently than other countries. Each American has at his disposal, each year, energy equivalent to that obtainable from 8 tons of coal. This is six times the world's per capita energy consumption * * *.

"With high energy consumption goes a high standard of living. Thus the enormous fossil energy which we in this country control feeds machines which make each of us master of an army of mechanical slaves. Man's muscle power is rated at 35 watts continuously, or one-twentieth horsepower. Machines therefore furnish every American industrial worker with energy equivalent to that of 244 men, while at least 2,000 men push his automobile along the road, and his family is supplied with 33 faithful household helpers. Each locomotive engineer controls energy equivalent to that of 100,000 men; each jet pilot of 700,000 men. Truly, the humblest American enjoys the services of more slaves than were once owned by the richest nobles, and lives better than most ancient kings. In retrospect, and despite wars, revolutions, and disasters, the hundred years just gone by may well seem like a golden age.

"Whether this golden age will continue depends entirely upon our ability to keep energy supplies in balance with the needs of our growing population * * *."

These facts give special urgency to the need for constructive thinking about our energy resources. We find ourselves speeding at an ever-accelerating rate toward a day when the sources we rely on for virtually all of our energy will be available no longer. Consider for a moment only that one factor; population growth.

The rate of population increase, standing alone, is enough to startle the most indifferent. Consider that in the 8,000 years since the beginning of history to the year 2000 A.D., world population will have grown from 10 million to 4 billion. Ninety percent of that growth will have occurred in the last twentieth of that period, namely 400 years. The first 3,000 years of recorded history were required to accomplish the first doubling of population, only 100 years for the last doubling. The next doubling, however, will require only 50 years. Calculation produces the astonishing fact that for every 26 human beings ever born into this world, one is alive today.

Considering America alone, by the year 2000 our population of 300 million will be 4 times the 75 million of 1900. Since this growth is as much the cause as the rsult of our prodigious consumption of irreplaceable fossil energy sources think what this means to the very wellsprings of our material civilization.

A popular speculation connected with long-range economic forecasts is the impact population growth will have on our prosperity. It will give business "a kick" by providing an ever-increasing army of customers for an ever-increasing flood of products. But this naive though optimistic view of an infinitely complicated phenomenon, does little but give further comfort to those who will not see.

Never forget that before such an increase in population can bring any benefits there must be a concurrent increase in the energy sources to provide the needed goods and services. And, most importantly, those energy sources must not only be available, but they must be available at a price which assures their being used at least to the extent our presently known reserves are being used. Preferably their utilization should be greater.

Thoughtful observers already point out that the increasing demands on energy sources imposed by population increase hasten the need to tap more costly sources of fuels. Whether or not this will mean reduced per capita consumption remains for careful consideration.

An interesting recent discussion of this question appears in a publication of the Mellon National Bank and Trust Co. Mr. James N. Land, a vice president of the bank, states it as follows, "* * * our rising population is creating pressures on natural resources which in a number of respects tend to retard further increases in material well-being. Because our population is expanding rapidly, we must drill deeper oil wells and exploit less productive veins of coal and other minerals and less accessible and poorer quality forest areas and go further afield for the water supplies of our cities, all of which adds to unit costs and is a drag on prosperity."

Is it not possible that fossil fuels may reach a stage of practical, economic exhaustion before they become physically exhausted? To expect engineering advances will speed up efficiency rates of our fossil fuels burning equipment enough to offset this factor of exhaustion relies very heavily on the speculative factor of human ingenuity.

No matter how we twist and turn to avoid it; no matter how difficult it may be to admit, a central fact inevitably emerges from all of this. The source of 94 percent of the energy used in the world today has a limited existence duration. The ultimate extent of those limits is much closer than we care to admit. The unpleasant, but uncontrovertible, fact emerges: that according to our best estimates total fossil fuel reserves recoverable at unit costs up to double today's are likely to run out some time between the year 2000 and 2050, assuming present living standards and population growth rates.

Prudent husbandry, until we see reasonable assurance that they will be replaced by something else, obviously calls for careful conservation of the resources at our disposal. In the area of my birth and boyhood there is a mythical organization the NESPIC. All New England Yankees have automatic membership in that brotherhood. Its letters mean: "New England Society for the Prevention of Impairment of Capital." It has well fostered the integrity and stability of both the financial institutions and the personal fortunes of New England.

Of vastly more pervasive importance, however, is the development of policy that views with equal abhorrence practices that threaten to exhaust the material nest egg of all modern civilization—its energy sources.

All domestic or international policies ever developed would be worthless if the nations and peoples they motivate are reduced to primeval incompetence for lack of energy resources. It took more than the addition of a few cubic centimeters of gray matter to a sloping prehistoric human skull to give society meaning. It took the understanding of how to develop, use, and control energy. Only with this accomplished did man's relation to man become important, and by extension: Nation's relations with nations only then became significant. When simple, dumb survival is a consuming 24-hour problem men have no patience or need for the finer humanitarian considerations.

Amongst us in this room are some of the most influential craftsmen who will shape our future energy use patterns. Within a few hundred miles radius of this podium some of the most important decisions affecting energy use in the century will be made, and this will occur in the very near future. It is in fact going on presently.

My desire in speaking with you is to suggest, first, the extent to which I feel these decisions are among the most important material decisions that man can possibly make. Secondly, it is to relate this conclusion to that part of the energy use policy we deal with most intimately, the natural gas pipeline business and its regulation by the Natural Gas Act.

Harnessing the energy released through the process of fission or fusion of appropriate materials, contains the most promising hope for future energy sources. So much remains to be done in this field, however, and so few understand the difficulties in adopting the energy produced in reactors, that a simple acceptance of "atomic energy" as a cure-all would be a grave mistake. Our national fossil energy policy must be given a broader foundation.

Consider, for example, that no one has even suggested how atomic energy may be used for such small vehicles as automobiles. Automobiles consume something like 50 percent of the petroleum used in this country. The Chief of Naval Reactors Branch of the Atomic Energy Commission says that because of its inherent characteristics, nuclear fuel cannot be used directly in small machines; further, that it is doubtful whether in the foreseeable future it could furnish economical fuel for civilian airplanes or ships, except the very large craft.

Nuclear fuels will probably find their first practical application in the generation of electric energy. Yet even in this area, despite intensive effort by governmental and private agencies, the prospect of meeting our energy needs remains distant. Once again, the practical problem of cost rears its ugly head.

The Panel on the Impact of the Peaceful Uses of Atomic Energy reported to the Congress in January 1956 on the total U.S. electric generating capability and on the portions of that capability that would be provided by nuclear powerplants. Their forecasts covered the period 1955 to 1980 and employed a wide range of assumptions. In both the lower range and the upper range, however, it will be between 1975 and 1980 before the annual additions to nuclear capability begin to provide more than half the new plant capacity being added. Notice—one-half the new capacity. The rest will still be burning fossil fuels. By that time, according to the careful and conservative estimates of the Federal Power Commission, electric generating capability will have reached the staggering total of 486 million kilowatts in this country alone. Compare this with the 110 million of 1955 and think what that means in terms of fuel consumption. Recall also that the striking gains in efficiency achieved by the manufacturers and the operating utilities have greatly narrowed the gains which remain to be made in reducing fuel consumption. With our most efficient units producing a kilowatt-hour of electricity from less than six-tenths of a pound of coal, there simply is not much more you can do.

(Obviously, we shall have much to answer for to the generations that follow us if we permit the promise of atomic energy to obscure our responsibility to develop a meaningful fossil fuels policy.

The magnitude of our energy demands shows itself most dramatically in forecasts of future needs for oil and gas. If oil and gas continue at the 1944–56 rate to increase their share of total energy used, as reported by the Oil and Gas Journal, by 1969 they will supply all energy. The same source calculates the demand for natural gas alone by the year 2000. Assuming that demand continues to increase at the 6.1 percent per year rate that characterized the period 1940–50, the Journal finds that a total of some 560 trunklines of a billion cubic feet daily capacity would be needed to move natural gas only 43 years from now. There are few such lines in existence today.

Another widely quoted recent study of future natural gas production in this country is that of Lyon Terry and John Winger of the Chase Manhattan Bank in New York. They predict an increase in use of 4.7 percent per year through 1966, when it will reach 16 trillion cubic feet. This is more than 55 percent above this year.

Under the pressure of these staggering demands, the known and discoverable reserves in this continent will be sorely taxed. Beyond question, if natural gas is consumed at a rate even approaching that predicted by these informed, conservative sources, our energy picture 20 years hence will be far less encouraging than that which now confronts us.

Natural gas is uniformly conceded to be the cleanest, most convenient of fuels. It was also the cheapest for so many years that the rate of growth in usage was phenomenal wherever it became available. That growth rate has continued in recent years. In the 5 years from 1951 through 1956, the share of natural gas in the total of energy derived from fuels and waterpower increased to 24 percent from less than 20 percent. This occurred while total energy used increased nearly one-third.

In view of these calculations, the expectation that natural gas demand will require the equivalent of four major pipelines a year for the next 10 years, does not seem startling to anyone in the industry familiar with these recent growth patterns.

Consideration of these figures, however, forces one to conclude that somewhere, somehow, rhyme and reason must share in determining what expansion takes place. A national fuels policy is absolutely indispensable.

I fondly and sincerely hope such a policy will result from enlightened thinking by the consumers and the industries whose best interest will be served by it.

Governmental channels, however, can do much to improve their part in other respects. Undoubtedly the dispersion of responsibility under the necessary minimum quantity of regulation is too wide. Wasteful jurisdictional differences, contradictory policy decisions, ineffective bureaucratic bungling are often the result. Whether such coordination will take place, however, is largely a matter for decision by the Congress. Personally, I should heartily endorse any promising effort to relieve consumer and industry alike from any needless, crushing pressure of governmental redtape, encumbering much that seems right and needful.

Another caution must be raised that is a direct consequence of the considerations so far discussed. How may the Federal Power Commission, in administering the act, and how may the companies subject to the act adapt their thinking to the stark realities of apparently insatiable demand and sharply limited supply?

Fortunately for consumer and industry, machinery has been available since early major gas pipeline expansion to insure that unnecessary lines are not built. Our national railroad web was spun by either shortsighted or unbelievably optimistic men. Duplicating lines, lopsided or highly watered capitalizations, lines leading through areas where traffic development could not be expected for generations, all were the result of unprincipled expansion. The inevitable, often disastrous, financial collapses that nearly wrecked the industry are now history.

The statutory standard of public convenience and necessity properly and firmly applied by the Federal Power Commission should prevent such a fate for the pipeline industry. Enlightened carrying out by the Commission of its ratemaking responsibilities provides another preventive measure. Let me emphasize that I do not question needed pipeline expansion. What I wish to underscore is the absolute necessity that the Commission and the industry weigh carefully any expansion prorgam against two overshadowing backdrops. First, unwise expansion will inevitably hasten fossil fuels bankruptcy. Second, uneconomic pricing to maintain artificial volumes contains the seeds of its own destruction.

On the first point, I need only say that there must be a point, even in the face of unprecedented demand, where optimum efficiency of any given natural gas transmission and distribution system will be achieved. To be sure, demand is rising. But costs are rising even faster. Demand for natural gas, when its national average selling price is 40 cents per m.c.f., is one thing. Demand may readily be an entirely different quantity when that same price reaches 60 cents. Remember that as recently as 1951 the average consumer cost of gas was 29.8 cents.

On the point that low priced sales of interruptible gas contains inherent hazards much can be said. The threat lurking behind every substantial interruptible sale of natural gas by a pipeline at a price not properly calculated with respect to costs and competitions is not speculative. Unless out-of-pocket costs and an economically sound allocation of constant costs are recovered the sale becomes an immediate burden. Unless the trend of competitive fuels prices and the trend of pipeline costs, especially costs of purchased gas, are taken into account the benefits that justify the sale at first may vanish quickly.

This is not the occasion to theorize about cost allocation, cost classification and the adaptability of given rate forms to cost structures. My concern arises because of risks that befall a pipeline, indeed a whole industry, which relies for its backbone on a disappearing prosthetic device.

The pipeline industry, like all public service industries except the rubber-tired industries, is charterized by a high proportion of plant to revenues, of fixed to variable costs. Most recent Federal Power Commission figures show the condition of the natural gas industry for 1955. Gross plant amounted to more than $7.5 billion while operating revenues during the year reached about $2.6 billion. In that year long-term debt represented 60.4 percent of total capitalization for the entire industry. The composite ratio of long-term debt to gross plant was 51.3 percent and to net plant 64.5 percent.

The absolute necessity that these high fixed costs be met each day of the year brings about the need for high load factor operation.

In this context the offpeak valley-filling sale bears the appearance of high advantage to the pipeline company. It offers the means to maintain the load-capacity ratio needed to support the closely competitive pricing thrust upon the company by availability to its customers of low-cost alternative fuels.

During the years of low wellhead and field prices of natural gas, this matter was often not viewed as a problem. Also, firms able to develop near-market storage facilities are measurably relieved from its burden. Less fortunate firms attracted by the seeming advantages of offpeak sales have provided a prominent feature of pipeline economics. Recent increases in gas producer prices have caused some of the apparent advantages of this business to lose much of their attractiveness.

The great proportion of total pipeline sales, often on interruptible terms, made for direct industrial uses, needs no telling to this audience. Consider with me, however, only the most price sensitive area of such sales; namely, the use of natural gas for fuel in thermal electric central generating stations.

In 1956, 15 percent of net marketed production was burned for this purpose. Some startling conclusions appear when we look at the prices at which this gas was sold and project them at the rate they have increased recently.

If wellhead prices during the next 3 years continue the rising trend that prevailed in the period 1952–56, they will average 15.5 cents by 1960, and if the proportion this average price bears to the average cost of boiler fuel is maintained at the 1955 level the average cost per million B.t.u. of gas used for electric generation in 1960 will be 26.3 cents.

Yet the average cost per million B.t.u. of coal for boiler fuel was 25.2 cents in 1955 having declined from a high of 27.3 cents in 1952.

This indicates that if natural gas prices and coal prices on a national average basis continue their relative trends of recent years, natural gas prices will be beyond competing with coal sometime before 1960.

These approximations necessarily are not conclusive. They have prompted me to undertake a somewhat more comprehensive study, however, which I should like to talk to you about briefly. This study indicates how critical is the problem confronting pipelines that rely on offpeak interruptible sales. To be sure, the hazard will arise first in the most competitive areas and in the most competitive uses. But if producer prices continue to climb, in time all interruptible sales will be placed in jeopardy.

On the basis of 1950–55 trends of steam-electric generating firms' cost of fuels in cents per million B.t.u. as consumed it was possible to anticipate a time when, in several sections of the country, gas would cease to be the lowest cost industrial fuel. While costs of all fuels have increased that of gas has been especially rapid, more than 27 percent between 1952 and 1956 for the entire United States, while the comparable increase in coal cost 3 percent.

Since these figures apply to the entire United States, some areas, especially those distant from natural gas sources and nearer to coal supplies, displayed the same trend more strikingly. In fact gas appears to be more costly than coal for several recent years in New England and the middle Atlantic States of New York, Pennsylvania, and New Jersey. The tendency is only apparent, for naturally considerable quantities of gas continue to be used even though the annual average cost of the commodity is greater than the annual average cost of coal. The two fuels mutually display numerous advantages, as standby fuels, for ignition uses, and a constant 8 or 10 percent advantage in combustion efficiency of coal due to the inherent moisture content of natural gas.

During the last year of the 1950–56 period appeared some mitigation of the tendency of gas cost to exceed that of coal. Perhaps the altered tendency is more prevalent today. It seems probable that recent coal cost increases due largely to higher freight rates have contributed to this situation. We cannot be certain, however, of the amount or extent of that contribution. Increased combustion efficiency is, naturally, a consideration in this connection. It affects all fuel costs similarly, however, and its local variations are lost or offsetting in area and national data.

There remains, therefore, a basis for the suspicion, that, in circumstances and areas of close interfuel competition and influenced by the conventional uses of the demand-commodity rate for gas sales, boiler fuel purchasers and other interruptible service customers, able to bargain stoutly for low gas prices and being valley fillers for the pipeline sellers, may be accorded special price favors whose continuation becoming habitual may be disastrous to the pipeline industry. The intensity of the problem is in proportion, of course, to the extent of dump-sale pricing of natural gas. It presents two evils, however, of a most sobering nature: The growing dependence of pipeline sellers upon a market that is, to say the least, transient. That market may, one fine day, be found to have disappeared with obvious and extremely unhappy consequences for the entire industry.

In the second place and from the viewpoint of the American consuming public, this form of service markedly expedites the exhaustion of a highly advantageous yet irreplaceable commodity. Toward its conservation, meaning its use by such means as to secure from it the maximum utility per cubic foot, our best efforts may well be directed.

In conclusion, the American energy picture is approaching a critical stage. We face the need for immediate formulation of a sound national fossil fuels policy, with Government coordinating and streamlining its efforts; industry and consumers assisting with sound planning for future growth and use. We who are intimately involved in the future of the natural gas industry can do our part by reappraising traditional approaches to the question whether a proposed pipeline expansion is economically sound.

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Perhaps attention should be given to revising negotiations with producers to give some effect to the elasticity of demand for the several classes of usage to which gas sold to pipelines, or to consumers directly and hauled by pipelines, will be put. Stability in producer prices is no less important than incentive to explore and develop new reserves. Undoubtedly much of the pressure for extremely low dump-sale prices by producers comes from pipelines needing to maintain artificially low purchase costs in order to retain certain sales that should never have been undertaken in the first place.

Reckless price increases, on the other hand, which make it impossible for the pipeline to compete effectively, could kill the proverbial goose unless they are carefully adjusted for two important factors: one, the intense competition between fuels and, second, the need that a pipeline make all sales at prices sufficient to recover the properly allocated costs. Much dissatisfaction now felt by producers could be avoided and eventual loss of markets and idling of pipeline capacity could be prevented if pipeline market building and future planning were based on sound national policy of this kind.

While the choice is ours to make, let us make it. Tomorrow it may be too late.

[From paper 1674, June 1958, Journal of the Pipeline Division, Proceedings of the American Society of Civil Engineers]

Future Prospects for International Pipelines [1]

William R. Connole [2] (proc. paper 1674)

One of the baffling paradoxes of all time is the fact that petroleum wealth is located in some of the most remote corners of the Nation and some of the most inaccessible parts of the world. Mankind seems to be engaged in a kind of mass treasure hunt, the rules of which were laid down ages and ages ago. Oil and gas are needed in New York, Boston, Washington, Chicago, and San Francisco, to name but a few. It is found in Texas, Louisiana, Oklahoma. Oil is needed in Western Europe. It is found in the Middle East, Venezuela, Sumatra, and even in the forbidding wastes of the Sahara Desert. Getting this oil and gas from where it is found to where it can be used is a true-life romance that never ceases to astonish men and to spark their sense of adventure.

These efforts demonstrate the premise widely recognized by geopoliticians, military men, scientists, and virtually all thinking men of our time that the fundamental measure of the extent of the success of modern material civilization is its ability to find and use energy. And fundamental to its success in finding and using energy is its success in mastering transportation problems. Energy and transportation—the two pillars on which our modern material civilization is erected.

Economists have a way of explaining how an inanimate thing like oil or gas lying unused and unwanted for ages can suddenly become so valuable and so important that whole civilizations will go to war over them. For the purposes of this discussion, however, they need not be reviewed. The simple fact is that natural gas remained locked in the sedimentary foundations of remote corners of our country and the world until something happened which made it possible and profitable for men to go after it.

The first thing that brought about this result was a prodigious increase in the demand for energy and the increasing reliance on fossil fuels for that energy. The second thing was the development of the means of carrying it cheaply from one place to another.

It is no secret, that as recently as 1850, only a century ago, fossil fuels supplied only 5 percent of the world's energy while men and animals were responsible for 94 percent. Today 93 percent of the world's energy is derived from coal, oil, and natural gas. In fact five-sixths of all the coal, oil and gas consumed since the beginning of the fossil fuel age has been burned up in the last 55 years.

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[1] Presented before the ASCE, Feb. 24, 1958, Chicago, Ill.

[2] Federal Power Commissioner, Washington, D.C.

NOTE.—Discussion open until Nov. 1, 1958. To extend the closing date 1 month, a written request must be filed with the executive secretary, ASCE. Paper 1674 is part of the copyrighted Journal of the Pipeline Division, Proceedings of the American Society of Civil Engineers, vol. 84, No. PL 2, June 1958.

But the appetite for energy is one thing. The means of satisfying it is another. Until men mastered the techniques of transporting oil and natural gas from where it was to where it could be used, that appetite would never be satisfied. To the engineers of our time, the great bulk of credit for this achievement must go. Consider the natural gas pipelines. Here is a field in which truly staggering progress has been made in less than 20 years. The Federal Power Commission has certificated nearly 76,000 miles of pipeline in this country alone, able to deliver 70 billion therms of natural gas each year and stretching into every State in the Union with the exception of Vermont and Maine. To the pipelines then must go the credit for transforming a waste product into one of the most valuable energy sources this country enjoys.

The basic idea of pipelines, then, is transportation—the transportation of energy. In America there is often too much emphasis on the pipelines' function of buying and selling natural gas. Unfortunately, this obscures the fundamental nature of a pipeline. The only reason a pipeline exists is to make natural gas more valuable than it was in the place it was found. In other words, the "utility of location," the traditional contribution of any transportation agency, has been added by the pipeline.

Of course the increase in value must be greater than the cost of moving the gas from here to there. Men of the engineering profession have succeeded in meeting the challenge of keeping that cost below that value, at least within the confines of the United States. But dramatic and intriguing challenges remain.

Natural gas is still landlocked and useless in some of the greatest reservoirs of energy in the world. When the pipeline engineers will solve the problems of getting natural gas out of the Middle East and across southern Europe into the population centers of western Europe or down into Africa is a question still to be resolved. When South and Central America will begin receiving the blessings of Venezuelan natural gas is also largely reserved for men of the engineering profession. Finally, when will the vast reserves of northwestern and western Canada be available in this country?

A look at the pipeline network in the United States superimposed on a map of continental North America is an interesting experience. If the map were a physical map and did not have political boundaries and if at the same time it showed the location of natural gas reserves, we would be struck by the absence of north-south pipelines connecting the Canadian reserves with sizable population centers in the United States. The reasons for this absence are simple and well known.

First of all, the existence and extent of these reserves is a very recent discovery. Second, the engineering and construction genius which could surmount frightening obstacles like the Canadian Rockies and the terrain north of the Great Lakes are recent developments. But now these two problems have been mastered. What then are the prospects of connecting the newly discovered reserves to markets in this country?

It is the writer's belief that the prospects are excellent.

As an entirely theoretical matter, all the world's energy could be considered as one pool and all the world's consuming areas as taps drawing on that pool. As a practical commonsense matter, however, this is no nearer possible than it is to look on the world's entire labor force as one pool and on the world's industries as taps on that pool.

Even on the North American Continent practical, realistic, and entirely valid considerations make it extremely difficult to carry out the possible distribution of energy between Canada and the United States on a purely theoretical basis. But, because it is difficult it certainly is not impossible.

The respective national interests of Canada and this country must be observed. They must be respected. They must be given their fair weight in dealing with any attempt to distribute energy between the two countries. People must never lose sight of this fact and people must never belittle it. It is easy to do both, it is easy even to feel a certain measure of frustration when it is realized how few physical impediments stand in the way of constructing a pipeline network between the two countries.

The first step in achieving mutual respect for each other's best interest is for each to make sure what his own best interests are. Fortunately, both Canada and the United States are in a position to make this determination now. And even more fortunately this determination is being made during the period when construction is being proposed and not after it has become an accomplished fact.

It is entirely fitting and proper for the Canadian Government to undertake the sweeping study which is now being carried out by the Royal Commission on Energy Resources, commonly known as the Borden commission. This commission was set up with extremely broad and sweeping authority and is charged with the responsibility of making recommendations concerning policies for energy use which will best serve the national interest of Canada. It also will inquire into and make recommendations concerning the extent of authority that might best be conferred on a national energy board to administer such aspects of energy policy coming within the jurisdiction of Parliament as may be desirable to entrust to it.

It is entirely proper for that nation to adopt whatever policy best serves its own interest with respect to whether there is surplus gas not needed to bolster its own economy and if so, how and in what quantities should it be exported into the United States. The Dominion, and indeed, the Provinces are to be congratulated and commended for their wisdom and foresight for undertaking this project now.

By the same token, it is entirely fitting and proper for the United States to determine its own best interests and to consider the question of utilizing Canadian natural gas on terms which are best devised to encourage and further the best interests of the United States.

In the writer's judgment the prospects for pipelines between Canada and this country are excellent. Certain physical and engineering problems have been met. The chances are that the mutual best interest of Canada and the United States will require some utilization of Canadian gas in American markets. For this reason the author feels that the remaining problems will be solved as efficiently and as satisfactorily.

There now exists ground rules for the construction of international pipelines between Canada and the United States. Also, some construction has been completed following these rules. Only by a knowledge of what has been done so far will it be safe to expect what might happen in the future.

In this country the Natural Gas Act contains a section which gives to the Federal Power Commission authority over imports or exports of natural gas. The standard set out in that section 3 states: "The Commission shall issue (an order authorizing exportation or importation) upon application unless after opportunity for hearing it finds that the proposed exportation or importation will not be consistent with the public interest." Notice that the congressional mandate is not worded as a prohibition. It is worded affirmatively. The Commission is directed to issue a certificate unless it finds that to do so is contrary to the public interest. This is interpreted by the writer as an expression of congressional intent favorable to the authorization of international pipelines.

The Commission has not had many opportunities of invoking this statute. In fact, there are only four connections presently of any consequence between Canada and the United States. The only existing connections for importation of natural gas are between West Coast Transmission in Canada and Pacific Northwest Pipeline in Washington and, secondly, the connection to serve the plant of Anaconda Copper Co. in Montana. Incidentally, this required the enactment of a special law by the Legislature of the Province of Alberta. There are only two connections for the exportation of gas from the United States into Canada. These are in Detroit and at Niagara Falls. As a result, expressions of opinion or interpretation of policy are few in this area. Looking at the language of opinion 271 of the Commission in the *Pacific Northwest Pipeline Corp.* case, as one example, this language is found: "We do not consider it to be in the public interest, however, to authorize a most important new project to serve a major area—involving a large and important segment of the American economy—which from the outset will be completely tied to and wholly dependent upon an exclusive source of supply entirely beyond the control of agencies of the United States." The later opinion No. 289 in this matter did not materially change this statement.

For another statement of the policy of the Federal Power Commission it is necessary to go "south of the border," so to speak, and read the language written in opinion No. 296 in the *Texas Eastern Transmission* case in which authority to import from Mexico was issued. Here the Commission said: "The importation of natural gas from Mexico is clearly not inconsistent with the public interest. All necessary authority to export the natural gas as proposed has been established of record. We view the importation as proposed as indicative of mutual benefit which our country and its neighbor to the south may receive by commercial relations and as illustrative of the mutual faith, confidence, and respect each has for the other."

In addition to the statutory authority contained in section 3 of the Natural Gas Act there is another source for the jurisdiction of the Federal Power Commission. This control of exports and imports is exercised in an indirect way through the issuance of so-called Presidential permits. Before any export or import of gas may be made, specific authority of the President of the United States is required. By an Executive order dated September 3, 1953, President Eistenhower delegated the authority of the issuance of such permits to the Federal Power Commission. Unfortunately, perhaps, no standards were transmitted to the Commission at that time by which the executive branch felt governed. Accordingly, the policy of the Commission has not been fixed. To date, the lack of such policy has not been important because of the limited exercise of the authority.

Now that large volume imports have become a distinct possibility, however, it has become imperative for the U.S. Government to establish some guideposts for the issuance of these permits. Since they are Presidential permits, presumably the standards could not be found in the Natural Gas Act. Accordingly, it is reasonable to expect that the executive branch of the Government will express some statement of policy in the foreseeable future with respect to the standards which can be expected to govern the issuance of these permits. Presumably, again, these standards would require the cooperation of agencies other than the Federal Power Commission since so many interests are involved. In any event, neither the lack of such standards now, nor the form they will take ultimately, should be allowed to impede the cordial exchange of energy between the United States and Canada.

On the other hand, Canada too has its own statutory powers and responsibilities which it must observe. No opinion is expressed as to whether they need further amplification or modification. This question properly may be reserved to the internal responsibility of that nation.

In Canada the only authority so far vested in a governmental Dominion Ministry is found in the Pipelines Act. Construction of a section of an interprovincial or international gas or oil pipeline may not be commenced without leave of the Board of Transport Commissioners for Canada. Applications for leave to construct pipelines are usually set down for public hearing after notice to interested parties by mail and newspaper advertisement. Leave has been granted to construct such major pipelines as the Trans-Canada natural gas line from Alberta to points in Ontario and Quebec; the West Coast Transmission gasoline from the Peace River areas to serve Vancouver and other points in British Columbia and markets in the United States. Major considerations in such applications are public interest, financial responsibility of the company, and the economic feasibility of the project.

The board may make regulations providing for the protection of property and the safety of the public and of the company's employees in the operation of pipelines.

It may make orders and regulations with respect to all matters relating to traffic, tolls, and tariffs of oil pipelines, but it does not have similar powers over gas pipelines.

The experience of the Canadian Government in authorizing exports of gas does not lend itself to analysis to determine policy. Moreover, the pending study being made by the Borden commission will develop this subject at some length.

Through sources such as newspapers and trade journals it is noted that briefs have been filed to the Borden energy commission by the several interests interested in the problem. Some of them apparently have called for a national policy in Canada that will assure development of the gas industry serving Canadian consumers while at the same time providing for the exportation of the surplus gas. The New York Times on February 13 reports that the Canadian Petroleum Association has taken a position that gas exports from Canada could go a long way in stimulating investment capital to develop the vast reserves in western Canada.

Since it is reliably reported in the press of as recently as February 22 that the Borden commission will definitely make an interim report on the problem of natural gas exports as soon as possible, it is reasonable to expect that a statement of opinion on this important matter is not far away.

Finally, the writer's optimism derives from confidence that cordial and friendly relations between Canada and the United States will continue. This is the strongest indication and soundest basis for judgment that the ultimate conclusions on the policy of construction of international pipelines will coincide with the best interests of both Canada and the United States.

No comment is expressed on pending applications for specific export authority into the United States. Naturally, these are in the process of litigation before the commission and any statement at this time is inappropriate.

Similarly, no comment on the possible outcome of any of the many issues which the Borden commission necessarily must consider. Indeed, like the applications pending before the conservation boards of the several Provinces, the national and provincial integrity is to be respected in this matter.

This discussion is directed entirely toward the long-range prospect of satisfactory solution of the problem of distributing the energy resources found in the far Pacific Northwest. It is felt that with this repeated hope and confidence that the solutions to these problems in the governmental and legal field will be as swift and sure and practical as the solutions in the engineering field which have been reached by men of that learned discipline.

The Role of Regulation in Developing the Transportation and Use of Liquefied Methane

William R. Connole, Federal Power Commissioner

(Briefing conference on natural gas and oil problems sponsored by the Federal Bar Association in cooperation with the Bureau of National Affairs, Inc., Washington, D.C., March 5, 1959)

When the SS *Methane Pioneer* was warped into the docking facilities of the British Gas Council located on Regent Oil Co.'s jetty at Canvey Island in the Thames estuary last month, something of immensely greater significance arrived than another tanker. This was the first successful effort to transport natural gas in liquid form in an oceangoing tanker and the first time hydrocarbon fuel, other than coal or liquid petroleum, had been brought to Western Europe from another continent.

The Economic Commission for Europe has estimated that well over 1 trillion cubic feet of natural gas is being flared annually in Venezuela and the Middle East. Another source, International Energy Reports, New York, has estimated total world reserves could total as much as 1,870 trillion cubic feet, on the basis of the gas-oil ratio prevailing in the United States. Considering that only four medium-sized tankers with a useful carrying capacity of 15,000 tons could supply Western Hemisphere natural gas to a European population center with a demand of 100 million cubic feet per day, it is obvious that the successful voyage of the *Methane Pioneer* is more than an engineering triumph. It could change the use pattern of energy throughout the entire world. And since our material civilization has advanced in direct proportion to the availability of usable energy, any development that affects our energy use pattern is of the most major importance.

What really arrived at the Thames last month, then, was not a ship, but a new branch of the petroleum industry and a new chapter in the story of energy utilization in the world.

Fundamentally, the importance of liquefied methane derives from the hope it offers for increasing the amount of available energy supplies in the world. "Available" is the key word here. Naturally, the development of the process for successfully liquidating, transporting, and regasifying methane does not add to the world's energy balance. What it does is make it possible to use vast quantities of fossil fuel energy that is now being wasted or else is locked in the crust of the earth because of the lack of a market. In a society predicated on high volume energy use any development promising to supply more useful energy is of major magnitude.

As is usually the case in making a new energy supply available the first problems to be solved were engineering or physical. Inevitably these resolved down to problems of transportation.

Once again here is an illustration of the two legs on which modern material society stands: transportation and energy.

Now that these engineering matters seem well on their way to successful solution, we reach the more delicate problems. These are in the intangible world of public interest and public policy. Generally speaking, they can all be grouped under the heading of regulatory matters. They are found in every domestic industry of such importance to the economy that it has been removed from the unpredictable and untable mercies of laissez-faire competition and made subject to the public interest as expressed in regulatory statutes. Of course, not every such industry is regulated or if regulated, subject to the same degree of governmental control. But all these problems have as a common denominator the general premise that businesses affected by the public interest must be run so as to further, primarily and before any other purpose, that public interest. The real difficulty comes in measuring how much governmental intervention is needed, if any, to assure that any given business will be run in such a manner.

Thus the issue that will soon be a live one with respect to liquefied methane is how much governmental regulation is it subject to under existing statutes, how much less or more is necessary, and, finally, what standards should be followed. These questions are especially perplexing because of the international nature of the business. It combines many of the problems of the oil import dilemma with those in the domestic natural gas issue.

There were problems enough in the natural gas industry when it was confined exclusively within the borders of the United States. These problems have been compounded recently with the addition of Canadian and Mexican reserves to those available within the United States. Before the industry and the regulatory community have had a chance to sharpen their wits on these relatively uncomplicated international import problems, however, the prospect of international competition from sources not located in continental North America is upon us. My purpose here is briefly to suggest areas where Government may be expected to impinge on the new liquefied methane business in this country.

Political problems first will be somewhat the same as those which confront the oil industry in its problem of import regulation but they will be much more complicated because the natural gas industry is a regulated industry and is already beset with so many problems that it forms one of the traditionally most contentious areas of domestic dispute.

Business problems too will be similar in many respects to those that now confront the domestic petroleum industry as a result of the growing quantity of foreign oil arriving at our shores. But here again the problem is compounded by the nature of the natural gas business, where much of the investment is in inflexible highly expensive pipeline facilities.

Of course, only if there is a reasonable possibility that our domestic fuel industry will be affected by this development would it become important to look at our own economic and governmental structure and see how they may be affected. Personally, however, I believe that there will be an effect. I am reassured in this position by the most eloquent of evidence, price comparisons. Every cost estimate I have seen concludes that natural gas from abroad can compete with pipeline gas in the densely populated coastal United States. The only question seems to be how much competition and how soon. Most of these questions are answered by the level of wellhead prices and the speed with which large capacity tankers can be placed in operation at maximum load factor. Let us look at some of the reasons, in addition to existing price advantages, why I believe it necessary that the domestic economy begin concerning itself now with liquefied methane.

Some tangible evidence that I am far from alone in this view appears in documents on file with the Federal Power Commission. In the now withdrawn application for disclaimer of jurisdiction or export license filed by Constock Liquid Methane Corp., the application set out as one reason for undertaking the experimental export, that it would "likewise determine the possibility of importing hydrocarbon fuels in liquid form from remote areas of supply into the United States should demand therefor arise in the future."

Those who argue that the future of liquified methane is principally in energy-hungry areas such as Western Europe overlook one of two important factors vital to the successful development of a liquefied methane industry. The first is adequate, large volume, inexpensive reserves and the second is large volume, well organized markets. Once the existence of the reserves is known these reserves are all as necessary to one market as another. Accordingly, the fact that there are large volumes of natural gas availble in the Middle East, Venezuela, the East Indies and probably Africa, does not argue necessarily for their use in Western Europe, Australia, Japan, or any other market not now being served. We must also find whether the economies of the potential markets can absorb large quantities of natural gas. Certainly any fuel using economy can convert from the use of one petroleum or other hydrocarbon to another over a period of time. The important word, however, is "time." Here in the United States a complicated highly efficient and almost fully integrated pipeline and distributing company system already exists in areas immediately adjacent to tidewater. A glance at the shape of the pipeline network will immediately confirm the fact that the majority of the pipeline investment since World War II has been made for the purpose of carrying gas from the Southwestern United States to the eight principals States in which most of the United States lives. Moreover, no distribution company conversion or appliance conversion is needed, and 1,000 British thermal units of gas can be placed directly into the mains and burners of the biggest customers.

What this means is that if the price is right the transportation of liquefied methane to the eastern seaboard and the west coast of the United States would be at least as appealing a prospect at this time as to Western Europe. I do not suggest that Western Europe does not form a logical market for Middle Eastern or even Venezuelan natural gas. What I do suggest is that the more effectively Western European markets build up the more likely it will be that unit processing and transporting costs will be reduced and the competitive position of liquefied methane in the United States improved. But in the meanwhile, even during this developmental period, cities like Boston, Providence, New York, Philadelphia, and Baltimore and densely populated areas such as Connecticut and New Jersey are within ready transportation distances and already have existing and apparently insatiable demands for gas.

On the premise that the domestic gas industry will be affected sooner or later by liquefied methane imported from abroad, it is vital that we examine some areas where the problems of public interest I talked about earlier will appear.

On the international level the principal problems seem to be those found in the import problem, such as the need to preserve a domestic economy, the natural preference for domestic producers over extraterritorial producers of natural gas, the need to avoid too much dependence on sources of energy which are beyond our control and which can be reached only through dangerously long and highly vulnerable supply lines. It seems to me that these are issues which must be determined on a national level by the use of every agency of government concerned with the problem. Some top-level unit whose membership cuts across many branches of government seems the logical place for this problem to be worked out, just as the oil import problem is being worked out by a similar organization. The Cabinet Committee on Energy Supplies and Resources Policy is one suggestion for this chore. And, of course, the Congress itself should set ultimate policy.

The economics problems, however, are not entirely divorced from the international and no international decision should be made in an atmosphere from which they have been purged. The Natural Gas Act prohibits the importation of natural gas without an order. Moreover, a permit from the President of the United States must be obtained before facilities can be built at the border.

This certainly represents a national policy that the introduction of natural gas from another nation is not a casual thing. While not positively hostile, there is a firm requirement that natural gas be imported only if to do so would not be consistent without the public interest.

Since liquefied methane will serve the same purpose and, indeed, practically speaking, will be natural gas, it would seem the national policy would apply to that also. Thus we are confronted with a typical governmental puzzle. How do we measure the dimensions of the public interest as it is found in this particular case? And how will we decide whether a given operation fits within those limits? At this point we are doubly confounded by the lack of any definitive expression by the Congress of our national fuels policy. We have such an expression at the beginning of the Interstate Commerce Act of a national transportation policy. But what is our fuels and energy policy? Is it in the best interest of the United States to preserve existing fuels use patterns, or should changes be encouraged? Are there "inherent advantages," to use the words of the transportation policy, to one form of energy or another? What about Canadian gas? Mexican gas? Even the role of nuclear energy is not clear.

The absence of such a national policy is of more immediate concern to the business community, however, than to the Government. For there are practical problems that may work to accelerate the time when imported liquefied methane will be attractive as a sheer matter of dollars and cents regardless whether a bureaucrat thinks it is or not.

The problem exists at all only because of a rather fundamental infirmity which underlies our pipeline network. It was built primarily on what has been proved to be an erroneous assumption. That assumption was the indefinite existence of low-priced natural gas at the wellhead. But with the average wellhead price of gas rising by 100 percent, from 6 cents per thousand cubic feet in 1947 to 12 cents per thousand cubic feet in 1957 and even higher in 1958, it is clear that no longer can we expect to obtain gas at the same prices that prevailed when the pipeline network was built. This fact has a relation to our present subject because, despite some misunderstanding to the contrary, there has been a close and continuous relationship between the prices at the wellhead and the revenues per thousand cubic feet at the point of consumption. For example, the figures annually published by the American Gas Association in its Gas Facts shows that on the average wellhead prices have held constant in recent years at about 26 percent of the revenues at point of consumption. Another reason, however, is even more important.

As I mentioned earlier, the principal markets for natural gas in this country are the large consuming areas located many thousands of miles from the wellhead along the densely populated eastern seaboard. Here the high costs of transporting gas make it necessary that investment per thousand cubic feet of peak capacity be kept as low as possible. The only alternative is that the valleys between the peaks be filled so that this investment cost will be spread over as many thousand cubic feet as possible. With the price at the wellhead and costs of transportation both increasing, eastern seaboard distributing companies are losing or soon will lose many of the markets into which valley sales used to be made. Until such time as gas-fired air conditioning or some other off-peak use is found, the high cost of incremental additions to the load curve of the average distributing company actually threatens the rate of growth of the gas industry. Here is where liquefied methane holds the greatest promise.

In any gas utility the most valuable unit of consumption is that found at the top of the load curve. This is because such large investment must be made to produce it. Accordingly, gas distributing companies can pay a very great deal per thousand cubic feet for non-pipeline peaking gas and still find it more economical than increasing their contract demand from a pipeline. It is with these peaking volumes that liquefied methane will compete first. But as the technique progresses and volume grows, the inherent economies of transoceanic transportation, the cheapest type of transportation known, will soon reduce the unit cost per thousand cubic feet of natural gas brought in by tanker to where it might well compete wtih firm loads or even interruptibles.

The cost figures that I have seen so far compare average cost of pipeline gas with the estimated costs of imported liquefied methane. In other words, these estimates assume a base load operation at 100 percent load factor.

Such an assumption I do not believe is realistic at this time, at least for the United States. Contracts with many pipelines do not permit the addition of a base supplier which would supplant the pipeline. As a matter of fact, there would be little chance of a sufficient increase in base firm load to require this new supply.

Since peakloads in the Northern Hemisphere occur at directly opposite times of the year as in the Southern Hemisphere, however, the possibilities of peaking in Northern and Southern Hemisphere cities with the same tanker equipment are good. Lederman and Williams' estimate of costs for the Venezuela-London operation indicate that the facilities for storing, docking, and regasifying amount to only 16.4 percent of the total capital cost of the entire operation. Since the per thousand cubic feet revenue will be so much greater for peaking gas, it would be easy to absorb the cost of adding 16.4 percent to the total cost and varying the deliveries from north to south, depending where peaking gas was most needed.

This extreme flexibility of transportation is one of the great advantages of transporting liquefied methane by tanker.

If a 100 percent load factor operation is indispensable to the success of transporting liquefied methane to the United States, the boiler fuel load seems to be about the best place to get it. But here a swarm of problems would arise. Competing fuels, such as coal and oil, would find their markets threatened. Existing boiler fuel sales by pipelines would be in jeopardy.

All of this and more would be matter for governmental and business concern. Under such conditions, the chief problems would be one of minimum price regulation for liquefied methane rather than maximum. There would be matters of tariffs, of import controls, even the chance of agitation for issuing permissions to import only on condition that prices would be above a given level. Obviously, there is need to look at such things in the relatively clear atmosphere that prevails now, before it has become fogged and confused by argument and contention.

The regulatory problem then seems to be one of minimum pricing rather than of maximum pricing. It seems to be one of avoiding disastrous rate wars between a pipeline network already in existence and attempting to maintain its existing markets as contracts expire and on the other hand, the growing international transportation structure bringing natural gas from abroad. We must remember that most contracts with the distributing companies were entered into in 1947 to 1950 and that by 1967 to 1970 they will begin to expire.

I do not suggest that the Federal Power Commission should initiate a docket tomorrow afternoon similar to docket G–580. Unfortunately, the tremendous pressure of other and more immediate problems makes this approach unlikely. I do think, however, that the regulatory community and the Congress in cooperation with consuming interests and all three segments of the natural gas industry, should begin careful and cooperative study of this problem now before it becomes inflamed by personal or private interest attempting to preserve a position which may not have been sound in the first instance.

The problem may be entirely different depending on which segment of the industry ultimately gets control of this transportation medium. For example, the producer industry will have one end in mind, particularly those major producers who have foreign production. The pipelines network, on the other hand, if it maintains control over the transportation of liquid natural gas or the admission of it into the United States, will have an entirely different and diametrically opposed interest to preserve. The distributing companies, on the other hand, much like the large consuming areas with respect to oil imports, will probably be satisfied to sit back and reap the benefits, illusory and temporary though they may be, of low-priced natural gas from abroad competing with existing pipeline gas.

When I think on this problem I am inevitably reminded of the difficulties, frustrations, and irritations that have surrounded the administration of the Natural Gas Act from 1938 to today because of the lack of congressional clarity in saying precisely whether independent producers should be regulated and secondly, by the problems in attempting to regulate independent producers once that jurisdictional question was answered by the Supreme Court. These problems were immensely more complicated because their solution had been postponed to a time after the pipeline pattern had been established.

If the *Phillips* case and the independent producer pricing problem taught us anything it should have taught us to start on this liquefied methane matter right now. Let us find whether it is a proper area for governmental concern. If it is, and I strongly suggest to you that it is, let us establish now the extent to which government, that is to say, the public rather than the private interest, will have a say in the matter and finally, let us reduce it to particulars as early as we possibly can. Let us determine what branch of Government, if any, need examine the question. Let us find whether import permits should be obtained; whether certificates of public convenience and necessity are necessary; let us establish whether existing energy distribution interests have a legitimate interest in opposing the admission of liquefied methane to this country; let us establish the extent, if any, to which Government should regulate the price level at which the gas will enter the United States. I think this is a proper area for long range concern of the Congress of the United States in the first instance and, once national policy has been established, is the proper area for cooperation considerations by all segments of the industry and all parts of the Federal Government in which the Congress ultimately vests this jurisdiction.

In conclusion, I believe that liquefied methane will find its way into the United States within the next 5 years and, barring some unhappy catastrophe such as the one that set back the development of liquefied methane in Cleveland in 1944, I believe that large volumes of the natural gas consumed in eastern seaboard and west coast population centers by 1970 will come from outside continental North America. If this prediction is even remotely accurate, and I believe it is, it behooves us now to begin thinking about it and it behooves the Congress to begin doing something about it.

"TAKE ONE GIANT STEP"

(By William R. Connole, Federal Power Commissioner, National Coal Association Annual Convention, June 3, 1959, Washington, D.C.)

When many of us were young children we enjoyed playing the game we knew as "Giant Steps." Remember that if were so told by the person who was "it" we advanced toward the goal by taking one or more steps. We were especially pleased when told to take a giant step.

I propose to take advantage of my position here and tell you people in the coal industry to take a real giant step in the direction of your goal. Whether I will have a similar opportúnity so to invite other segments of the energy business, I do not know. You recall that the players in the children's game always had to initiate the request before the invitation was issued. Perhaps, however, the echoes of this invitation will bounce around enough that they may be heard by the oil and gas industry, the electric utility industry and the more esoteric fields of energy production and use that are just now being born.

The goal I speak of, of course, is the same goal everybody in this business should be looking for. I am talking about a meaningful, practical, and equitable energy policy for this Nation.

Let me begin by congratulating the coal industry, the mineworkers, the equipment manufacturing industries, the electric utility industry and the railroads for their foresight and courage in setting up the national coal policy conference. I think the creation of this group was significant not only as an unprecedented example of cooperation and unity among groups that are often widely separated in their goals, but perhaps more importantly because it forms a jumping-off spot from which even greater progress can be made.

All of us, I suppose, have heard unfavorable comments on the conference. These have ranged all over the lot. Some have observed cynically that it was just another study and wondered with undisguised derision how often this ground would be picked over.

Some others have objected that it was obviously a "one fuel" approach to the energy problem and that it promised very little for any group other than the coal operators and those dependent upon the coal industry directly. Some have even suggested it was an effort to build up one or more particular coal-producing companies or coal-carrying railroads.

In these days when restraint in public comment is as rare as common courtesy in the streetcar we have become hardened to such intemperate and ill-advised comments. But it is of controlling importance, I think, that we not let this indifference to discourtesy obscure the insidious effect such comments have. Unfortunately, however, there is only one effective way of combating them. That is to make it so abundantly clear by actions and not merely by words that all of these criticisms are as erroneous as they are ill advised.

Positive action, then, is needed. No concentration on batting down random accusations hurled at such an organization as the national coal policy conference will make such positive progress. The only effective way is the successful development and untiring promotion of a true national energy policy. It is the only completely effective way to demonstrate that an organization such as this one which you have created is more than an offshoot of a coal operators meeting and something more valuable than a lodge meeting.

I suggest to you, then, that this positive action be in the form of a giant step forward, immodestly if you will, but confidently and without concern that you are risking the criticism of those who would be convinced you are wrong no matter what you did.

The need for a national energy policy seems so patently obvious that I am simply unable to understand how thoughtful people concerned with this business can overlook it. I don't believe the issue is whether we ought to have a national fuels policy. The only question is, What energy policy are we making and where does it lead us? The fact of the matter is that everything energy producing and distributing industries do and everything that consumer preference does and everything that governmental action in the energy field does is part of an emerging energy policy. In other words, whether it is an unconscious or a conscious act on the part of the people of this country we are creating a national energy policy.

Now you might well ask, Why, then, is it necessary for industry, consumers, and government to exercise itself over the need for an energy policy if we are already creating one? A logical question, true. But one which has a ready answer. Much more important than whether we are making an energy policy is the qualitative judgment whether that energy policy is best for all segments of the economy for as many years in the future as it is possible reasonably to plan for.

We are told that one of the proofs of the higher nature of man is the ability of his mind to withdraw from itself and look upon itself in objective judgment. This practice of self-evaluation, so indispensable to the deliberations of mankind, has applications outside the limits of the human skull. Indeed, it is only when a unit of society, whether it be a family, a community, a political unit or even an industry, can exercise the same critical ability to examine and judge itself that it, too, will measurably succeed.

I urge that the national coal policy conference take steps to evaluate its segment of the industry in just that fashion. I further urge that it enlist the aid of as many other units or areas of the economy as possible so that all sides of the problem will be seen and evaluated.

Perhaps the best starting point is to ask ourselves in what form will the ultimate judgment appear. If the effort is successful, with what will it come up? Under our system of society in which government is a matter of law and not a matter of whim, it seems clear that the ultimate conclusion will be legislation. That legislation, to be acceptable, must have been the joint product of as many groups as possible and it must have been motivated by as independent an analysis as possible.

Elimination of what should not be in a national energy policy is the quickest way to narrow down the field of choice. Such a process undoubtedly will occupy those who undertake the considerations I propose. Permit me to give what I believe are two of the most important factors to avoid.

First, I do not believe a national energy policy should be so detailed that it will set not an order of priorities in which fuels will be used in each home or industry. Indeed, it ought not to attempt to dictate what part of the country will use any particular fuel or method of burning it. That type of "social planning" comes too close to the idea of a big brother in Washington issuing decrees to a slavish population.

Neither, I believe, should an energy policy for this country needlessly prefer one area of this land to another. Naturally, the economic growth of a nation can be fundamentally altered by the kind of energy that is used in various parts and by the amount of it. To avoid a dwarfed or misshapen nation we had best be sure we know what the full growth healthy specimen is supposed to look like. There is grave danger in using our energy balance as a means of subsidy or artificial stimulus to one part of the Nation or another.

Of course, we must consider carefully the need to avoid the exact opposite. I refer to the unnatural stunting of the growth of one segment of the energy economy or the other. This can be the result of misguided, conscious government or business policy. Or, more likely, it can be the result of unconscious government or business policies that lead to that result unknown to those who are doing the damage. Only a well-planned analysis of the present direction of our energy policy can avoid this.

Starting with a firm resolve to avoid these pitfalls, a study could soon isolate the direction in which the various forces, all pushing in apparent random directions, are taking us. I recall working out problems in physics involving several forces acting on one object. The idea was to see where these combined forces would push the object. I should consider the first task of an energy study would be to make such an analysis of the forces now pushing our energy economy to see where it is headed.

Now there are two ways in which such a study or effort to evaluate an energy policy can be carried out. It can be financed and staffed by the joint efforts of the private industries and interests affected or it can be financed by public funds and staffed wholly or in part by public employees working with the agents of private interests. I have neither the right nor the inclination to recommend to you the procedure the conference ought to follow. However, certain things stand out that seem to require consideration in any study such as this.

Looking back at the experience which others have had in attempting to persuade competing industries to accept their conclusions and considering likewise the unsuccessful efforts competing industries have made to reach voluntary cooperation it seems rather plain that if our effort to evaluate our energy policy and propose needed modifications is to succeed the direction at the top must come from a source identified with the broadest base possible.

The practicalities of public law are such that never will there be found in a sprawling thing like the Federal Government an agency which has all the virtues of objectivity and dispassion needed to make the type of study I envision. An ad hoc institution, then, taken from sources within the Government and from industry composed of as few people as possible who start business with an agenda whose first item will be a determination of a deadline beyond which they will cease operation seems the easiest and cleanest way of doing what I suggest is necessary. The usefulness of organizations such as Resources for the Future and other research groups should not be ignored.

Such a committee could be formed of people with a broad background in the various energy fields not necessarily technical but certainly of sufficient breadth and depth that the sifnificance of new facts would not be lost on them. It should have men with demonstrated judicial temperment and demonstrated devotion to the welfare of all the country and not one segment of it and should be composed of men whose opinions are likely to command respect among their fellowmen. Once such a body was formed it could devote a period of time to investigation, public hearings, and task force study of the characteristics of our energy structure and at the end of this predetermined period arrive at some conclusions. These would be first, what energy use policy have we been creating; secondly, how well suited to the needs of this Nation is that policy and, finally, what changes, if any, could be made.

This independent judgment reached after public hearing and reconsideration of all affected views could then be addressed to the Congress and be used to form the background for confirmation of or changes in existing statutes, principles of taxation, governmental policies both national and local, antitrust policies, regulatory commission policies and every other aspect of the public economy involved in the pervasive business of energy use.

The genius and value of the National Coal Policy Conference is that it has been organized by a sufficiently broad base of industries to command immediate attention and respect. If it should adopt and encourage a study along such lines as I have indicated it would be clear that this is no crackpot idea of a textbook idealist but rather the considered opinion of sound and sober businessmen.

I do not propose to enter the controversial field of what changes should be made and what is wrong, if anything, with our present policy. I am not adverse to commenting, however, that in the privacy of my own mind, and not speaking as a member of the Federal Power Commission, I see much that could be improved in our present energy use pattern. I do say again that a body organized as I have suggested will be able to reach these conclusions in its official capacity, that those conclusions will be respected by legislators and opinionmakers throughout the country. I believe that a body which has the stature of a quasi-public institution which numbers among its members and staff men of the talents and qualities I have suggested and whose deliberations are based on information received in public hearings, and serious academic investigations and whose conclusions are contained in well-reasoned, clearly worked-out reports, is the only way in which the meaningful, practical, and equitable energy policy I urged at the outset of this talk will be developed. There are simply too many interests in this country ever voluntarily to bring them together. There are too many who would be hurt at that particularly sensitive place in the human body, the pocketbook, ever to expect voluntary energy policymaking.

The key suggestions I make, in summary, are these. The study ought to be wide enough to cover all forms of energy, not just one or two. The study ought to decide first where our present policy is taking us. The study ought to be made by an objective group dominated by Government but using the facilities of industry and independent research groups. The study should employ public hearings across the Nation as well as task force studies. The study should have as its aim, legislation.

When we think that our energy resources are being consumed at such an incredible rate that, for an example, all the fossil fuel consumed in the history of the world up to the year 1900 would last only 5 years at today's rate of consumption, we know how important this whole subject is to all the peoples of the world.

And when we think how directly and acutely Government and business policies affect our energy industries, we know how important a policy is to industry.

Natural gas pipeline certification and ratemaking, natural gas and oil importing problems, freight ratemaking for coal movements, tax structures and their effect on incentive and development of competing fuels, all these are but a partial catalog. Indeed, there is much that needs doing here.

With our strong and good neighbor to the north, Canada, just now considering legislation to create a National Energy Board to administer that nation's energy policy, a more propitious time could scarcely be imagined. And, with world peace such a delicate matter that a change in the energy balance could upset it, a more necessary time wold be hard to find.

Again, I congratulate the National Coal Policy Conference. Again, I urge you to take a giant step forward to promote the creation of an energy study board of the type I have suggested to avoid the criticisms which inevitably will be directed to you but, and this is of infinitely greater importance, to achieve the lofty and honorable purpose which you have set out for yourselves.

Statement Prepared for Joint Economic Committee, Subcommittee on Automation and Energy Resources

My name is Irwin M. Stelzer. In my capacity as vice president and economist with the consulting firm of Boni, Watkins, Jason & Co., Inc., I have, for the past several years, been engaged in studies relating to trends in the natural gas industry. No study of our energy resources can be complete without a consideration of the adequacy of our natural gas reserves.

In schedule 1 I have set forth such data as are available relating to reserve adequacy. It will be noted from column 9 that at the end of 1958 known reserves of gas equaled 22.18 times production. Since underwriters frequently require that a natural gas pipeline have 20 years' supply committed to it before they will underwrite pipeline debt, and since the Federal Power Commission generally requires such reserves, particularly of new, major pipelines, it has been common in the industry to accept 20 years of reserves as adequate. The question of the adequacy of gas reserves, then, falls into two broad categories: (1) the prospects for the maintenance of a 20-year life index, and (2) the real need for a 20-year reserve requirement.

Summary of annual estimates of natural gas reserves for period Dec. 31, 1945, to Dec. 31, 1957

[Millions of cubic feet—14.65 p.s.i.a., at 60° F.]

Year	Natural gas added during year			Net change in underground storage	Net production during year	Estimated proved reserves as of end of year	Increase over previous year	Finding-to-production ratio (3)÷(5)	Life index (6)÷(5)
	Extensions and revisions	Discoveries of new fields and new pools in old fields	Total of discoveries, revisions and extensions (new supply)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1945						147, 789, 367			
1946	(1)	(1)	17, 729, 152	(1)	4, 942, 617	160, 575, 901	12, 786, 534	3. 59	32. 49
1947	7, 570, 654	3, 410, 170	10, 980, 824	(1)	5, 629, 811	165, 926, 914	5, 351, 013	1. 95	29. 47
1948	9, 769, 483	4, 129, 089	13, 898, 572	51, 482	6, 007, 628	173, 869, 340	7, 942, 426	2. 31	28. 94
1949	8, 061, 429	4, 612, 870	12, 674, 299	82, 756	6, 245, 041	180, 381, 344	6, 512, 004	2. 03	28. 88
1950	9, 172, 381	2, 877, 351	12, 049, 732	54, 301	6, 892, 678	185, 592, 699	5, 211, 355	1. 75	26. 93
1951	13, 013, 606	3, 039, 385	16, 052, 991	132, 751	7, 966, 941	193, 811, 500	8, 218, 801	2. 01	24. 33
1952	8, 934, 470	5, 411, 043	14, 345, 513	198, 850	8, 639, 638	199, 716, 225	5, 904, 725	1. 66	23. 12
1953	13, 371, 355	7, 081, 661	20, 453, 016	[2] 516, 431	9, 238, 540	211, 447, 132	11, 730, 907	2. 21	22. 90
1954	4, 632, 309	4, 966, 894	9, 599, 203	90, 906	9, 426, 509	211, 710, 732	263, 600	1. 02	22. 46
1955	16, 298, 125	5, 719, 069	22, 017, 194	87, 637	10, 118, 118	223, 697, 445	11, 986, 713	2. 18	22. 11
1956	19, 214, 604	5, 636, 476	24, 851, 080	133, 970	10, 907, 926	237, 774, 569	14, 077, 124	2. 28	21. 80
1957	11, 118, 319	8, 998, 993	20, 117, 312	179, 733	11, 502, 359	246, 569, 255	8, 794, 686	1. 75	21. 44
1958	13, 388, 808	5, 611, 098	18, 999, 906	57, 902	11, 458, 026	254, 142, 037	7, 572, 782	1. 66	22. 18

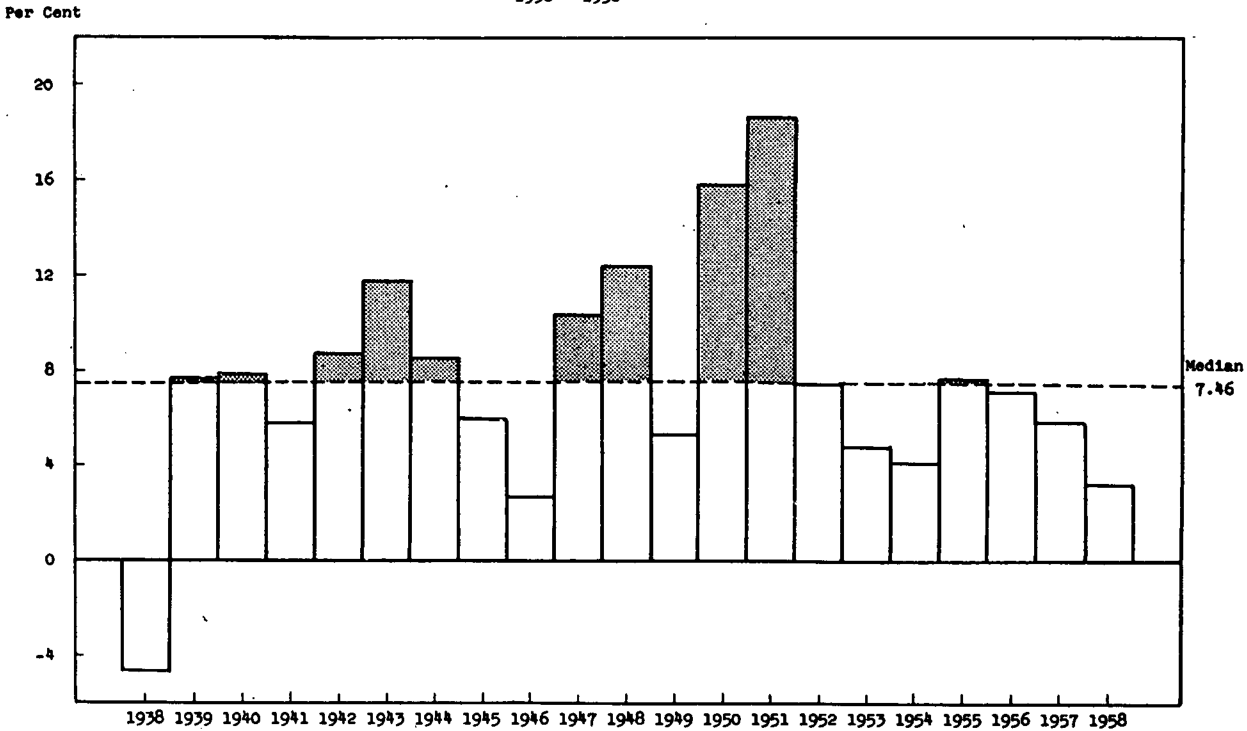
[1] Not estimated.
[2] All native gas in storage reservoirs formerly classified as a natural gas reserve is included in this figure.

Source: American Gas Association and American Petroleum Institute, Reports on Proved Reserves of Crude Oil, Natural Gas Liquids and Natural Gas.[1]

(1) The data presented in schedule 1, when matched against the natural gas demand projections made by experts within the oil and gas producing industry, would indicate little cause for alarm. By averaging the finding-to-production ratios shown in column (8) of schedule 1, we obtain a postwar average of 2.03. In other words we have found, on the average, more than twice the quantities of gas we have produced. Even if the 2 extreme years—1946 and 1954, the one atypically high, the other atypically low—are excluded, the average ratio is 1.98. If we accept as valid the demand projections presented, for example, by producer witness Gonzalez in the Federal Power Commission's omnibus proceeding (docket No. G-9277, et al., tr. pp. 271-273) or by producer witness Turner in the *Phillips* proceeding (docket No. G-1148, et al., exhibit 293), and assume the necessity of preserving a 20-year life index, the future required finding-to-production rate would have to average only 1.6 to 1.7, and in no year would ever have to reach 2.0.

I might add here that many analysts have expressed concern about the decline in the life index from its 1946 level of 32.49 years to its present level of 22.18 years. Now, this decline certainly bears watching. There are, however, a number of factors which, it seems to me, support the conclusion that this trend is not particularly alarming. First, the decline must be viewed in the light of the fact that the 1946 life index of 32.49 years was at a level which gives every indication of having been a historical peak. During the period preceding World War II, large volumes of dry gas reserves, discovered incident to the search for oil, were shut in awaiting markets. With the long distance pipeline transmission of natural gas neither technically nor economically feasible on anything like the present-day scale, gas production did not keep pace with the growth in reserves. In the immediate postwar period, on the other hand, there occurred a sudden and, in terms of its magnitude, temporary acceleration in the expansion of demand. Thus, as is shown on page 1 of schedule 2, the percentage increase in marketed production of natural gas exceeded the median increase for the 1938-58 period in 1947, 1948, 1950 and 1951. In the years subsequent to 1951, the rate of increase in marketed production exceeded the median level for the 1938-58 period only once—in 1955—and fell below that median in 1953, 1954, 1956, 1957, and 1958. When viewed in this light—as the result of a temporary boom in demand and production—the postwar decline in the life index becomes less than alarming.

YEAR-TO-YEAR RELATIVE CHANGE IN MARKETED PRODUCTION OF NATURAL GAS
1938 - 1958



SCHEDULE 2—*Marketed production of natural gas and percent change from previous years, 1937–58, inclusive*

[Million cubic feet]

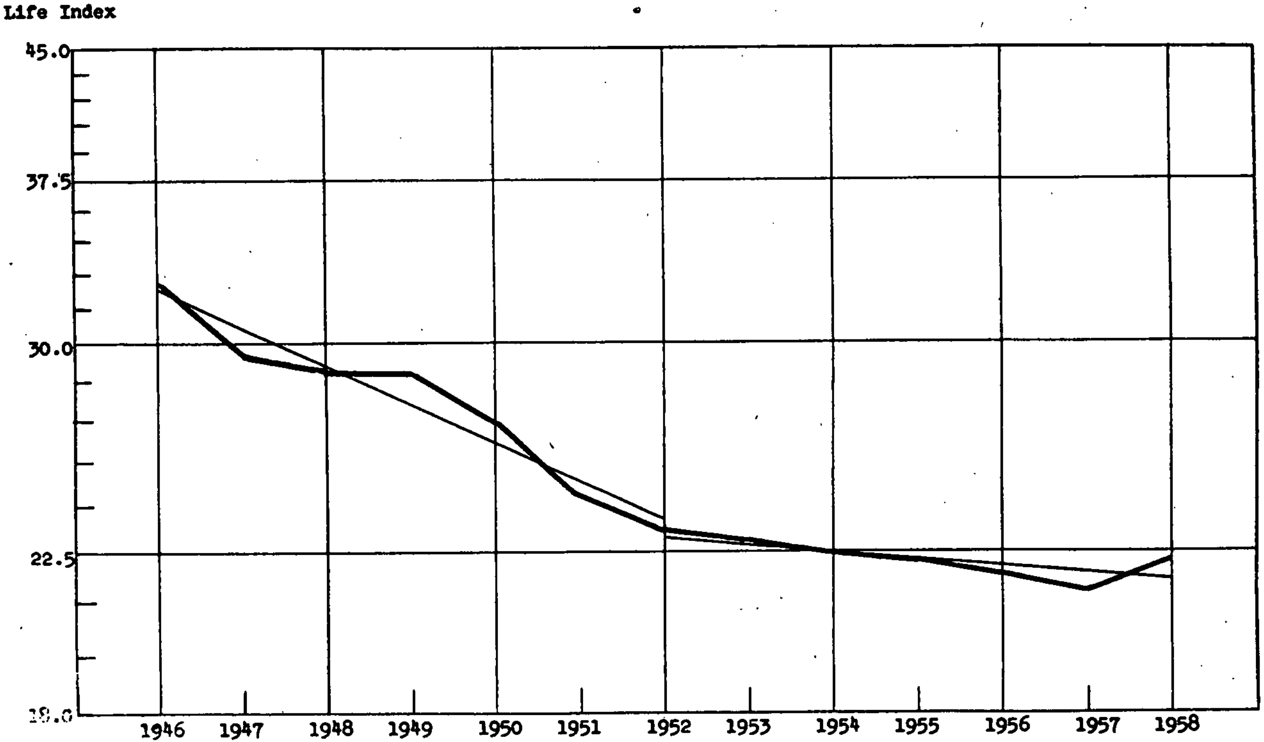
Year	Marketed production of natural gas (1)	Percent change from previous year (2)	Year	Marketed production of natural gas (1)	Percent change from previous year (2)
1937	2,473,483		1948	5,148,020	+12.35
1938	2,358,201	−4.66	1949	5,419,736	+5.28
1939	2,538,383	+7.64	1950	6,282,060	+15.91
1940	2,733,819	+7.70	1951	7,457,359	+18.71
1941	2,893,525	+5.84	1952	8,013,457	[1]+7.46
1942	3,145,694	+8.71	1953	8,396,916	+4.79
1943	3,515,531	+11.76	1954	8,742,546	+4.12
1944	3,815,024	+8.52	1955	9,405,351	+7.58
1945	4,042,002	+5.95	1956	10,081,923	+7.19
1946	4,152,762	+2.74	1957	10,680,258	+5.93
1947	4,582,173	+10.34	1958	11,030,248	+3.28

[1] Median.

Source: American Gas Association, "Historical Statistics of the Gas Industry, 1958 Gas Facts," and U.S. Department of the Interior, Bureau of Mines, "Mineral Industry Surveys."

A second fact which cannot be ignored in any analysis of the trend in the gas life index is that the bulk of the decline occurred prior to 1953. On page 1 of schedule 3, I have had the life index for each year plotted on semilogarithmic paper. I then had mathematically determined trends for the periods 1946–52 and 1952–58 computed and plotted on the same chart. From page 2 of schedule 3, containing the data in support of page 1, it can be seen that the annual rate of decline in the index between 1946 and 1952 averaged 5.1 percent; since that time the annual decline has averaged only 1.0 percent. Note that during the entire period of this decline—1946 to 1958—the volume of natural gas reserves increased by 58 percent, from 161 trillion cubic feet in 1946 to 254 trillion cubic feet at the end of 1958.

LIFE INDEX: RATIO OF RESERVES TO PRODUCTION, ACTUAL VALUES COMPARED WITH TREND VALUES
1946 - 1952 and 1952 - 1958



SCHEDULE 3.—*Life index: Ratio of reserves to production, actual values compared with trend values, 1946–52 and 1952–58*

Year	Life index		Year	Life index	
	Actual (1)	Trend (2)		Actual (1)	Trend (2)
1946	32.49	32.30	1952	23.12	22.96
1947	29.47	30.64	1953	22.90	22.73
1948	28.94	29.06	1954	22.46	22.50
1949	28.88	27.57	1955	22.11	22.28
1950	26.93	26.16	1956	21.80	22.05
1951	24.33	24.81	1957	21.44	21.83
1952	23.12	23.54	1958	22.18	21.61
Annual average rate of change, 1946–52, percent		5.1	Annual average rate of change, 1952–57, percent		1.0

Source: (1) schedule 1.

(2) Even if the maintenance of a 20-year life index were not likely, there would be little reason for alarm so long as natural gas reserves added (new supply) exceed production. This view is shared by the petroleum experts of the Chase Manhattan Bank, Messrs. Lyon Terry and John Winger. They have stated, "a further decrease in the reserves-to-production ratio even below 20 should not be alarming so long as additions to reserves substantially exceed production. The proved reserves comprise only a small part of the total future supply—the more important part is that which is to be discovered in the future." And the oil industry itself has, for many years, taken an identical position concerning the future supply of crude oil. Consider, for example, the following portion of the report on "Petroleum Productive Capacity: a Report on Present and Future Supplies of Oil and Gas" by the National Petroleum Council, the oil industry committee set up officially to advise the Department of the Interior on this subject.

"Future supplies are not determined by the reserves known today * * *.

"A common mistake made in discussing future oil supplies is to consider only proved reserves. Frequently the proved reserves are compared with the current annual production to arrive at the number of years that supplies will last. By such calculation it would have seemed almost any time in the past that supplies could last only 10 to 20 years. On this basis there have been many predictions that we are running out of oil. Such predictions are nonsense today because they fail to consider the rate of oil finding and development. It is future supplies, not presently known reserves, that will determine available supplies for the long run" (report of Jan. 29, 1952, presented by Committee on Oil and Gas Availability, to the National Petroleum Council, p. 41).

It would seem, therefore, that this subcommittee has little reason to be concerned about the current and immediately prospective adequacy of our natural gas reserves.

OCTOBER 16, 1959.

HUMBLE OIL & REFINING CO.,
Houston, Tex., October 21, 1959.

Hon. WRIGHT PATMAN,
Chairman, Subcommittee on Automation and Energy Resources, House Office Building, Washington, D.C.

DEAR SIR: In view of the testimony presented by representatives of the coal industry subsequent to my appearance at the hearings on automation and energy resources held by your committee last week, I submit this statement for the record as a supplement to the material already presented.

I should like to call attention, first, to the well-established policies on fuels that have (*a*) provided ample supplies for both economic progress and national security, and (*b*) provided consumers with a choice among competing forms of energy at attractive prices. The major elements of policy are as follows:

1. Reasonable tax provisions have served to encourage development of domestic energy resources.
2. Conservation has been viewed positively as efficient production and use of known resources rather than negatively in terms of hoarding based on fears of future shortages.
3. Conservation has been considered a proper subject for administration by the States, with the encouragement of the Federal Government.
4. Competition among fuels has been fostered as the best way of serving consumers and of stimulating efficiency on the part of suppliers of energy.
5. Regulation by the Federal Government has been limited to measures considered necessary for security reasons or considered desirable for the protection of the public interest.

The most recent statement of national policy on fuels was presented by the Secretary of the Interior, the Honorable Fred A. Seaton, before the American Gas Association convention in Chicago on October 7, 1959. His statement was as follows:

"A thriving industry in each case is certainly desirable from a national standpoint, and it is a function of Government to help maintain an economic environment within which efficiently run business enterprises may prosper and contribute to national economic strength. But it is not the proper role of our Government to carve out or 'freeze' a portion of the total energy market for each competing fuel.

"I cannot believe that it would be appropriate or just for the Government to distort the picture by preventing the functioning of normal economic forces. I do believe the consumption of fuels should continue to be determined by such factors as relative costs at specific locations, efficiency of use, dependability of supply, cleanliness, convenience, ease of control—in short, a combination of consumer preference and cost per British thermal unit delivered at the burner."

The coal industry claims that it is adversely affected by what it calls "dumping" of heavy fuel oil and of natural gas in industrial markets. Mr. George A. Lamb, of Consolidation Coal Co., said in his testimony that oil and gas are able to recoup their losses from the alleged dumping by charging more for other products and for natural gas sold for household consumption. He asserted that it will not be too many years before it will be a problem for oil and gas to supply adequately superior uses if these practices continue. Several points need to be noted in connection with these claims. (1) The efficient conversion of crude oil into various products enables the industry to supply all of its customers at lower prices than would otherwise be possible. (2) Sales of natural gas on an interruptible basis to industrial customers permit a lower transportation cost and thereby result in lower prices to residential users of gas than would be possible without such sales. (3) The chief competition of heavy fuel oil with coal is from imported fuel oil that is largely a prime product of the heavy crude oil produced in Latin America rather than a byproduct. (4) For the preceding reasons it is inappropriate to describe as "dumping" the competition of fuel oil and natural gas with coal in industrial markets. (5) The impact of this competition on coal is not great, according to the following significant statement by Mr. George A. Lamb: "From a volume standpoint, the amount of coal business lost annually because of these practices does not appear large, probably 20 million tons presently." According to this statement, the competitive practices complained of represent less than 5 percent of annual production of coal and only a small fraction of the decline in coal consumption that has occurred in recent years due to technological developments and other changes. Furthermore, these volumes represent less than 2 percent of the current consumption of oil and gas and cannot have a significant influence on the long-term life of domestic supplies.

The chief complaint of the coal industry seems to be that the competition from fuel oil and natural gas affects its price structure. Without such competition, consumers would have to pay higher prices for fuels. It is understandable that the coal industry would like to be protected against price competition, but it seems strange that proposals designed to reduce competition should be disguised as a plea for "an objective study" of a national fuels policy.

The question of national fuels policy has not been neglected by the Federal Government. The testimony by Mr. Joseph E. Moody shows that numerous governmental agencies have considered all aspects of energy resources in the past. The current study by the Committee on Automation and Energy Resources is another illustration of the Government's continuing review. The present hearings have brought out the testimony of expert witnesses that ample supplies of domestic energy resources at reasonable real costs will be available under proper economic stimulus for the foreseeable future. Consequently, as stated in my testimony, the impartial evaluation of future prospects by governmental and private experts serves to answer any proposal that national policy should be based on fears of an imminent shortage of oil or of gas in the United States. The evidence presented to your committee last week by various witnesses indicated that additional alternative sources of energy will become significant in the future, in addition to those used in large quantities in the past, so that there is no basis for anticipating any shortage of energy under the policies now in effect.

The charges by the coal industry of unfair competition from oil and gas leave the impression that there is no Government regulation of these matters. Actually, the Federal Government already controls the price of gas in interstate sales and regulated imports of crude oil and fuel oil to levels that it considers consistent with the rate of development of domestic energy resources desirable for reasons of national security. The coal industry has intervened in many natural gas cases and has had ample opportunity to present its point of view before the Federal Power Commission. Therefore, the arguments of the coal industry have been considered by this governmental agency in arriving at decisions in the public interest.

I suspect that the coal industry's real objective is not an impartial study, such as that being conducted by your committee, but a plan for creation of an agency designed to limit competition from oil and gas with coal in industrial uses. The inevitable consequences of such objective would be higher fuel prices in electric power generation and in many industries. Where coal is the cheapest fuel, it already dominates the industrial markets and enjoys an increasing demand. There are large areas, however, in which natural gas and fuel oil are much cheaper than coal. To deprive consumers of the right to use the fuel of their choice in these areas would run counter to our basic philosophy of competition and raise the price of fuels to consumers. As noted in my testimony last week, adjustments in the use of alternative fuels will continue to occur gradually and to the benefit of consumers in response to changing economic conditions unless the system of interfuel competition that has worked so well in the past is upset by Government regulation.

In his testimony before the committee, Mr. Joseph E. Moody quoted with approval one of the conclusions of the President's Materials Policy Commission in 1952 that all parties concerned with energy policy must "work from a common base of understanding of the total energy outlook, of the interrelations within the energy field, and of the relations between energy and the rest of the economy." The work of the President's Materials Policy Commission, of the Cabinet Committee on Energy Supplies and Resources Policy, and of your committee have all contributed to the development of such common understanding of all these aspects of the energy situation and outlook. It does not follow that this common understanding calls for new policies or for restrictions on competition among fuels. On the contrary, the evidence supports the following conclusions of the President's Materials Policy Commission against artificial restrictions upon competing fuels:

"Industry and Government experts agree that natural gas consumption should be shifted as rapidly and fully as possible toward special advantage uses. Some observers believe that Government should impose direct curbs on economically inferior uses of natural gas. The Commission strongly doubts the efficacy of meeting the problem by detailed regulation. Other reasons aside, there appears no economic basis for designing curbs which would be any more suitable and valid than the normal pressures of price relationships" ("Resources for Freedom," vol. I, p. 114).

"In the Commission's opinion, this positive approach to putting the Nation's coal resources more fully to work through aggressive improvements in productivity and use is the only pattern that can be followed in the light of the expansion of the economy that will have to be sustained. The negative approach which seeks to cure the coal industry's past ills by imposing artificial restrictions upon competing fuels is unacceptable" ("Resources for Freedom," vol. I, p. 117).

In conclusion, several points in the evidence presented before your committee last week are pertinent to the issue of need for any further study of a national fuels policy. First, a large growth in demand for coal was indicated in the years ahead under the policies now in effect. Mr. Schurr estimated that the use of bituminous coal would increase 75 percent between 1955 and 1975. Mr. Sporn estimated that the demand for coal would more than double between 1957 and 1975. In view of this outlook, the coal industry will have ample incentive and opportunity to increase production without any restrictions on the freedom of consumers to use other fuels when they find it economically attractive to do so. Second, the evidence by Mr. Netschert indicated that domestic resources of coal, oil, and gas appear adequate to meet foreseeable demands at relatively constant real costs. Third, a substantial margin of current reserve capacity available to meet emergencies was shown to exist for crude oil and coal. Finally, evidence on the large potential supplies of energy available from shale oil and other new sources leaves no doubt that technology will make available additional alternative fuels to serve the best interest of consumers and of the Nation, provided we do not restrict the opportunity for different fuels to compete freely in the market.

The evidence presented before your committee has provided the basis for a common understanding of the total energy situation and outlook and for confidence that the energy supplies needed for economic progress and national security will be available without any need for further governmental controls. It would be unfortunate, indeed, if the valuable information assembled by your committee were misused by the sponsors of an expensive and unnecessary new study that could only cover the same ground that has already been reviewed thoroughly.

Respectfully submitted.

RICHARD J. GONZALEZ.

Representative PATMAN. This concludes the hearings for this week. I expect to confer with Mr. Widnall and other members of the subcommittee about the possibility of having additional hearings in January or February. In the meantime, the record will be printed as quickly as possible. It is my hope that the members of the committee, after having an opportunity to examine the record will agree to an interim report which we would like to get out within the next 30 to 60 days.

The committee will stand in recess, subject to the call of the Chair.

(Thereupon, at 12:30 p.m., the committee recessed to reconvene subject to call of the Chair.)

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