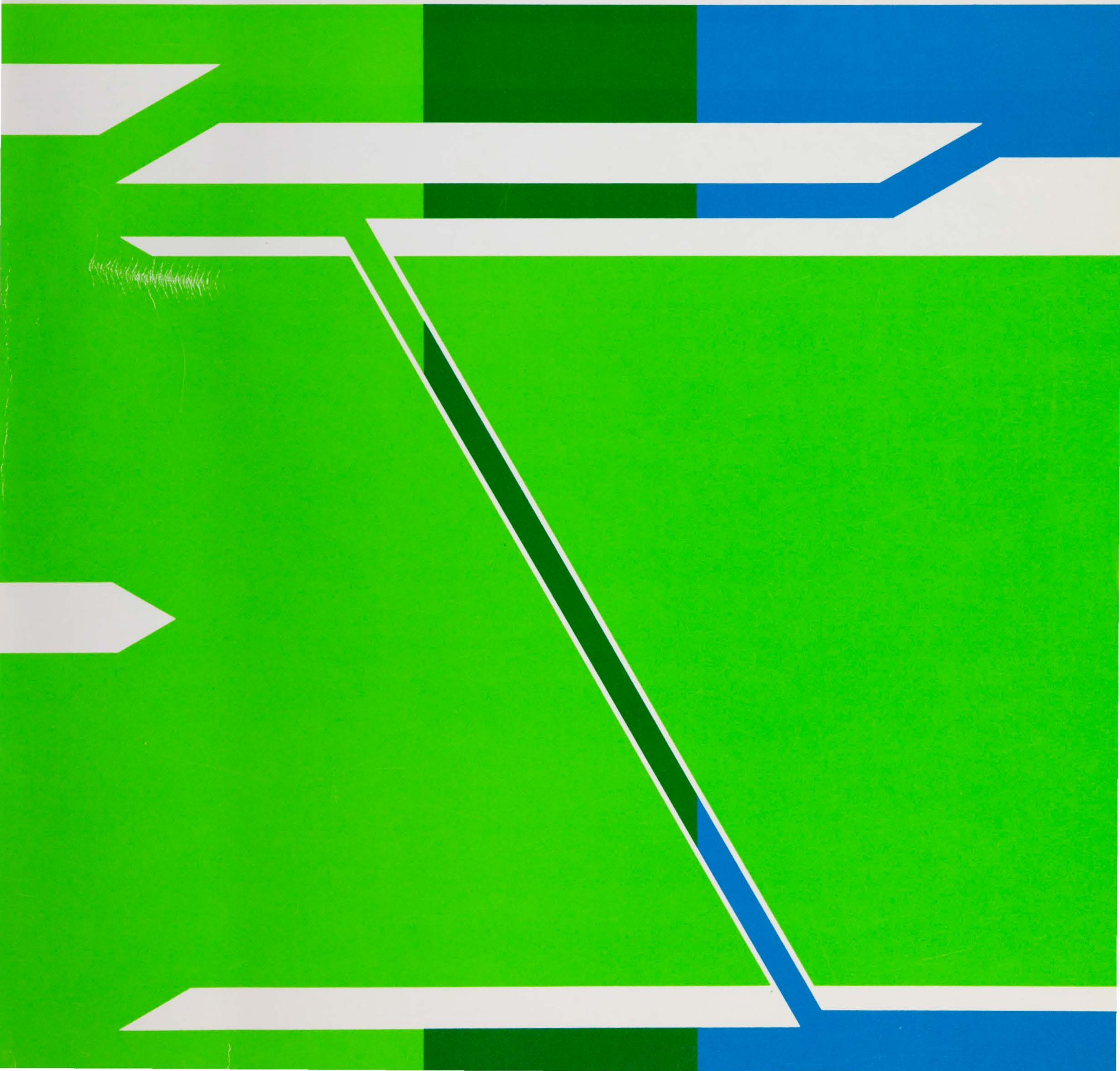
ENERGY IN TEXAS
VOLUME I:
ELECTRIC-POWER GENERATION

LYNDON B. JOHNSON SCHOOL OF PUBLIC AFFAIRS POLICY RESEARCH PROJECT REPORT



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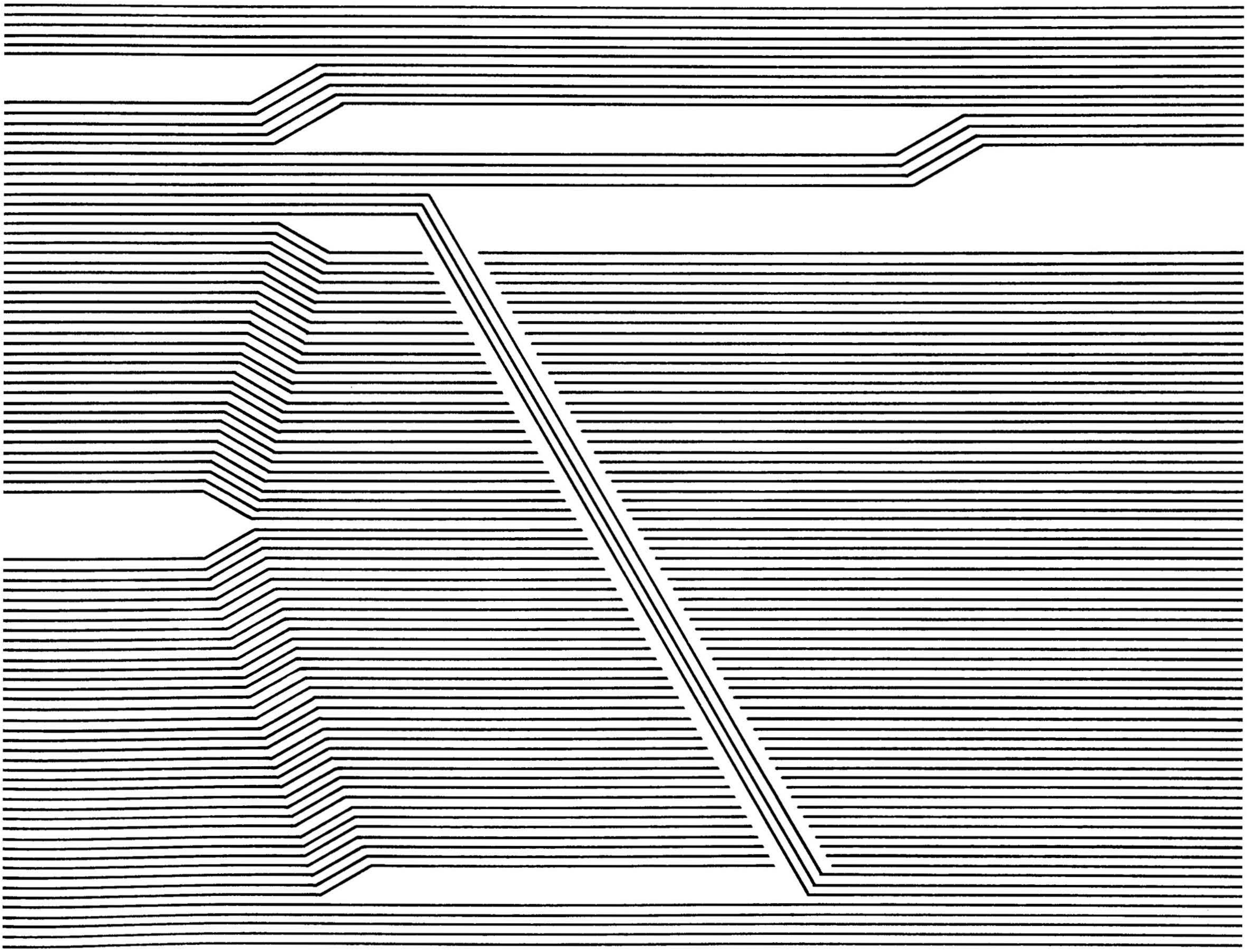

Lyndon B. Johnson School of Public Affairs
The University of Texas at Austin 1976

FOREWORD

The Lyndon B. Johnson School of Public Affairs has established interdisciplinary research on policy problems as the core of its educational program. A major part of this program is the policy research project, in the course of which three faculty members, each from a different profession or discipline, and about fifteen graduate students with diverse backgrounds examine an important issue and make policy recommendations based on extensive research and analysis. These projects are conducted in response to public and governmental needs.

Energy policy in Texas is a matter of obvious importance, and it has received particular attention at the LBJ School. This volume, concerned with electric power generation, is one of two policy studies which resulted from policy research projects on energy in Texas, conducted over a two-year period (1972-74) at the LBJ School. Additional work was done during 1975 in order to incorporate the most recent information into this volume.

It is our hope that this report and its companion volume (*Energy in Texas, Volume II: Policy Alternatives*) will be of value both to policy makers and to the public in considering policy alternatives for energy in Texas.

Kenneth W. Tolo
Acting Dean

PREFACE

This publication is the product of a Policy Research Project on State Planning for Electric Power, undertaken by the Lyndon B. Johnson School of Public Affairs during the academic year, 1972-73. Eleven students and three faculty members participated in the project. Further research on electric power development was completed during the summer of 1975 and additional data from the Federal Power Commission was integrated into the report.

The study was initiated in response to a public need for information about power system planning in Texas and an assessment of the risks and benefits of alternative forms of power generation. Structurally, the report is divided into six chapters that describe and analyze the state's electric power industry (Chapter I), its future electricity demand (Chapter II), fuel costs and resources (Chapter III), environmental considerations in electric power generation (Chapter IV), power-plant siting procedures (Chapter V), and public participation in power system planning (Chapter VI). Current changes in fuel prices and regulatory policies are also included.

In its present form, this volume has been approved for publication by the project's faculty and is responsive to comments and corrections offered by reviewers of an earlier draft. A companion volume *(Energy in Texas, Volume II: Policy Alternatives)* prepared by a separate policy research project, but under the same Director, surveys a much broader energy spectrum and develops a number of state policy alternatives for coping with immediate and long-range energy demands.

Marlan Blissett, *Project Director*
Kingsley E. Haynes
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SUMMARY OF RECOMMENDATIONS

FUTURE POWER RELIABILITY

Future power reliability should be met by increased generation capacity, not by regional interconnections.

ELECTRICITY DEMAND AND CONSERVATION

Electric-power planning in Texas in the next two decades is not likely to be changed because of population trends or in-migration patterns. Thus, for short-term planning, neither the price of electricity nor population trends will make a significant difference. Long-range planning, however, can be substantially affected by pricing policies. The price of electricity, identified as an important and adjustable factor, can be used to conserve energy as well as to influence the growth of electricity demand.

DIVERSIFYING THE USE OF BOILER FUELS

Power-system planning in Texas should aim for greater diversity in the use of boiler fuels. Current reliance upon natural gas as the primary boiler fuel must be decreased and provisions made for the greater use of lignite, coal, and nuclear power.

NEW BOILER TECHNOLOGY FOR FOSSIL-FUEL PLANTS

Efforts should be made to improve the economy of fossil-fuel plants in the future by constructing boilers capable of burning a combination of coal, fuel oil, and natural gas.

USE OF WASTE HEAT FROM POWER PLANTS

Attention should be drawn to the use of waste heat for irrigation, desalination of sea water, certain chemical processes in industries, and heating purposes in nearby structures.

SURVEY OF POTENTIAL POWER-PLANT SITES

The electric utilities in cooperation with the Governor's Power-Plant Siting Committee and the Governor's Energy Advisory Council should conduct a survey of potential power-plant sites in the state, including an analysis of the local and regional impacts that would result from alternative siting patterns.

THE RIGHT OF EMINENT DOMAIN TO COAL-SLURRY PIPELINES

Diversifying the use of boiler fuels in Texas requires increased consumption of coal. A large portion of this coal will come from mines in New Mexico, Colorado, and Wyoming. Currently, the only feasible method of transporting the coal is by rail car. An alternative means is by pipeline in a slurry composed of pulverized coal and water. To develop this new technology it is necessary to pass legislation giving coal-slurry pipelines the right of eminent domain.

JOINT PUBLIC-PRIVATE OWNERSHIP OF FUTURE POWER PLANTS

In view of the rising costs of power generating plants, joint ventures should be considered that can take advantage of the tax-free nature of municipal and state-backed bonds.

ELECTRIC POWER AND THE ENVIRONMENT

Power-system planning should include an assessment of the environmental costs associated with the addition of new power facilities, including the misuse of water.

ADMINISTRATIVE PROCEDURES FOR ELECTRIC POWER-PLANT SITING IN TEXAS

The siting of nuclear and fossil-fuel plants requires permits from both federal and state agencies. Within Texas, the regulatory procedures for protecting air and water resources should be periodically reviewed to insure continuing conformity with federal and state policies.

PUBLIC PARTICIPATION AND POWER-SYSTEM PLANNING

A balance must be struck between the interests of the public and the expertise of the utility. If concern for an adequate power supply is to be weighed more heavily than environmental impacts, then the present efforts of utilities to meet their customer's demands should be regarded with less contempt. On the other hand, if public values are viewed as important elements of planning, a number of possibilities exist for insuring greater public participation. For example:

a) Both state and federal agencies should respond promptly to citizen inquiries.

b) Each agency should maintain a register of persons who have communicated an interest in agency matters.

c) An agency should inform all registered persons of upcoming proceedings in the areas of their interest.

d) An interested person or party should have the right to intervene in agency proceedings.

e) Intervening parties should be loaned or provided with copies of documents, hearings, and testimony free of charge.

f) Where circumstances warrant, intervening parties might be provided with legal assistance or counsel by the administrative agency.

g) Written submissions by interested parties should be accepted for filing regardless of defects in form, substance, or omission. If such defect cannot be remedied or supplied by the agency, the interested party should be notified by mail of the defect and given reasonable time in which to remedy the defect.

TABLE OF CONTENTS

CHAPTER ONE

STRUCTURE OF THE TEXAS ELECTRIC-POWER INDUSTRY

INTRODUCTION

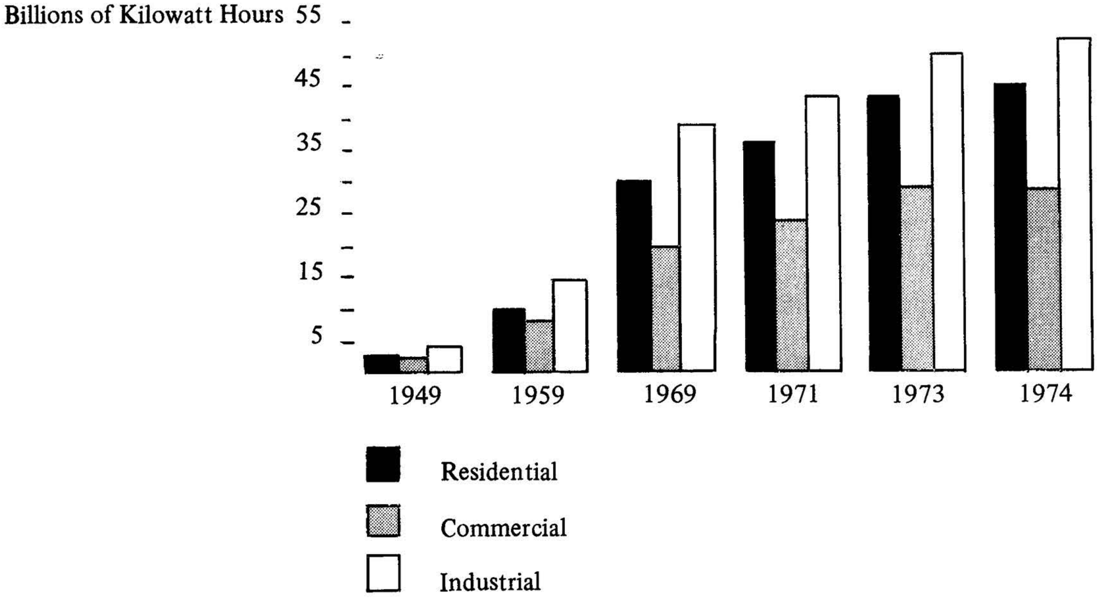
Due to the versatility of electric power, the state of Texas, like the rest of the nation, has experienced, historically, an 8 to 9 percent annual increase in demand for electricity. If conservation measures are not applied, most power estimates project that electricity demand will double in the next 10 years. There are a variety of economic problems associated with this growth: the need for more fuel (Texas is greatly dependent on diminishing supplies of natural gas as a power-plant fuel), the need for more electricity-generating facilities, and the need for more transmission lines. All of these needs require large-scale financing and must compete for limited capital and labor resources.

In general, two policy options are available: (1) to inhibit demand, or (2) to meet the demand. In the latter case there are further options: (a) to build the necessary electric power plants and transmission lines, (b) to increase the efficiency of existing plants, and (c) to interconnect in order to take advantage of potential efficiencies within existing electric-power systems. A coordinated effort using each of these alternatives according to its economic feasibility is likely.

CONSUMPTION PATTERNS BY SECTORS

In reviewing the years 1949 to 1974 it is apparent that the use of electrical energy in Texas has risen in all sectors–industrial, residential, and commercial–although not at the same rate. Industry far exceeds the other sectors in the amount of consumption (see Figure I-1), but residential and commercial use has been increasing as a percentage of total annual consumption in the state.

FIGURE I-1
ELECTRIC POWER USE IN TEXAS

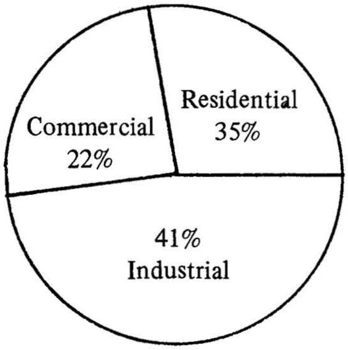


Source: Federal Power Commission, Office of Accounting and Finance

In 1974, the state's consumption of electricity was 35 percent residential, 22 percent commercial, and 41 percent industrial (see Figure I-2).

FIGURE I-2

Statewide Consumption: By Sector



Total KW Hours Sold = 125,902,836,000

Source: Federal Power Commission, Office of Accounting and Finance

While industrial users consume a much greater amount of electricity, the average price per unit paid by industrial consumers is considerably lower than that paid by consumers in the residential and commercial sectors. (See Table I-1.) This price differential is due to several factors: economies of scale can be realized in deliveries to the industrial sector; industrial demand is relatively constant over time and is not subject to variations in temperature or other external "peaking" factors; lastly, many industrial users, because of their size, have, in the past, had the option of substituting in-house generation for commercially produced electricity. (This has induced the electric utility to offer a competitive rate in order to procure the market.)

TABLE I-1

AVERAGE MONTHLY ELECTRICITY BILLS FOR RESIDENTIAL, COMMERCIAL, AND INDUSTRIAL CONSUMERS IN TEXAS, 1974

BILLS

	250 KWH	500 KWH	750 KWH	1000 KWH
Residential	$8.29	$11.58	$15.50	$19.82
	750 KWH	1500 KWH	6000 KWH	10,000 KWH
Commercial	$27.84	$51.84	$162.79	$235.23
	30,000 KWH	60,000 KWH	200,000 KWH	
Industrial	$632	$1,157	$3,277	

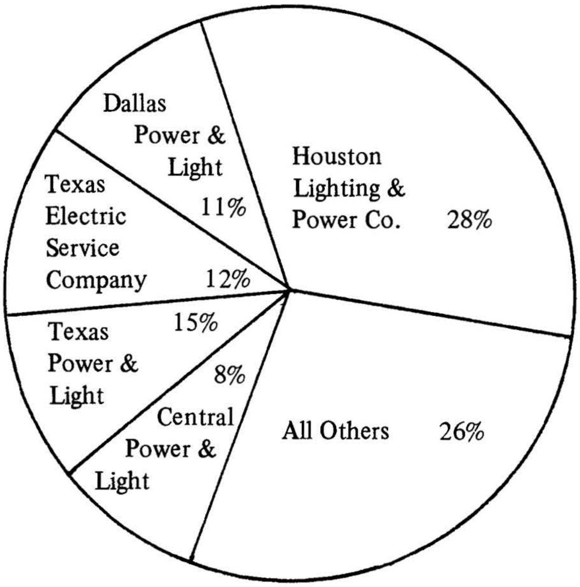
Source: *Typical Electric Bills*, Federal Power Commission, 1974

CURRENT POWER-GENERATING FACILITIES

In 1973, five investor-owned electric-utility companies in Texas accounted for 74 percent of the statewide kilowatt capacity (see Figure I-3) and 67 percent (see Figure I-4) of reported KWH sales.

FIGURE I-3

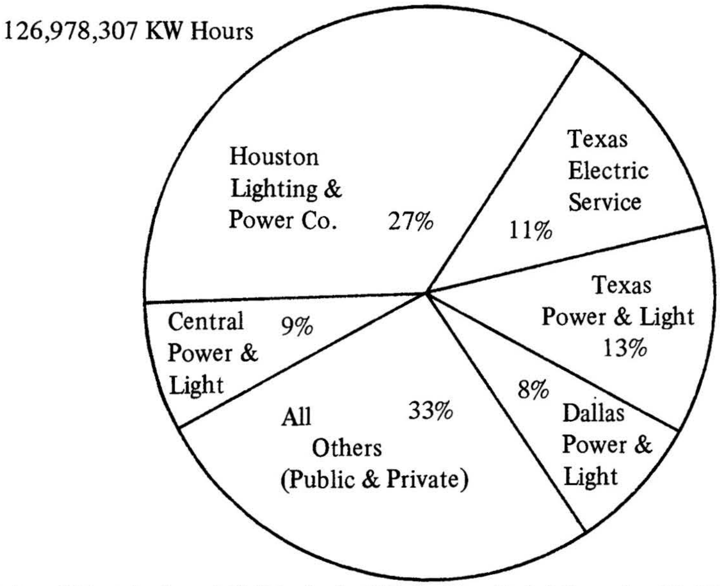
STATEWIDE KILOWATT CAPACITY: 32,043,238 KW



Sources: *Statistics of Publicly Owned Utilities in the U.S. for Year Ended December 31, 1973,* Federal Power Commission.
Statistics of Privately Owned Utilities in the U.S. for Year Ended December 31, 1973, Federal Power Commission.

FIGURE I-4

STATEWIDE KILOWATT HOUR SALES (THOUSANDS)

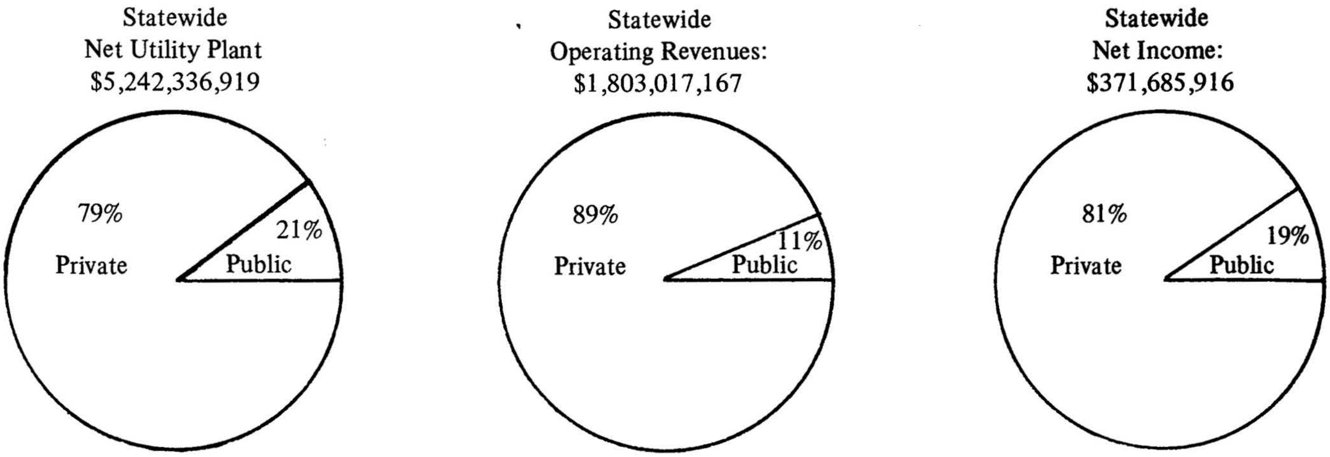


Sources: *Statistics of Privately Owned Utilities in the U.S. for Year Ended December 31, 1973,* Federal Power Commission.
Statistics of Publicly Owned Utilities in the U.S. for Year Ended December 31, 1973, Federal Power Commission.

In 1973, investor-owned, electric-utility companies in Texas accounted for 79 percent of assessed utility-plant valuation, 89 percent of annual operation revenues, and 81 percent of net income for all Texas-based utility companies. (See Figure I-5.)

FIGURE I-5

FISCAL COMPARISON: PRIVATELY AND PUBLICLY OWNED UTILITIES



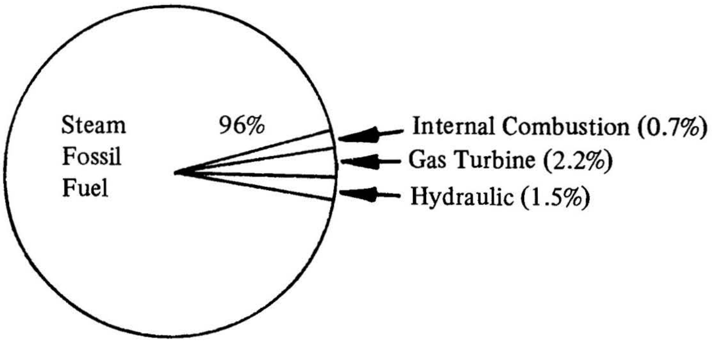
Sources: *Statistics of Privately Owned Utilities in the U.S. for Year Ended December 31, 1973,* Federal Power Commission.
Statistics of Publicly Owned Utilities in the U.S. for Year Ended December 31, 1973, Federal Power Commission.

Steam fossil-fuel generating plants were the source of 96 percent of the 32, 043, 238 KW total generating capacity reported in the state for 1973 (see Figure I-6), with gas turbines, hydro, and internal combustion accounting for the remaining 4 percent.

FIGURE I-6

Total Electric Capacity by Type of Generation

Total Capacity = 32,043,238



Sources: *Statistics of Privately Owned Utilities in the U.S. for Year Ended December 31, 1973,* Federal Power Commission.
Statistics of Publicly Owned Utilities in the U.S. for Year Ended December 31, 1973, Federal Power Commission.

The greater part of the state's kilowatt capacity and KWH sales is marketed in two major metropolitan areas. Houston Lighting and Power supplied 27 percent of the total 1973 state KWH sales in the Houston-Galveston area, while Dallas Power and Light and Texas Electric Service Company marketed 8 and 11 percent, respectively, of the state's total 1973 KWH sales in the service area that includes Dallas-Fort Worth.

The investor-owned companies serve by far the largest geographical areas in the state (See Map I), and their transmission lines provide the bulk of the Texas Interconnected System. The major transmission lines (345 kilovolts or greater) run from the Odessa area in West Texas on a line east-northeast to Abilene, northeast from Abilene to Wichita Falls, southeast from Wichita Falls to Dallas-Fort Worth, and southeast from Dallas-Fort Worth to Houston. (Current and future lines, 345 kilovolts or greater, are depicted in Map II.) Three investor-owned companies—Dallas Power and Light, Texas Electric Service Company, and Texas Power and Light—have joint ownership of the high-voltage lines that run from the Odessa area to Dallas-Fort Worth and southeast to Marlin, Texas, where they connect with similar lines owned by Houston Lighting and Power (ERCOT, 1972).

PLANNED EXPANSION OF TEXAS ELECTRIC-POWER FACILITIES

In view of national fuel shortages, planning for new power facilities in Texas has taken into account the need to shift to boiler fuels other than natural gas. Nuclear power is obviously one alternative, but with escalating construction and capital costs several planned nuclear projects (See Table I-2) have been postponed. In its 1975 report to the Federal Power Commission, the Electric Reliability Council of Texas projects that by 1985 nuclear power will supply 7,200 megawatts of electricity to Texas consumers. While this figure is considerably below the planned nuclear capacity (see Table I-2), it still represents 25 percent of the 28,819 megawatts that ERCOT predicts will be added in the next 10 years.

Lignite and coal-fired plants constitute another alternative. ERCOT figures indicate that by 1985, 40 percent of the planned generating capacity will be supplied by lignite, while boilers capable of burning coal (if it is available) or a combination of coal, fuel oil, or gas will supply 18 percent.

INTERCONNECTION

The interconnection of electric-power systems is one possible method for providing increased electric reliability in interconnected service areas. Economies are achieved by reducing the reserve requirements by sharing reserves, and by more efficient distribution of electricity. All of these benefits may be measured in terms of savings to the individual utilities and, therefore, to the customer. The primary savings occur because fewer power plants are required to meet the electric-power demand in any of the connected areas. The primary cost of interconnecting is for building and maintaining transmission lines between electric-power systems capable of handling the load necessary to ensure the reliable operation of both systems.

The purposes of interconnection are: (1) to allow the transportation of electricity between areas to meet power shortages, and (2) to allow the interchange of electricity between areas, thus reducing generating-facility investments and the cost of electricity (FPC, *National Power Survey*, 1970). At the minimum, an interconnection should allow sufficient capacity to be transferred from one system to another to substitute for the loss of generating facilities in either system.

Description of the Electric-Power System in Texas

The Texas Interconnected System (TIS) is the largest electric system in the state, providing 80 percent of total electricity consumed. TIS members are: The City of Austin, Central Power & Light Co., Dallas Power & Light Co., Houston Lighting & Power Co., Lower Colorado River Authority, San Antonio City Public Service Board, Texas Electric Service Co., Texas Power & Light Co., and West Texas Utilities Co. TIS is organized into two load-control regions that are coordinated for maximum reliability through an administrative committee to provide:

- Determination of spinning reserve requirements,
- Analysis of installed generating capacity requirements,
- Transmission system study,
- Investigation of interconnection requirements,
- Transmission line loading under normal and abnormal conditions,
- Review of automatic under-frequency, load-shedding relays and settings,
- Adoption of criteria for planning and operations, and
- Determination of bias settings (FPC, *National Power Survey*, 1970).

The Texas Municipal Power Pool (TMPP) is a second interconnected electric-power system in Texas and consists of the Brazos Electric Power Cooperative, Inc., the City of Garland Municipal Electric System, the City of Greenville Municipal Electric System, and the Texas Municipal Electric System (City of Bryan).

Coordination for the system is achieved through a technical committee which provides for:

- Comparison and approval of load projections of members,

TABLE I-2

STATUS OF NUCLEAR PLANTS PLANNED IN TEXAS, AS OF AUGUST 31, 1974

Owner, station and unit, and location	Installed capacity (megawatts)	Status[1]	Scheduled operation	Reactor supplies	Reactor type	Constructor
Houston Lighting & Power Co.*						
Allens Creek 1	1,200	ACP	1980	General Electric Co.	boiling-water	Ebasco Services,
Allens Creek 2	1,200	ACP	1982		boiling water	Inc.
near Wallis, Austin County						
Gulf States Utilities Co.						
Blue Hills 1	930	ACP	1981	Combustion	pressurized-water	Becthel Corp.
Blue Hills 2	930	ACP	1983	Engineering, Inc.	pressurized-water	Bechtel Corp.
near Mill Creek, Newton County						
Texas Utilities Co.[2]						
Comanche Peak 1	1,150	ACP	1980	Westinghouse	pressurized-water	Brown & Root,
Comanche Peak 2	1,150	ACP	1982	Electric Corp.	pressurized-water	Inc.
near Glen Rose, Somervell County						
Consortium[3]						
South Texas Project	1,250	ACP	1982	Westinghouse	pressurized-water	Brown & Root,
near Palacios, Matagorda County				Electric Corp.		Inc.
Consortium[4]						
Unnamed 1	1,250	planned	1983	unknown	unknown	unknown
Unnamed 2	1,250	planned	1985	unknown	unknown	unknown
Undetermined South Texas location						

---

[1] ACP = Application for construction permit pending.

[2] Owns all or most common stock of Dallas Power & Light Co., Southwestern Electric Service Co., and Texas Power & Light Co.

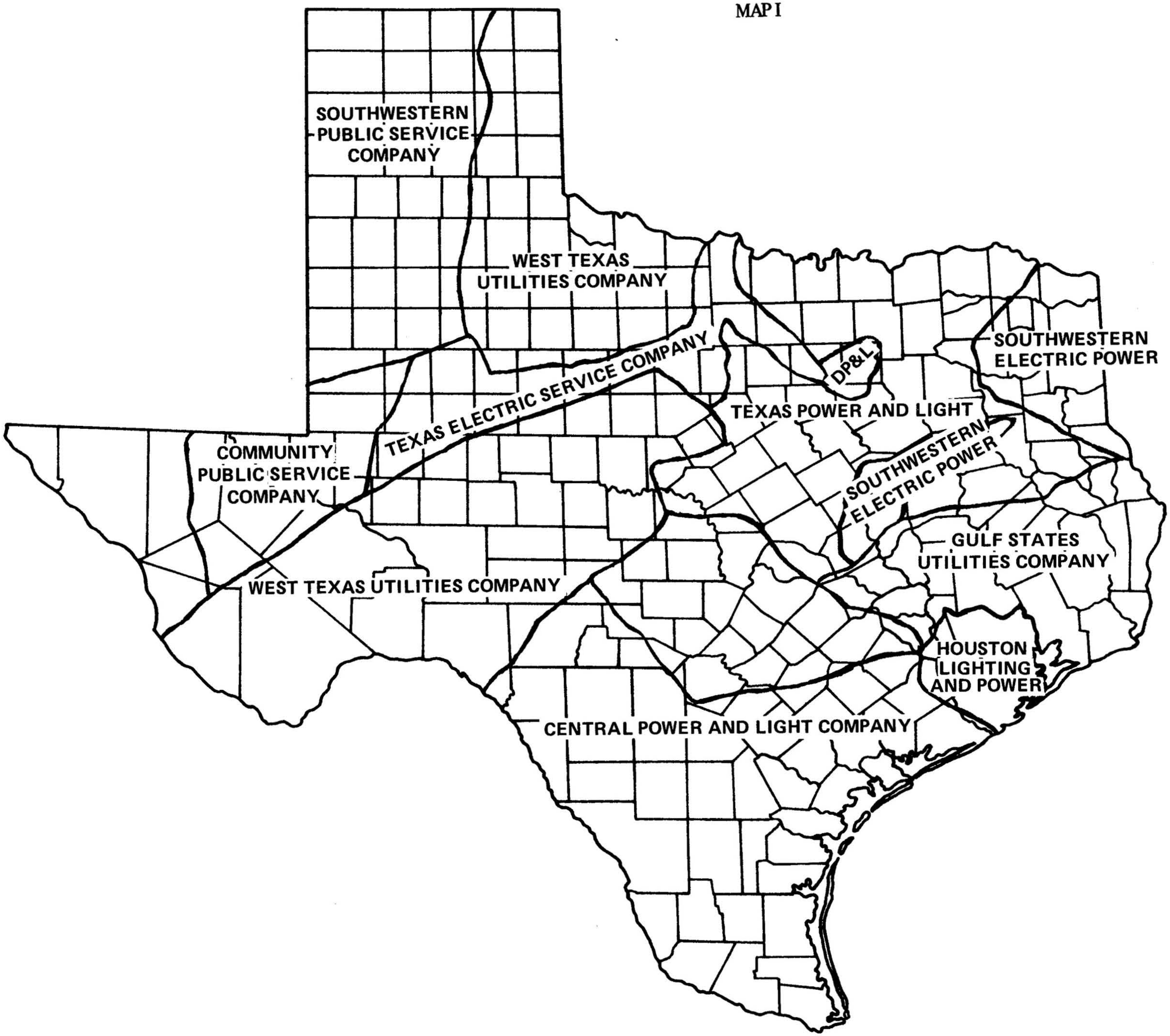
[3] Houston Lighting & Power Co. - 30.8%; City Public Service Board (San Antonio) - 28.0%; Central Power & Light Co. - 25.2%; and City of Austin - 16.0%.

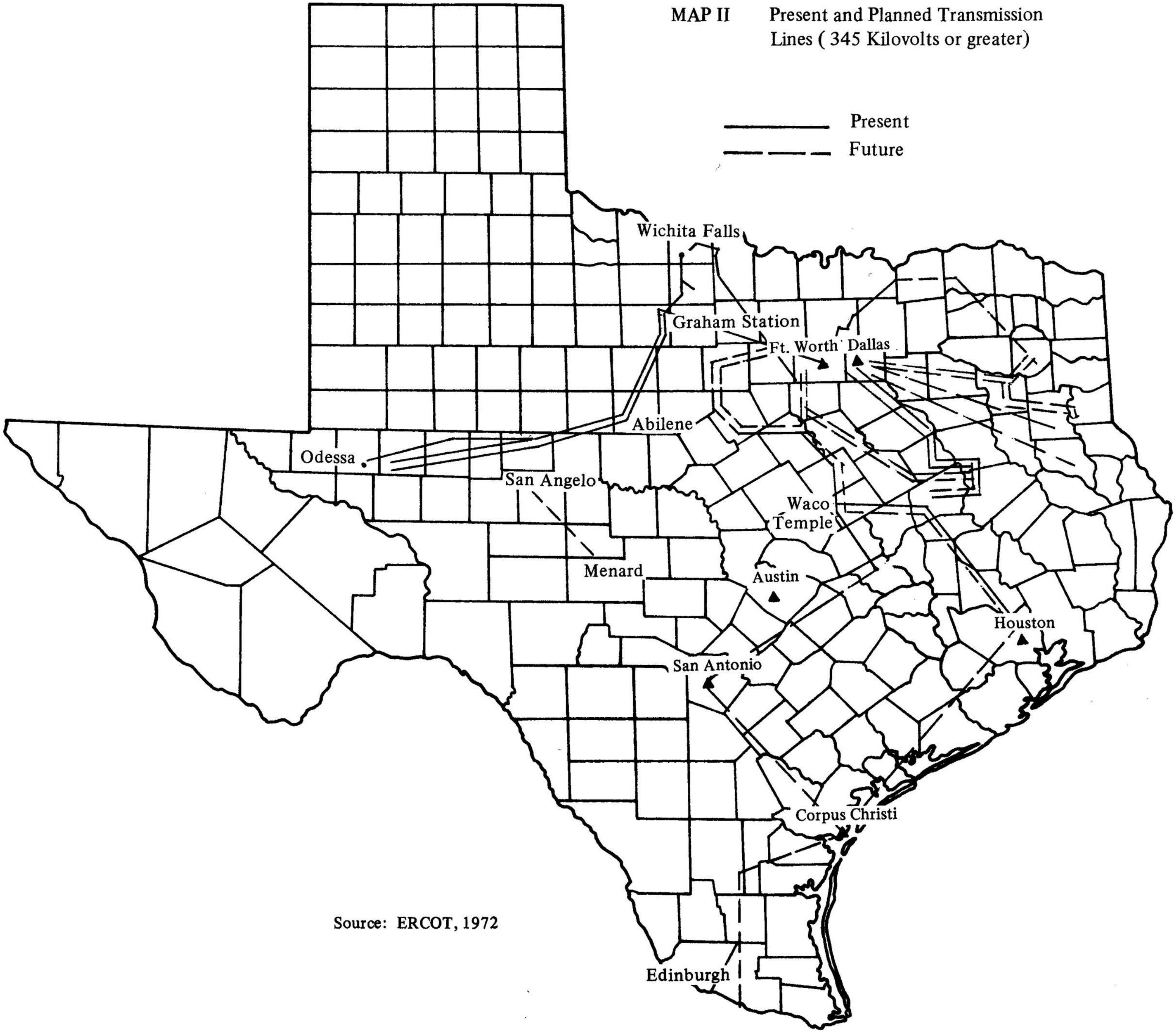
[4] Same four utilities as in Note 3, with the addition of the Lower Colorado River Authority. Shares of ownership undetermined.

Sources: *Nuclear News Buyers Guide*, mid-February 1974, p. 49; company annual reports; press clippings.
Compiled by: Center for Energy Studies, The University of Texas at Austin, 1975.

*On September 10, 1975, the Allens Creek Nuclear Generating Station was indefinitely deferred.

MAP I


SOUTHWESTERN PUBLIC SERVICE COMPANY
WEST TEXAS UTILITIES COMPANY
TEXAS ELECTRIC SERVICE COMPANY
DP&L
SOUTHWESTERN ELECTRIC POWER
TEXAS POWER AND LIGHT
COMMUNITY PUBLIC SERVICE COMPANY
SOUTHWESTERN ELECTRIC POWER
GULF STATES UTILITIES COMPANY
WEST TEXAS UTILITIES COMPANY
HOUSTON LIGHTING AND POWER
CENTRAL POWER AND LIGHT COMPANY



MAP II Present and Planned Transmission Lines (345 Kilovolts or greater)

Source: ERCOT, 1972

- Coordinated generation-installation schedules,
- Exchange of capacity and energy,
- Allocation of spinning reserve,
- Coordination of maintenance outage schedules, and
- Investigation of installing economic dispatch facilities (FPC, *National Power Survey*, 1970).

Interconnection of electric-power systems within Texas has long been an established fact. However, the Electric Reliability Council of Texas (ERCOT), which includes TIS, TMPP, and 70 other electric-power companies (41 cooperatives, 27 municipalities, and 2 others), is connected to neither the New Mexico Power Pool (NMPP) nor the South West Power Pool (SWPP). All other major, regional electric-power systems in the U.S. (See Map III) are interconnected for purposes of reliability and economy.

ERCOT serves 195,000 square miles, has a load of approximately 20,000 MW, and is designed to withstand:

- Loss of all generating capacity at any generating station;
- Outage of any single- or double-circuit transmission line, transformer, or bus;
- Outage of any circuit during scheduled maintenance of another line;
- Simultaneous outage of overhead transmission lines parallel to each other for a substantial distance, a spacing between circuits of less than the height of the structures;
- Any fault cleared by normal operation of backup relays; and
- Loss of any large-load or concentrated-load area (Fort Worth Regional Office, FPC, 1972).

How Interconnection Would Affect ERCOT

Section 202(a) of the Federal Power Act authorizes the Federal Power Commission (FPC) to promote and encourage voluntary interconnection and the coordination of facilities for the generation, transmission, and sale of electric energy for the purpose of assuring an abundant supply with the greatest possible economy and with regard to the proper utilization and conservation of natural resources (Fort Worth Regional Office, FPC, 1972).

The worth of interconnection may be examined by computing the difference in reserve requirements between the isolated operation of ERCOT and its hypothetical interconnection with another system over time, on a present cost basis. To this end, an October, 1972, staff report released by the Fort Worth Regional Office of the FPC, *Study of Proposed Interconnection Between the Electric Reliability Council of Texas (ERCOT) and the South West Power Pool (SWPP)*, recommended that ERCOT interconnect with SWPP at three points (see Map IV). The reasons supporting the recommendation to interconnect were primarily economic. According to the FPC, the interconnection would cost an estimated $37 million in present value over 10 years, but could result in total savings of $193 million in present value over 10 years, with a net gain of about $156 million. The report, however, did not specify who would incur the costs or how the benefits would be distributed (Table I-3).

ERCOT's reaction to the FPC proposal is not favorable. The objections of Texas utility companies encompass five main areas: (1) reliability, (2) financial considerations, (3) management problems, (4) FPC jurisdiction, and (5) the adequacy of proposed interconnections.

Reliability. Of primary concern to utilities is the issue of reliability. In order for all the savings described in the report to be realized, ERCOT must reduce its average system-reserves from 18.6 percent to 15.5 percent. In spite of decreased reserves, the FPC argues that both ERCOT and SWPP could still meet a "one day in 10 years" reliability criterion. (Table I-4.)

The resolution of the reliability issue hinges upon the measure of reliability. Three different measures (or standards) are commonly used:

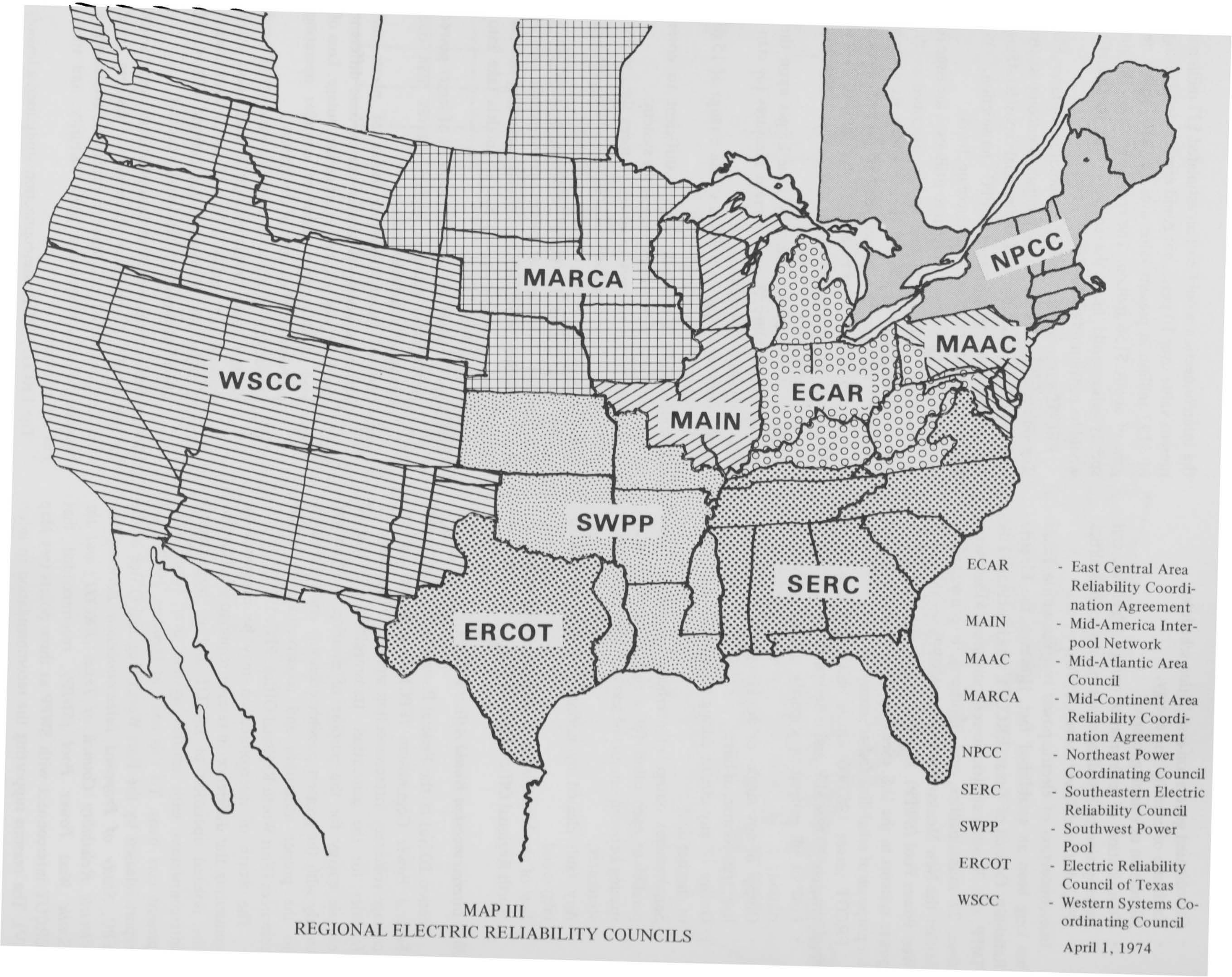
a) maintenance of spining reserves within a range of 15 to 25 percent of annual peak-load;
b) maintenance of spinning reserves sufficient to cover forced outage of the largest unit in the system;
c) maintenance of reserves adequate to meet the cumulative probabilities that load will exceed capacity because of forced outage on any one day in 10 years.

The "one day in 10 years" criterion is based on a computerized simulation of electric-power-system operations. Variables differ among models according to the desired level of sophistication, but all models take into account at least three factors:

(i) *size of plant* (A system composed of larger power plants must maintain higher reserves than one composed of smaller units.)
(ii) *type of plant* (Differing types of plants and individual plants of similar size all have different probability of a forced or scheduled outage. Loss of load models must therefore consider operating probablities of all units in the system.)
(iii) *probability of demand exceeding capacity* (Forced outages cause problems only if they occur when demand (i.e., load) is high. Loss of load models consider the probability that demand will exceed operating capacity when outages occur.)

Other variables employed by more sophisticated approaches include details on weather fluctuations, business cycle variations, scheduled maintenance, functional relationships between forced outages and plant maturity, and transmission reliability.

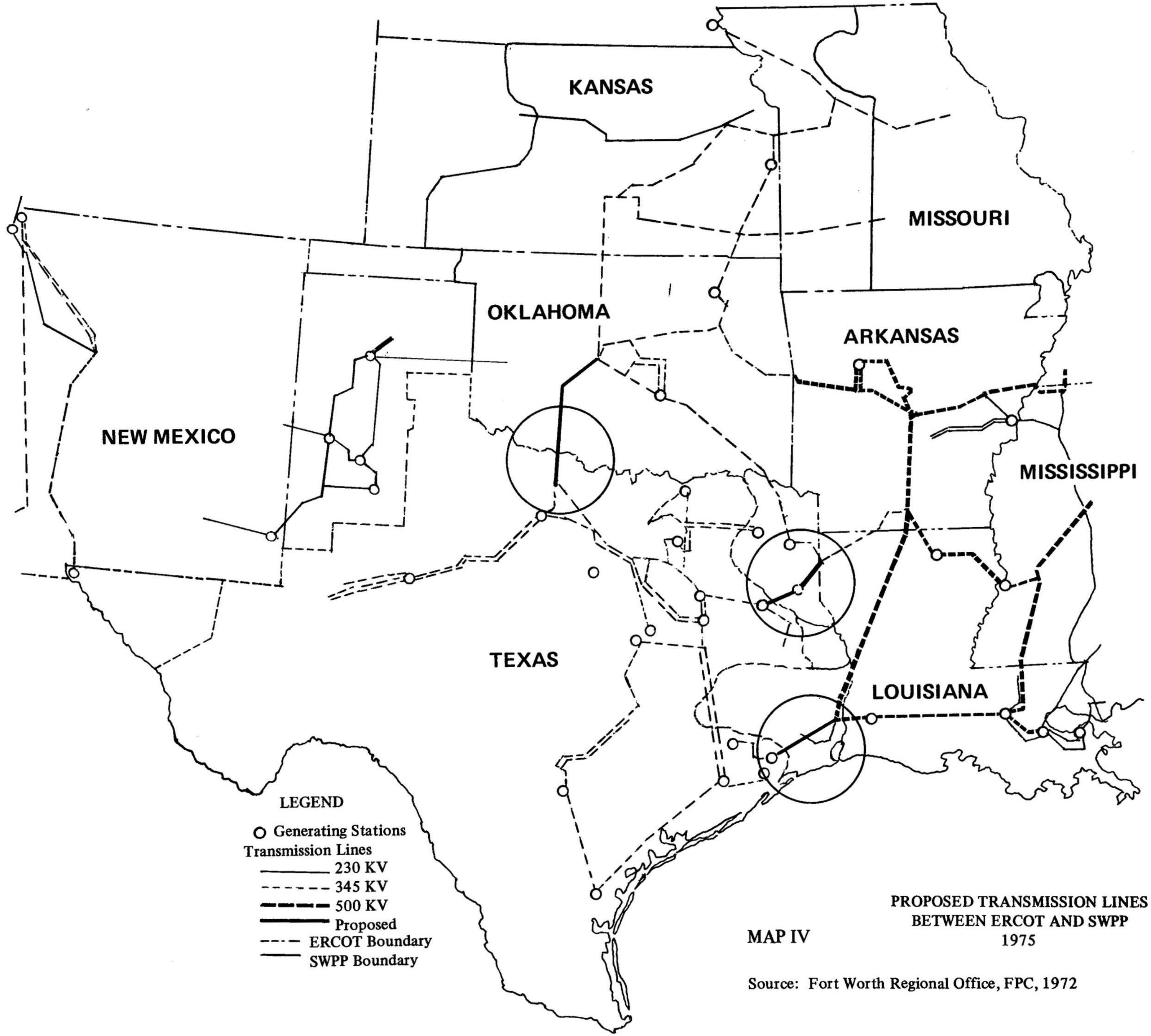
The ERCOT/SWPP interconnection study used a loss-of-load probability model to simulate operations of both



ECAR	- East Central Area Reliability Coordination Agreement
MAIN	- Mid-America Interpool Network
MAAC	- Mid-Atlantic Area Council
MARCA	- Mid-Continent Area Reliability Coordination Agreement
NPCC	- Northeast Power Coordinating Council
SERC	- Southeastern Electric Reliability Council
SWPP	- Southwest Power Pool
ERCOT	- Electric Reliability Council of Texas
WSCC	- Western Systems Coordinating Council

April 1, 1974

MAP III
REGIONAL ELECTRIC RELIABILITY COUNCILS



MAP IV

PROPOSED TRANSMISSION LINES
BETWEEN ERCOT AND SWPP
1975

Source: Fort Worth Regional Office, FPC, 1972

TABLE I-3

Summary of Annual Costs

Year	Generation						Transmission		Net Savings Over Isolated Operation	
	(1) Capacity Added Isolated Operation (MW)	(2) Capacity Added Interconnected Operation (MW)	(3) Annual Capacity Difference (MW)	(4) Cumulative Annual Capacity Savings (MW)	(5) Annual Cost Difference 1/ ($1,000)	(6) Present Worth of Annual Cost Difference 2/ ($1,000)	(7) Annual Cost 3/ ($1,000)	(8) Present Worth of Annual Cost2/ ($1,000)	(9) Annual Savings Col. 5-Col. 7 ($1,000)	(10) Present Worth of Annual Savings Col. 6 -Col. 8 ($1,000)
1975	4,160	400	3,760	3,760	55,310	51,024	8,053	7,429	47,257	43,595
1976	5,760	5,920	(160)	3,600	52,956	45,067	8,053	6,853	44,903	38,214
1977	6,480	6,720	(240)	3,360	49,426	38,803	8,053	6,322	41,373	32,481
1978	6,150	7,440	(1,280)	2,080	30,597	22,160	8,053	5,832	22,544	16,328
1979	7,680	8,000	(320)	1,760	25,890	17,298	8,053	5,380	17,837	11,918
1980	9,440	9,120	320	2,080	30,597	18,858	8,053	4,963	22,544	13,895
TOTAL	39,680	37,600	2,080		244,776	193,210	48,318	36,779	196,458	156,431

1/ Annual cost difference between isolated and interconnected operation is estimated at 14.71 dollars per kilowatt per year including 12.96 dollars per kilowatt per year fixed charges plus 1.75 dollars per kilowatt operation and maintenance cost times the cumulative annual capacity savings (Col. 4). The fixed charges are based on a generating unit investment cost of $90 per KW.

2/ Present Worth interest rate of 8.4 percent referenced to the year 1975 is assumed.

3/ Annual cost is estimated at 15.9 percent (14.46 fixed charges and 1.5% operation and maintenance expense) of the total estimated investment of $50.65 million.

Source: Fort Worth Regional Office, FPC, 1972

TABLE I-4

Minimum Reserves to Meet 1 Day/10 Year Risk

Year	ERCOT Isolated (%)	ERCOT and SWPP Interconnected (%)	Difference (%)	ERCOT Presently Planned Reserves (%)
1975	18.33	14.86	3.47	21.66
1976	18.49	15.13	3.36	19.76
1977	18.17	15.60	2.57	17.68
1978	17.91	15.54	2.37	18.42
1979	18.15	15.93	2.22	17.83
1980	20.73	16.13	4.60	18.13

Source: Fort Worth Regional Office, FPC, 1972 systems individually and when hypothetically interconnected. It concluded that both systems could operate with 2,080 MW less generating-capacity over 10 years if they were interconnected than if they were independent (Fort Worth Regional Office, FPC, 1972).

Conspicuously absent in the FPC study is an analysis of the loss-of-load risk-index that both systems have independently maintained in the past, and what the savings would be if that same risk-index were extended to the future under independent and interconnected conditions. The "one day in 10 years" standard, while frequently accepted, is still arbitrary. Moreover, assuming the validity of the standard, the probablity that load will exceed operating capacity is always positive; that is, "one day in 10 years" may be tomorrow as easily as 10 years from tomorrow.*

The utilities' standards are based on the forced outage of the largest unit, but they do not formally anticipate the possibility that a smaller unit could experience a forced outage at the same time as the largest plant. In practice, however, such coincidental outages are not overlooked. ERCOT engineers maintain excellent communications with each other and utilize automatic equipment that can absorb load losses without a blink of lights throughout the pool.

The Texas electric utilities have demonstrated their reliability, with neither a brownout nor a blackout in their operating history. Their standards have proved adequate, and the utilities see no need to change them.

FPC engineers agree that reliability has been demonstrated and that several crises have been handled with maximum efficiency and coordination. However, they also indicate that good fortune has played a role.

Financial Considerations. Electric-power reliability is maintained by a combination of adequate generation- and transmission-facilities. Interconnection increases the intensity of transmission facilities relative to generation investment. Texas utilities indicate that they prefer to invest in generation rather than transmission to provide for reliability. As a result, utilities' financial resources are earmarked for increased development of generation capacity.

ERCOT maintains transmission facilities within Texas sufficient to carry the Texas electric-power load. System growth will be met by building new generation-capacity, including nuclear plants, and supplementing transmission facilities. "Capacity" is a measure primarily of generation, and additions to capacity must be made by investment in generation. Reserves are an integral part of capacity and cannot be increased by building transmission lines, according to the utilities.

The FPC discounts these arguments on the grounds that seasonal, weekly, or hourly reserve sharing can effectively add to total capacity by decreasing reserve requirements, and that this can be affected by building transmission facilities that interconnect with SWPP. Further, the FPC points out that investment in generation facilities costs substantially more per unit of productivity than investment in transmission facilities.

Management. Management costs, expressed in terms of both money and effectiveness, increase as system size increases. Texas utilities are fearful that management of a pool as large as ERCOT and SWPP combined could not be effective.

The FPC disagrees, citing the effective managerial history of the rest of the national electric-power grid.

While the historical effectiveness of national grid management is debatable, ERCOT rests its case on its impeccable record. Effective management of ERCOT has been demonstrated, and intervention in the managerial relationships that have developed in Texas could, in the utilities' viewpoint, be disruptive. Definition of maintenance responsibilities and emergency-response rates are the utilities' areas of primary concern.

FPC Jurisdiction. Interconnection would bring Texas utilities under the regulatory scrutiny of the FPC; this would include the regulation of wholesale prices for interstate transmission as well as financial auditing. Texas utilities confirm that this is undesirable from their point of view, but they do not regard this as a primary concern.

The FPC, however, sees this issue as central to the interconnection question. The FPC regards the United States as a cooperative federation of states; it believes Texas electric-power companies should volunteer to aid other states, and, in turn, accept help when Texas is in need.

Utility representatives say that their desire for independence is based upon a fear of the costs involved in coping with the federal bureaucracy. They believe that the state can adequately protect the public interest and that the relatively low rates charged by Texas electric-power utilities preclude the need for regulation.

Adequacy of Proposed Interconnections. One utility

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*The Regional Office (Ft. Worth) of the Federal Power Commission responded to these observations as follows:

1) We felt that these systems' reliability index over the past years was probably better than one day in ten years as the utilities themselves have suggested. Therefore, to use a higher standard for the purpose of timing in future generating unit additions would result in even greater savings for interconnected operation over that for isolated operation. It was our intention to use a conservative approach throughout the study so that any benefits would not be overstated but would be fully realizable.
2) Any actual historical risk index would fluctuate widely from year to year so that some average would have to be used which would not really have much meaning and would complicate understanding the final results.
3) To perform a historical analysis, as was suggested, would have extended the study an additional year and this was not considered justifiable.

spokesman expressed the opinion that the three interconnections proposed in the FPC study are not sufficient to carry the load between ERCOT and SWPP. He focuses the need for three to four times the proposed transmission-capacity, with additional backup facilities.

The FPC's proposal for interconnection is based upon a mid-1960s study of Texas utilities. FPC spokesmen do not believe that conditions have changed so dramatically since then as to require additional transmission facilities.

Other Considerations. The FPC study, with an eye to history, further notes that "it is natural to consider interregional ties between ERCOT and SWPP as the next logical step in the evolutionary development of their transmission grids" (Fort Worth Regional Office, FPC, 1972). The eventual ties between TIS and TMPP, which had been advocated much earlier, were effected when mutual benefits outweighed costs. The FPC foresees the day when system expansion will make interconnection a desirable policy for all concerned. In the interim, the FPC believes that the public interest is not being served.

It is important to note, however, that retail electricity prices would not necessarily decrease (or increase more slowly) if all economic benefits from interconnection were realized. Retail rates are not under FPC jurisdiction, and dramatically increasing fuel prices can only mean higher electricity bills for ultimate consumers.

In general, arguments in favor of an ERCOT-SWPP interconnection conclude that:

- Interconnection might facilitate the joint financing of larger, more efficient generating-plants.
- Interconnection could facilitate the provision of capacity and energy to an electric-power system during maintenance, emergency shutdown, or replacement of a system's generating facilities.
- Interconnection may provide insurance against unexpected natural or man-made disasters.

On the other hand, opponents of interconnection argue that:

- Interconnected systems operating in tandem may allow a local power failure to become a widespread blackout.
- There is no assurance that large interregional systems will be able to plan for and provide electricity to meet the tremendous growth in demand that is expected.
- There may be opposition by environmental groups to the large EHV transmission lines characteristic of interconnections.

Summary. More than 80 percent of the generating capacity in Texas is coordinated through ERCOT. This electric-power group conducts business only in Texas, and history shows that its electric-power reliability has been excellent.

The FPC recommendation that ERCOT interconnect with SWPP is based on possible economic benefits resulting from lower reserve-requirements for a given measure of reliability. Utility objections to the FPC interconnection proposal are based upon differences of opinion regarding reliability, financial considerations, management problems, regulatory jurisdiction, and adequacy of the proposed ties. Given the limits of current knowledge, these differences remain, for the most part, moot questions. Each opinion is logically derived from the relative points of view of the parties directly concerned.

Since the proposal is justified on economic grounds, it must also be judged on economic grounds, within a political sphere. In line with its statutory mandate, the FPC notes:

> While the resulting reserves in this study fall within the generally acceptable range of 15 to 25 percent of annual peak-load, an actual reduction in reserves is not necessarily being advocated. It is utility management's prerogative to determine whether to reduce reserves after interconnection to a level which would provide the same reliability or risk as under isolated operation and pass the resultant savings to their customers or to maintain reserves under interconnected operation as otherwise planned for isolated operation in order to achieve improved power-supply reliability (Fort Worth Regional Office, FPC, 1972).

From this comment, it is not clear that interconnection would necessarily decrease capital investment. But even if capital investment were decreased, there is no assurance that the savings would be passed on to consumers. It is probable that the FPC would insure that the savings would be passed on through wholesale transactions, but market competition would have to determine the degree to which the savings would be passed on to the retail customers.

It has been shown, however, that the electricity market in Texas does not display characteristics which would be associated with a high degree of competition, so it is doubtful that the market would insure lower retail rates as a result of lower capital investment. The only way lower retail rates can be insured uniformly is through state regulation of such rates; and it is unrealistic to anticipate such regulatory action in view of rising capital costs to utilities and increases in the price of boiler fuels.

In conclusion, it does not seem that interconnection would necessarily benefit the consumer, and management problems could, in fact, work to the detriment of consumer interests. Therefore, we feel that interconnection between ERCOT and SWPP does not seem to be justifiable at present.*

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*The Regional Office (Ft. Worth) of the FPC disagrees with this conclusion and notes:

> Although . . .[your] report states the Texas utilities' position with regard to interconnection, our own report includes written comments from all major companies in both ERCOT and SWPP that wished to comment on the study. It is interesting to note that although the SWPP companies would not benefit from an interconnection with ERCOT to the same extent as ERCOT for the reason that SWPP is already realizing benefits from interconnected operation, many of the SWPP companies expressed a willingness to undertake further studies at great cost whenever the ERCOT companies express a similar willingness.

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4. ________, *1970 National Power Survey*, U.S. Government Printing Office, Washington, D.C., 1970.
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6. ________, *Statistics of Publicly Owned Electric Utilities in the United States for Year Ended December 31, 1970*, Washington, D.C., February, 1973.
7. ________, *Typical Electric Bills*, 1974.
8. United States House of Representatives, *Hearings Before the Subcommittee on Communications and Power of the Committee on Interstate and Foreign Commerce, 92nd Congress, 1st session, on HR 5277, HR 6970, and HR 6971, HR 6972, HR 3838, HR 7045, HR 1079, and HR 1486,* Bills relating to Powerplant Siting and Environmental Protection, May 4, 6, 7, 11, 12, 13, 25, 26, and 27, 1971, Serial No. 92-32, U.S. Government Printing Office, Washington, 1971, Part 2.

CHAPTER TWO

ELECTRICITY DEMAND ANALYSES

INTRODUCTION

Public concern for power reliability reflects a growing awareness of the importance of electricity in today's economy. Power reliability requires planning for an adequate supply of power; this, in turn, is greatly influenced by forecasts of electricity demand.

To a great extent, demand forecasts determine and justify new technologies of generation as well as new supply alternatives. In this respect, it is quite important that the demand forecasts be done accurately. An underestimation of electrical energy demand may result in brownouts, interrupted service, and increased production costs due to overloading. An overestimation, on the other hand, may lead to under-utilization of equipment, wasteful investment leading to higher operating costs, hasty application of imperfect technology, and consequent environmental damage.

This chapter begins with an examination of the process of making future estimates by reviewing projections of national electric-power demand. Next there is an analysis of electric-power production to identify factors associated with increases in power production over time. This is complemented by an attempt to identify regional influences associated with electric-power production, since demand projections made for the United States may be inadequate for anticipating state electric-power requirements. Finally, there is a forecast of electric-power demand for the State of Texas and the prospects for energy conservation.

A REVIEW OF ELECTRICITY-DEMAND STUDIES

Numerous studies have attempted to predict national demand for electricity for various periods between 1950 and 2000. Table II-1 shows the results of several of these studies, with consumption expressed in billions of kilowatt hours (KWH). The values for the first five of these projections, with historical bases, are shown graphically in Figures II-1 through II-8, with the average annual percentage increases in demand also indicated. Reasons for the wide range of reported values are discussed below.

Both theoretical and practical problems arise in predicting the demand for electricity.

Theoretically, the quantity of electricity consumed is assumed to be available at a given price. Unless demand is perfectly price-inelastic in the relevant range, a change in the price of electricity will effect a change in the quantity consumed. Historical data on electricity consumption do not show this relationship; rather, the data show only the quantity demanded during a period in which the price might be subject to change. Without knowing the precise nature of the present demand-curve—its slope, elasticity, and cross-elasticities with respect to other forms of energy—it is difficult to predict the nature of the demand curve in the future. Yet the studies cited in Table II-1 attempt to do just that.

Most studies accept past consumption of electricity as an indication of historical demand. Implicit in this acceptance is the assumption that price, expressed in constant dollars, has not significantly affected electricity demand over time. This means that the economy has always remained substantially at the same point on the demand curve, though the curve as a whole may have shifted dynamically. The price assumption, while not precisely true, is necessary where there is a lack of data on elasticity which precludes interpolation of the quantity demanded at a truly constant price. If price is assumed to be held constant, elasticity ceases to be a relevant statistic.

Further problems arise in predicting electricity demand once theory is brought into contact with practicality. In the studies under review, these problems are basically of three types: (1) those that concern the use of different methodologies; (2) those without explicit analytical assumptions; and (3) those that emerge from different data bases.

1. *Methodologies.* Variations on three basic methodologies were found:
   - a. *Judgment*: The judgment method is the least precise and the least scientific, but it could generate results as accurate as any other approach. Variations in range, however, can be extreme.
   - b. *Data Analysis*: By analyzing historical elec-

TABLE II-1: FORECASTS OF ELECTRICITY DEMAND
(Billions of KWH)

STUDY / YEAR	1965	1970	1975	1980	1985	1990	2000
Actual Generation[a]	1,153.073	1,632.128					
Total Utilities (only)	1,051.577	1,520.087					
NF&ESG[b]				2,700			
B.O.M.[c] Utilities		1,493.4	2,047.3	2,757.0			
Schurr[d] Total			1,965.5				
Utilities			1,809.1				
Landsberg[e]							
Total Low		1,197		1,706		2,225	2,974
Medium		1,400		2,229		3,237	4,711
High		1,780		3,088		4,882	7,767
Util. Low		1,077		1,550		2,071	2,762
Medium		1,257		2,014		2,943	4,305
High		1,590		2,763		4,384	6,999
N.P.S. 1970[f] Total		1,643.3		3,201.9		5,978.2	
Utilities		1,534.6		3,074.9		5,828.2	
AEC[g] Utilities				2,700			
T.E.T. Corp.[h] Utilities		1,448	1,995	2,581	3,363		
Vogely[i] Utilities				2,739			
Cook[j] Utilities				3,086			

SOURCES:

[a] *Production of Electric Energy, Capacity of Generating Plants*, Federal Power Commission, monthly between 1951 and 1962; *Electric Power Statistics*, Federal Power Commission, monthly between 1963 and 1970. Figures for Alaska and Hawaii subtracted from total.

[b] "Report of the National Fuels and Energy Study Group on Assessment of Available Information on Energy in the United States," Committee on Interior and Insular Affairs, United States Senate, *87th Congress, 2d Session, S. Doc. 159*, September, 1962.

[c] "An Energy Model for the United States Featuring Energy Balances for the Years 1947 to 1965 and Projections and Forecasts to the Years 1980 and 2000," *Information Circular 8384*, Bureau of Mines, U. S. Department of the Interior, July, 1968.

[d] Schurr, Sam H., Bruce C. Netschert, with Vero Eliasberg, Joseph Lerner, and Hans H. Landsberg, *Energy in the American Economy, 1850-1975: An Economic Study of Its History and Prospects*, Johns Hopkins Press, Baltimore, 1960.

[e] Landsberg, Hans H., Leonard L. Fischman, and Joseph L. Fisher, *Resources in America's Future: Patterns of Requirements and Availabilities, 1960-2000*, Resources for the Future, Inc., Johns Hopkins Press, Baltimore, 1963.

[f] *The 1970 National Power Survey*, Federal Power Commission, U. S. Government Printing Office, 1970, vol. 1, Appendices A and B.

[g] "Civilian Nuclear Power - A Report to the President," U.S. Atomic Energy Commission, 1962 (and 1967 Supplement).

[h] "Competition and Growth in American Energy Market, 1947-1985," Texas Eastern Transmission Corporation, 1968.

[i] Vogely, William A., "Patterns of Energy Consumption in the U.S.," Division of Economic Analysis, Bureau of Mines, U.S. Department of the Interior, 1962.

[j] Cook, Michael C., "Energy in the United States, 1960-1985," Sortorius & Co., September, 1967.

TABLE II-1 (cont.): FORECASTS OF ELECTRICITY DEMAND
(Billions of KWH)

STUDY YEAR	1965	1970	1975	1980	1985	1990	2000
Nathan Assoc.[k] Utilities				2,641			
Paley (1952)[l]				1,400			
Teitelbaum (1958)[m]				1,795			
Lamb (1959)[n] Utilities				2,800			
Sporn (1959)[o] Utilities				2,800			6,000
E.E.I. (1960)[p]				2,895			6,000 10,000
FPC (1961)[q]				2,994			
Elect. World (1962)[r]				3,315			
N.P.S. (1964)[s] Total				2,820			
Utilities		1,484	2,024	2,693			

SOURCES:

[k] Robert R. Nathan Associates, Inc., "Projection of the Consumption of Commodities Producible on the Public Lands of the United States 1980-2000," prepared for the Public Land Law Review Commission, Washington, D.C., May, 1968.

[l] "The Outlook for Key Commodities," *Report of the President's Materials Policy Commission, vol. II,* Government Priniting Office, June, 1952.

[m] Teitelbaum, P. D., "Nuclear Energy and the U.S. Fuel Economy, 1955-1980," National Planning Association, Washington, D. C., 1958.

[n] Lamb, G. A., in hearings before the Subcommittee on Automation and Energy Resources of the Joint Economic Committee, 86th Congress, 1st Session, October 12-16, 1959, pp. 215-225.

[o] Sporn, Philip, direct communication to authors of "Report of the National Fuels and Energy Study Group," *op. cit.*, cited, p. 36.

[p] Edison Electric Institute, "Water Resources Activities of the United States," *Report of the Select Committee on National Water Resources*, U.S. Senate, Committee Print No. 10, 1960.

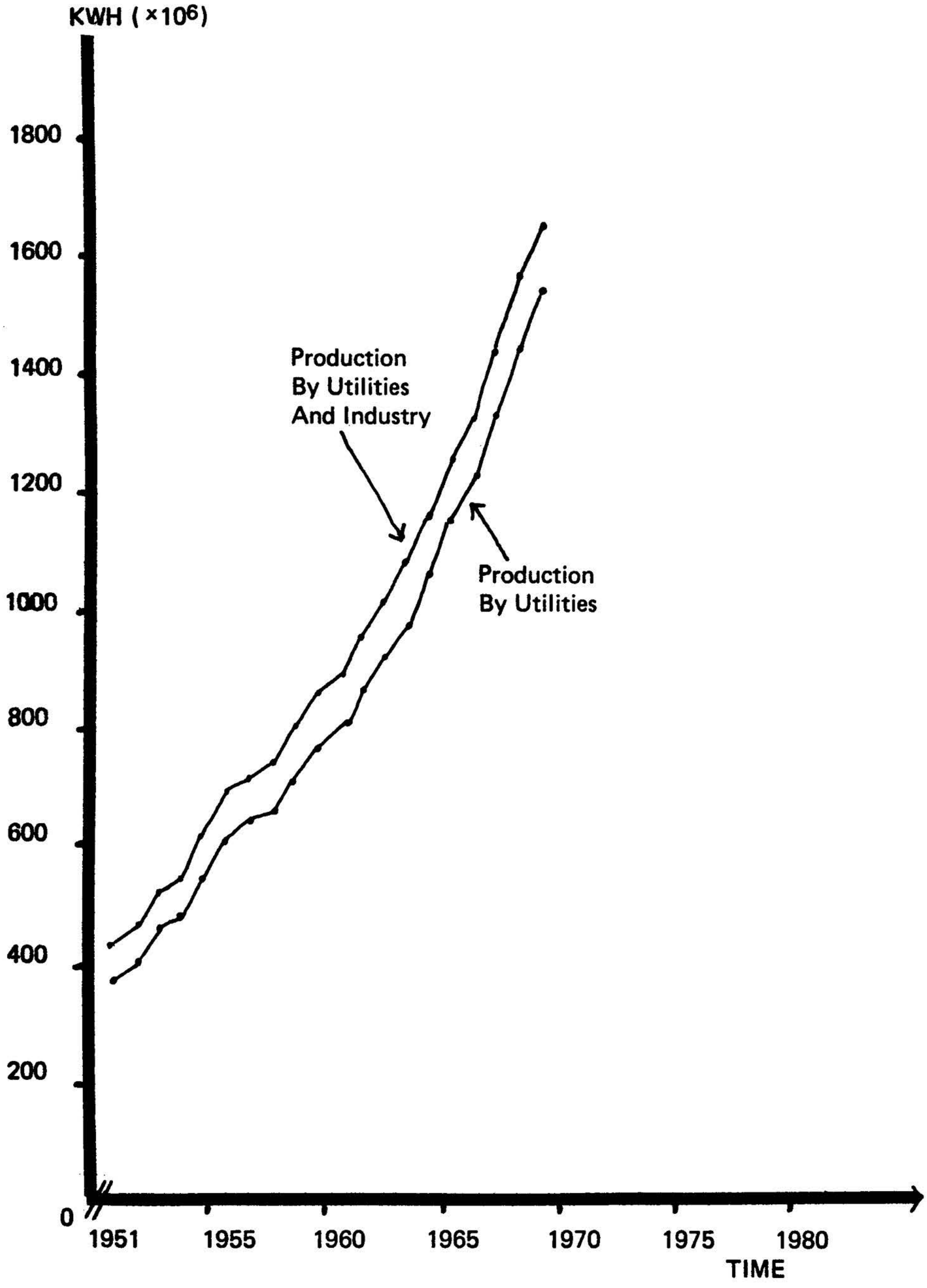
[q] Federal Power Commission, letter of November 28, 1961, to authors of "Report of the National Fuels and Energy Study Group," *op. cit.*, cited, p. 36.

[r] *Electrical World*, 4th Annual Survey, 1962.

[s] *The 1964 National Power Survey*, Federal Power Commission, U.S. Government Printing Office, 1964.

FIGURE II-1

HISTORICAL PRODUCTION OF ELECTRICITY; 48 CONTIGUOUS STATES (EXCLUDING IMPORTS)



tricity consumption using the least-squares criterion, a curve-fitting prediction of the growth of consumption (and hence, demand) can be found. All assumptions are implicitly static in such a model; the result is only a function of the data base.

   c. *Causal Analysis*: Causal analysis assumes that an array of factors causes demand to change over time. It thus reduces demand to its components, and predicts the value of the components individually, using any appropriate method. The summed and weighted changes over time, plus a constant, give total demand. The weights are determined by the statistical relationships between historical consumption (the dependent variable) and the demand components (independent variables).

2. *Assumptions*: Judgment and data analysis, as noted, assume that the causal factors of demand will change at the same rates in the future as they have in the past. Such an assumption is tantamount to saying that no parameters will change with respect to each other. On the other hand, causal analysis requires explicit assumptions as to the change over time of the independent variables. In predicting the demand for electricity, six categories of such assumptions were used in the studies citied in Table II-1:
   a. *Gross National Product* (GNP) growth: Most studies assume the GNP will increase at the rate of 4 percent per year, but the growth rates in those studies examined ranged from 3 to 5.1 percent per year (real growth).
   b. *Population* growth: Most studies accept the U.S. Census Bureau's projection of 1.6 percent per year, though the range is from 1.3 to almost 1.9 percent per year growth.
   c. *Relative pricing* of fuels: Most studies assume that prices will remain about the same, relatively. Yet by using judgment to predict reserves of various fuels, some studies project future shortages at present rates of consumption with the relative changes in prices that will result. Assumptions of the sizes of reserves add additional constraints to model builders and influence their results.
   d. *Technology*: Most projections, especially those not extending beyond 1975, assume no significant changes in technology. Others use varying assumptions of evolutionary and revolutionary technological changes in different cases. Evolutionary changes frequently concern efficiency rates, while revolutionary assumptions might include fusion or magnetohydrodynamics.
   e. *Business cycles*: All studies assume no long-term cyclical changes in economic activity.
   f. *National defense*: "Cold war" defense relationships are generally assumed, and little change in the budgetary proportion of defense spending from the 1960s is projected. Most of these studies were made before the Vietnam escalation. Some case approaches, however, vary this assumption significantly.
3. *Data Bases*: Contrary to what might be thought, definitions of the amount of electricity consumed historically vary widely. Some studies examine only electricity generated by utilities. Others expand this definition to include electricity generated by industry for its own consumption. Some include imports of electricity, while others do not. Even the estimates of the amount of imported electricity vary, and some studies differ in the conversion factor between KWH and British thermal units (BTU).

Comparison of Studies

Five predictions of the demand for electricity were closely examined. Their methodologies, assumptions, and data bases are compared below; their results are plotted in Figure II-8.

National Fuels and Energy Study Group. The judgment method is used in this study. Citing seven previous estimates, this study eliminates the most extreme of the seven and accepts an approximation of the central tendency of the remaining five, as shown in Figure II-2. The authors do not identify the two extreme values, however; one extreme value is obvious (Paley), but if the study next farthest from the reported value is eliminated (Schurr and Netschert), then the reported value is lower than any measure of central tendency. If the FPC estimate is eliminated instead, the reported value becomes more in line with the five studies being compared, but the FPC projection is less extreme, relatively, than that of Schurr and Netschert.

As noted above, the judgment method assumes the validity of the assumptions of the studies from which it is derived. The specific methodologies, assumptions, and data bases of the seven studies cited by this group are not determinable, however. (National Fuels and Energy Study Group, 1962)

U.S. Bureau of Mines. This report uses causal analysis, relating "projected trends of a number of relevant determining variables" to the historical consumption of electricity produced by utilities, excluding imports, from a base year of 1965 (see Figure II-3). Many of the "relevant determining variables," or components of demand, are reasonably straightforward, *e.g.*, economic activity levels, population, industrial production; and the assumptions concerning changes in these variables are not radical. Others are somewhat less quantifiable, *e.g.*, environmental restrictions, political energy-policy considerations and trade-offs. Energy demand is also divided into fuel-source demand-

FIGURE II-2

NATIONAL FUELS AND ENERGY STUDY GROUP

ESTIMATE OF (TOTAL) DEMAND FOR ELECTRICITY

(BASE YEAR, 1960)

ALSO SHOWN ARE METHODOLOGICAL COMPARISON STUDIES

AVG. ANNUAL PERCENT INCREASE= 11.0

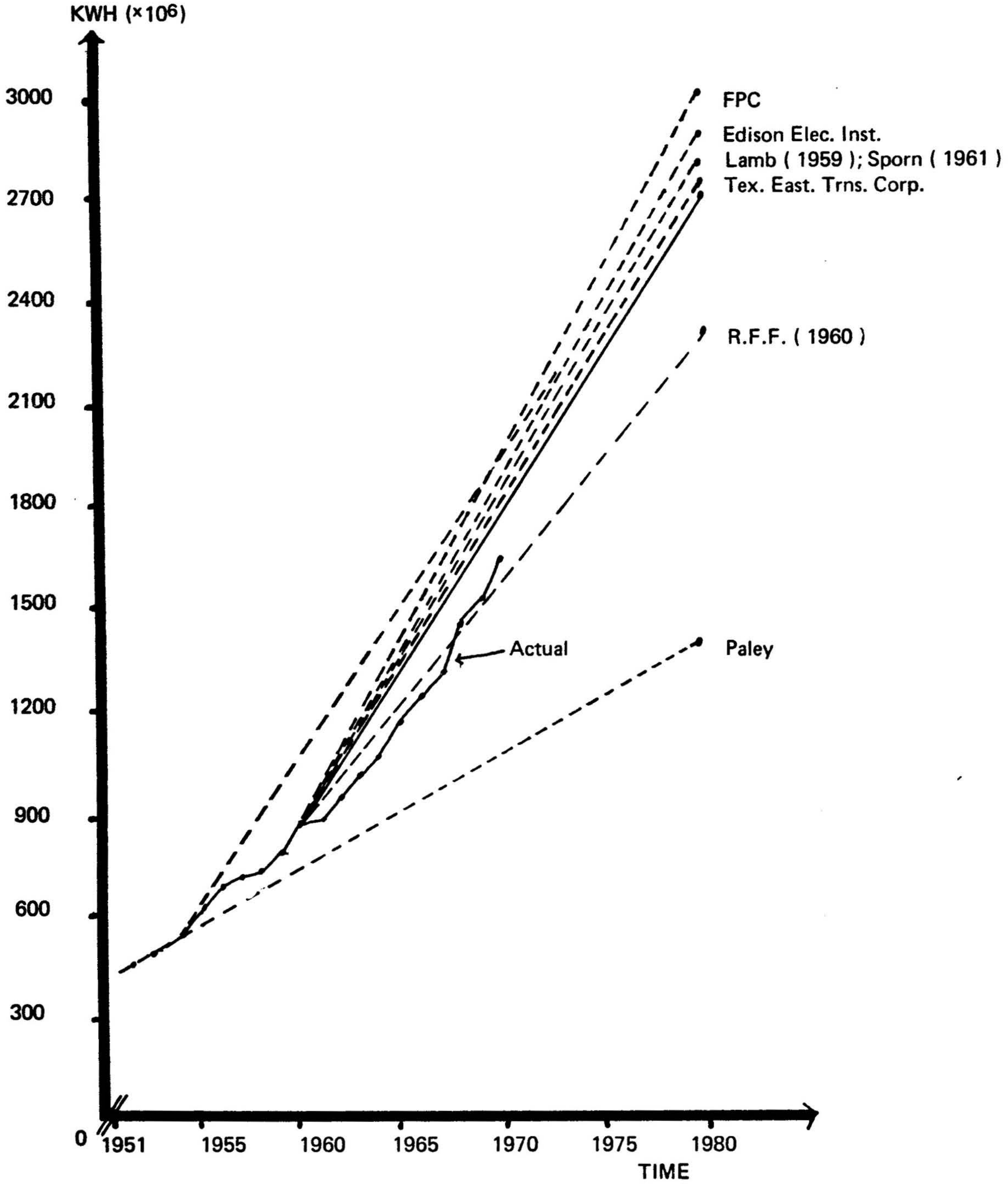
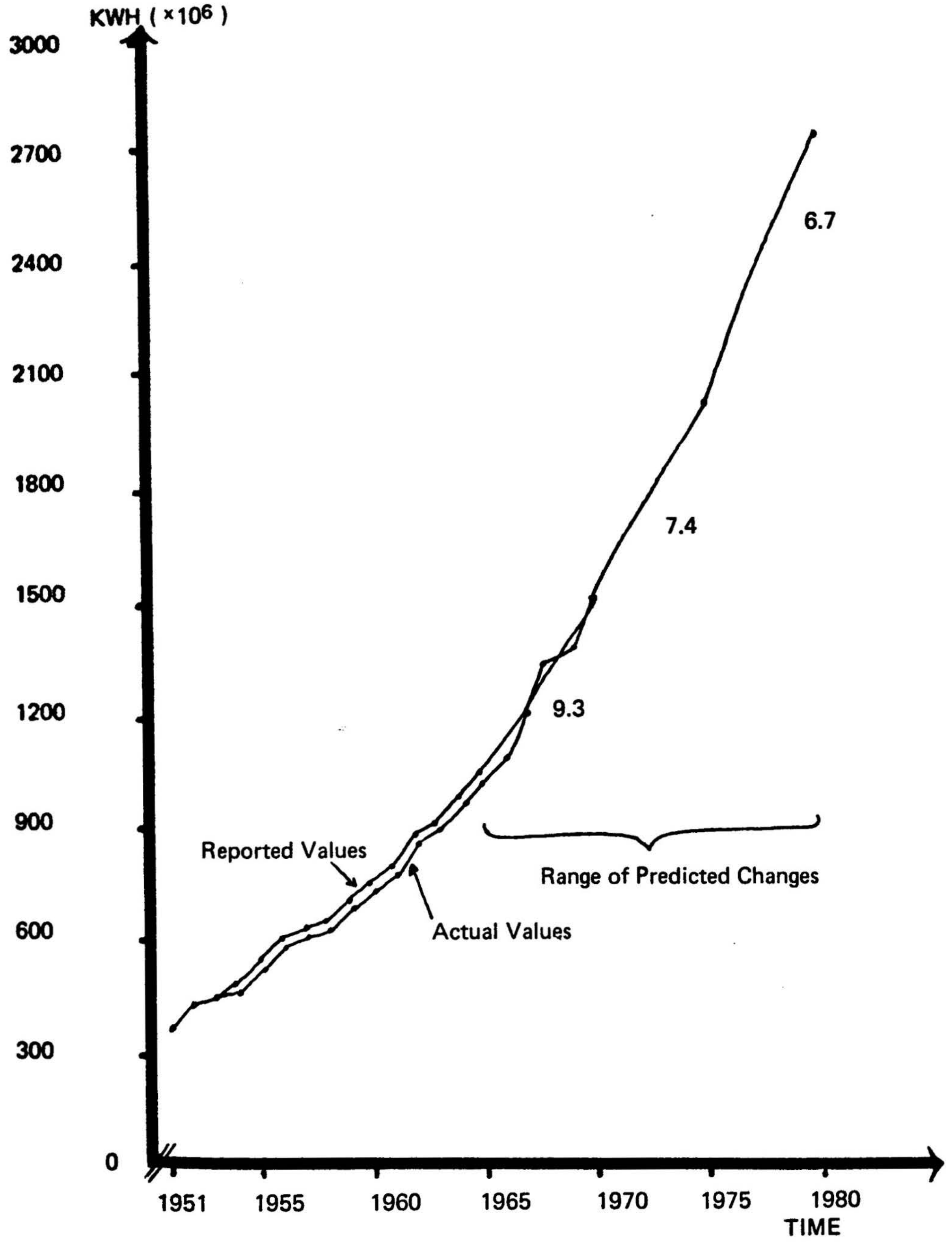


FIGURE II-3

U. S. BUREAU OF MINES ESTIMATE OF DEMAND FOR (UTILITY) ELECTRICITY
(BASE YEAR, 1965)
DIFFERENCE IN ACTUAL *V.* REPORTED VALUES
DUE TO B.T.U. TO KWH CONVERSION FACTOR
NUMBERS REPRESENT AVG. ANNUAL PERCENT INCREASE



components, market demand-sectors, and fuel-consumption demand-determinants. Thus, by splitting demand into various parts, the Bureau of Mines is able to provide cross-checks on its results. (Bureau of Mines, 1968)

Schurr & Netschert. This study identifies major sectors of consumer demand and extrapolates changes in the demand sectors, as shown in Figure II-4. By proportionately summing these demands, total energy consumption is predicted. Growth assumptions are generally conservative, especially with respect to technology, but this is due primarily to the short scope of the study. Two projections of demand are reported, one for utility production and one for total electricity production. (Schurr & Netschert, 1960)

Landsberg. This study also uses causal analysis, extrapolating past trends of the independent variables which determine energy demand, e.g., population, GNP, size of the labor force. Varying assumptions of the future state of technology are made, and different cases are reported as being associated with different predictions about technology. Again, two projections are reported for two data bases; these are illustrated in Figures II-5 and II-6. (Landsberg, Fischman, Fisher, 1963)

1970 National Power Survey. In this study, the Federal Power Commission groups the 48 contiguous states into regions and uses causal analysis to project electricity demand in each region (Figure II-7). By summing these regional projections vertically, a national projection of demand is determined.

Considerable attention is given to the residential sector, and for this, a total of eight predictions is found. The study uses two formulae, two GNP growth assumptions, and two ratios of the price of electricity to the price of gas in projecting residential demand. The projections are generally higher when the number (and size) of households is used in place of population as a parameter (the second formula). (Federal Power Commission, 1970)

Summary

To this point we have reviewed a number of attempts to project electricity demand. In the short run, the projections closely approximate each other. However, after 1980 they start to vary widely. Differences in projections are attributable to differences in methodologies, assumptions, and data bases. Thus, for short-term (5 to 10 year) planning, any of these studies could be used.

For long-range planning, however, it is necessary to question the methodology and assumptions of each study. Perhaps projections based on judgment or historical data analysis alone may not suffice, and additional analysis may be required to identify factors that influence electricity demand, both nationally and regionally.

ANALYSIS OF NATIONAL ELECTRICITY PRODUCTION

Time-Series Analysis

Our interest in the analysis of national electrical energy production is not to project it as such, but rather to identify those factors closely associated with it. "Closely associated" does not imply a causal analysis. The causes underlying electrical energy consumption, especially residential consumption, include many social and behavioral factors that are difficult to identify. Moreover, we define "closely associated" factors as those aspects of society that have varied over time in a functional relationship with electricity production. We do not need to know why the relationship holds true, only that changes in one factor are accompanied by changes in another.

The first step in developing such an analysis was to identify as many items as possible that *might* be associated with electricity production, limiting the list only by the availability of data. These items were selected: population, families and unrelated individuals, industrial employment, service employment, total employment, personal consumption, durable goods, residential investment, total service GNP, total goods GNP, and total GNP.

The time period 1950-1970 was chosen as being workable in terms of data collection and long enough to be representative of any trends that might exist.

Moreover, we were forced to deal with the 48 contiguous states due to the recent statehood of Alaska and Hawaii and the subsequent discontinuity in the historical records. The figures for employment were originally listed under more specific headings, and for this reason it was necessary to group mining, construction, and manufacturing under the category "industrial employment". A similar grouping was made for "service employment", including services, finance, real estate, wholesale and retail trade, transportation, and similar classifications.

The last task was to gather figures on electric-power production, and this added unexpected complications. First, production figures do not take into account imports and exports of electricity, which are apparently commonplace along the Canadian border. However, the only figures available for imports and exports were estimates, and there was such disparity among them that it seemed most advantageous to work without them. Another consideration was the distinction between utility and industrial or private production of electricity. Since private generation of electricty may be the result of such factors as historical accident, local efficiency or reliability, or simply the absence of a local utility, the distinction seemed to be purely artificial, and hence the figures chosen were the sum

FIGURE II-4

SCHURR & NETSCHERT ESTIMATES OF DEMAND FOR ELECTRICITY
(BASE YEAR, 1955)
NUMBERS REPRESENT AVG. ANNUAL PERCENT INCREASE

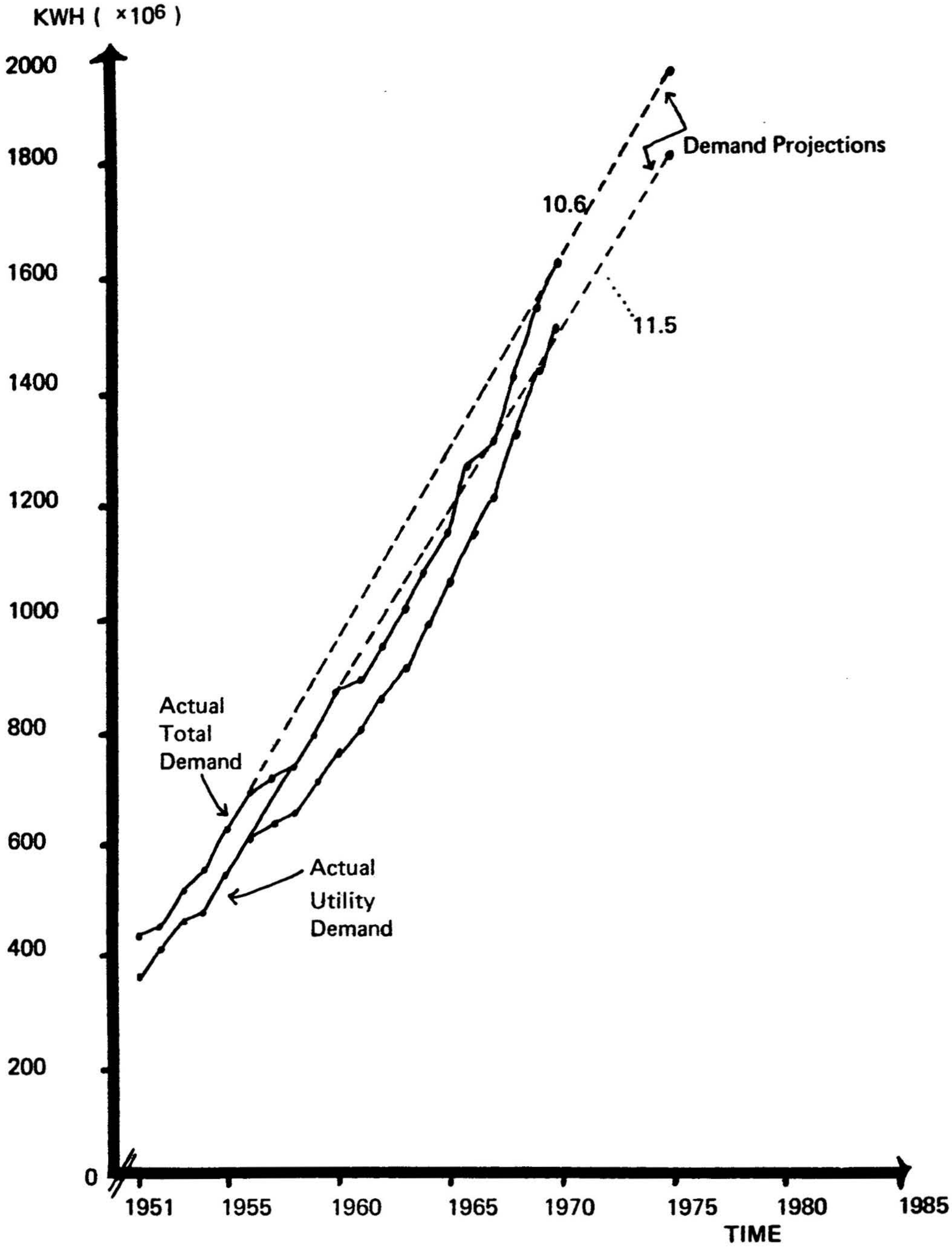


FIGURE II-5

LANDSBERG ESTIMATES OF (TOTAL) DEMAND FOR ELECTRICITY
(BASE YEAR, 1960 - INCLUDES IMPORTS)
DIFFERENT ESTIMATES REPRESENT DIFFERENT ASSUMPTION SETS
NUMBERS REPRESENT AVG. ANNUAL PERCENT INCREASE

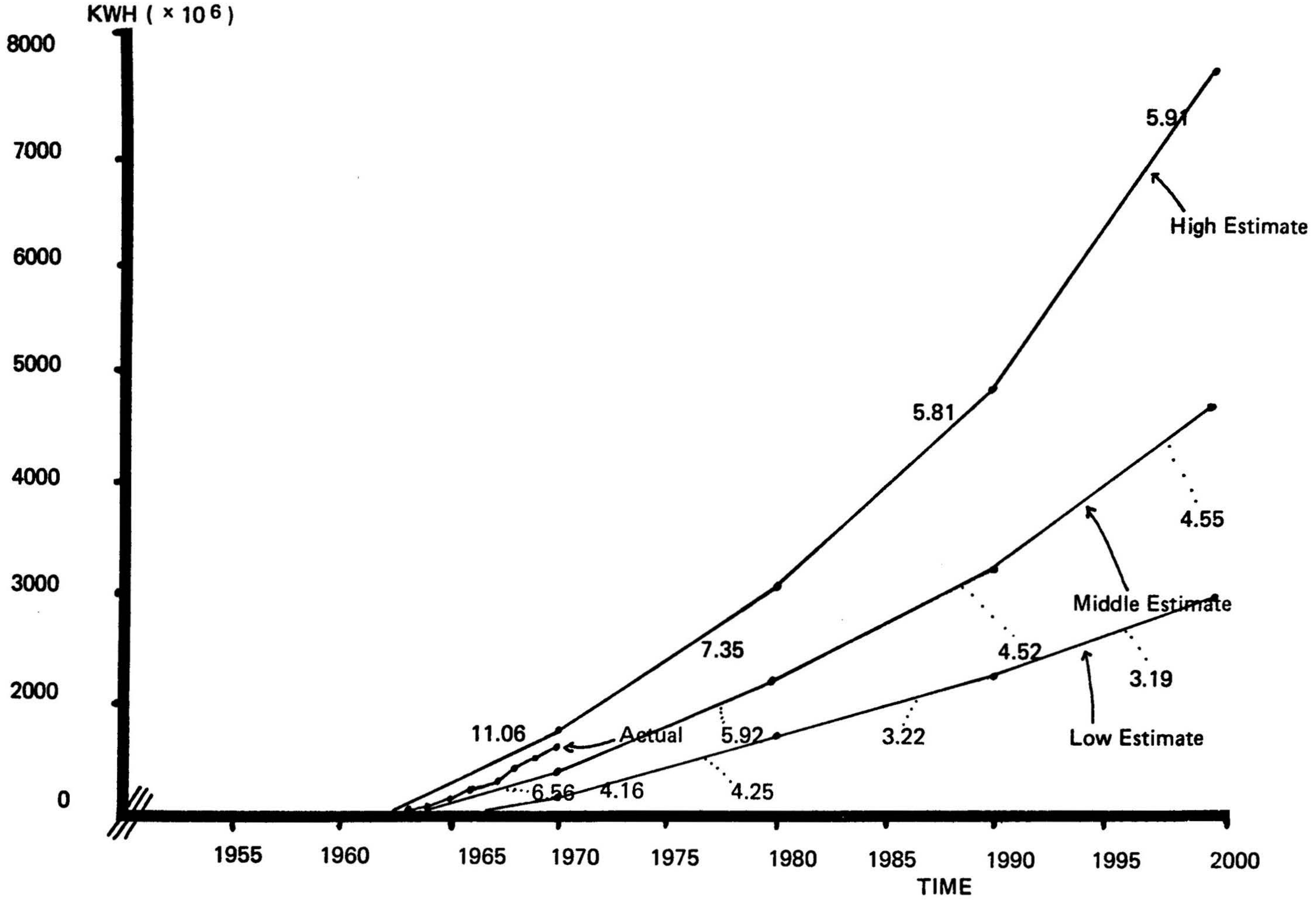


FIGURE II-6

LANDSBERG ESTIMATES OF DEMAND FOR (UTILITY) ELECTRICITY
(BASE YEAR, 1960)
DIFFERENT ESTIMATES REPRESENT DIFFERENT ASSUMPTION SETS
NUMBERS REPRESENT AVG. PERCENT INCREASE

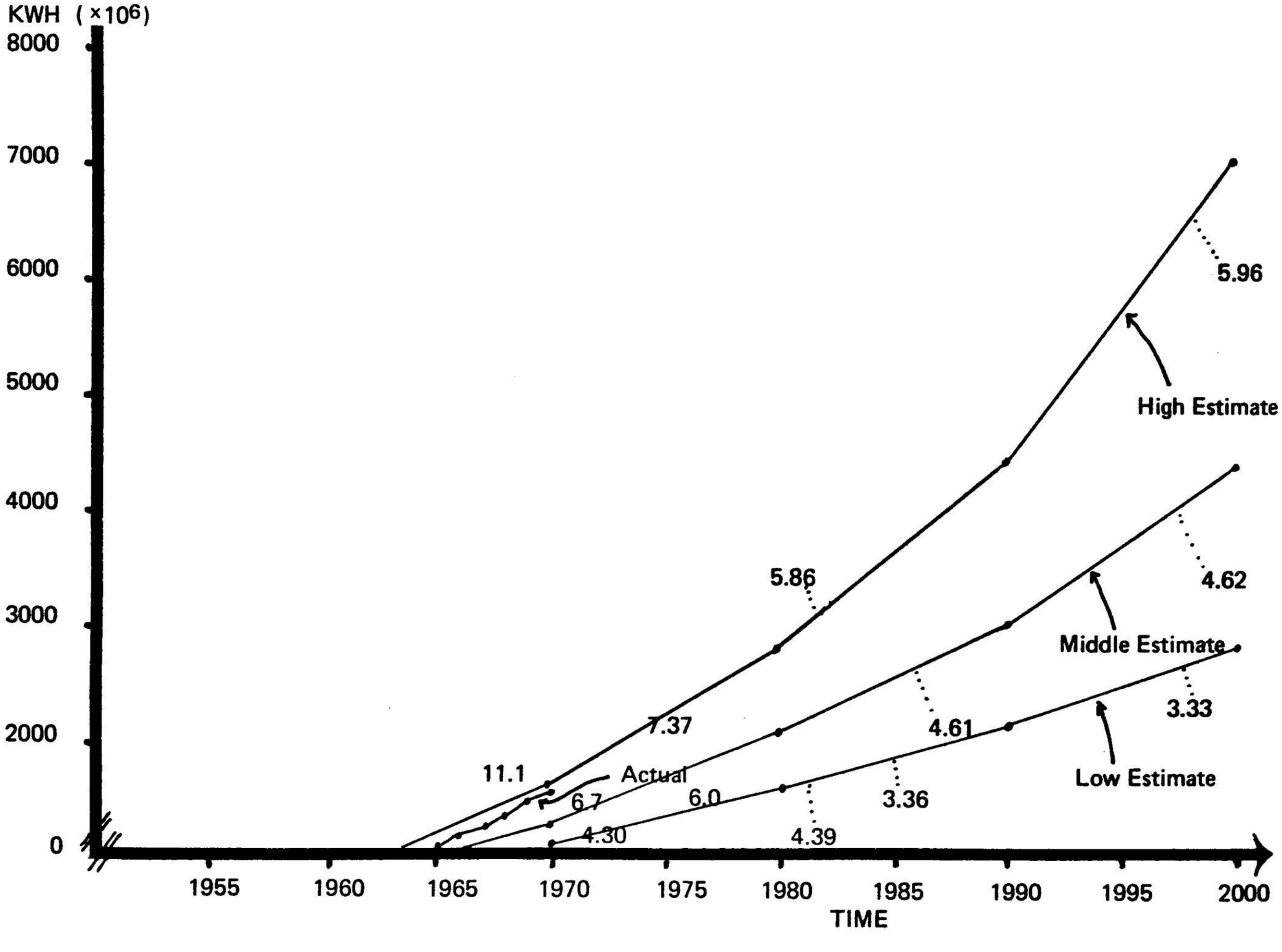


FIGURE II-7

1970 NATIONAL POWER SURVEY

ESTIMATES OF DEMAND FOR ELECTRICITY
(BASE YEAR, 1965)
NUMBERS REPRESENT AVG. ANNUAL PERCENT INCREASE

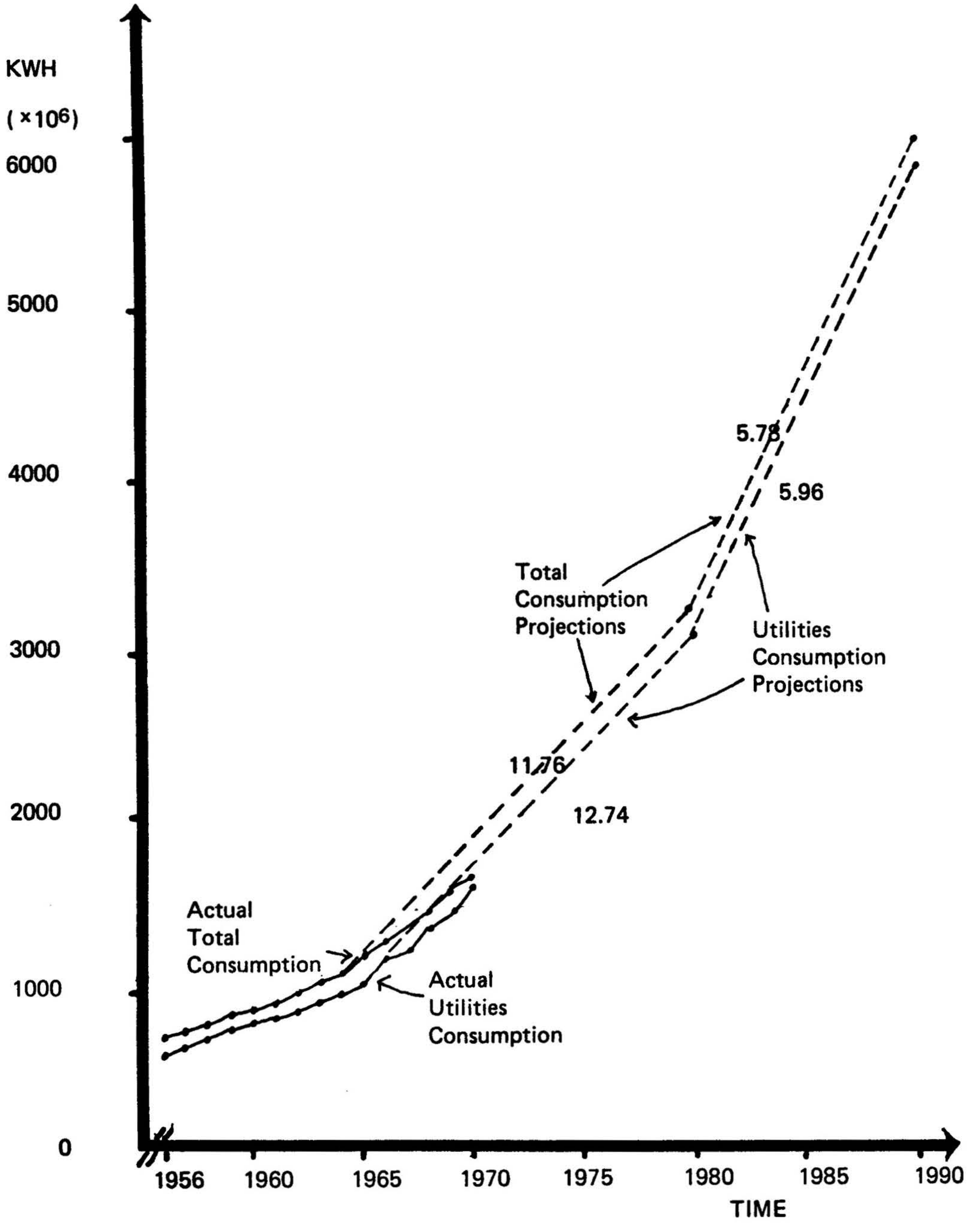
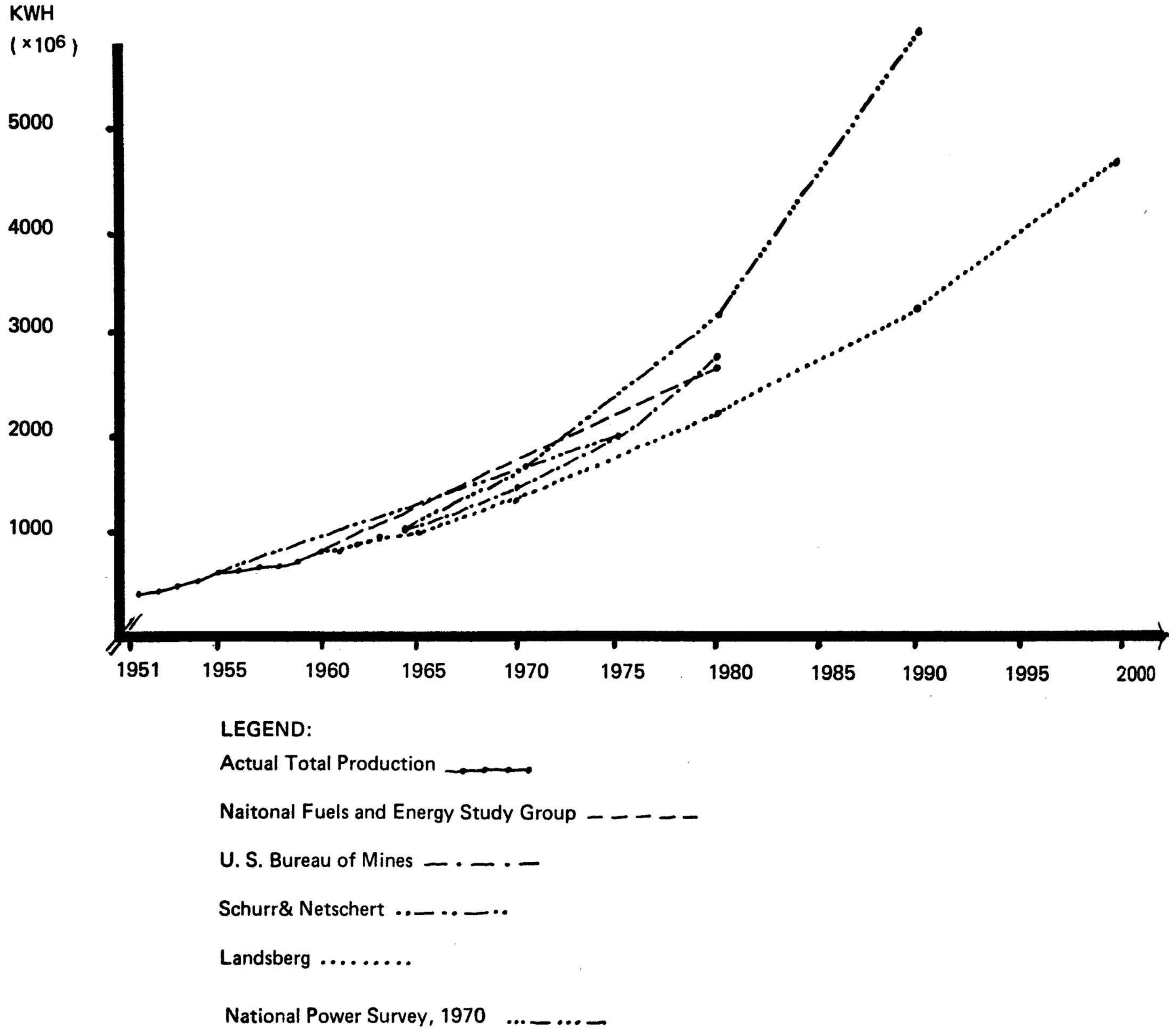


FIGURE II-8

COMPARISON OF FIVE PREDICTIONS OF DEMAND FOR ELECTRICITY



of both utility and industrial generation.

A multiple linear-correlation analysis was used, and from a series of relevant variables the equation was reduced to one having the three primary variables noted below (see Appendix A):

$$X_1 = -1.78\text{x}10^9 + 26452\ X_3 + 22029\ X_5 + 1213456\ X_7$$

or, $X_1 = .3807\ X_3 + .3578\ X_5 + .2636\ X_7$ (normalized)

where X_1 is electricity production (thousands of KWH);
X_3 is families and unrelated individuals (thousands);
X_5 is service employment (thousands);
X_7 is personal consumption (billions of dollars).

Simply stated, the normalized equation shows the relative effect that each variable has on electricity production. It can be seen that each of the three variables is approximately of equal importance, with each accounting for about one-third of the result. The multiple correlation value for this equation is .9996, which means that the straight-line analysis almost perfectly describes the actual historical trends, and hence there is no need to attempt to fit a different curve.

This equation can be used to predict future electricity production for the nation by substituting projected values for the three independent variables (families, service employment, and personal consumption). The assumption is that the relationship will hold true for the future as they have for the past 20 years. Of course, the accuracy of the prediction will only be as good as the accuracy of the projections for the independent variables.

This analytical model could be employed to forecast national electric-power production. However, a more important aspect of the analysis is the identification of three factors closely associated with national production.* Comparing these factors with factors associated with regional electric-power production may help explain whether national growth is necessarily related to the same factors as regional growth.

Regional Analysis

Once a set of factors was determined that could be associated with national electricity production over time, an effort was made to see whether individual factors might also be associated in a geographical sense. In other words, if the nation were broken into smaller regions, such as states, would the same factors apply to each of the regions separately?

An attempt was made to gather data for each of the 48 contiguous states for as many of the previous factors as possible. Since state figures analogous to GNP were not available because imports and exports for each state are too cumbersome to compute, value added by manufacture was substituted as the best approximation. In addition, the number of households was selected as a close approximation for families and unrelated individuals, which was not broken down by state (actual difference for 1968: 6 percent). The most recent year for which data were readily available was 1969, and using this as the base year we compiled state figures for population, households, industrial employment, service employment, total employment, personal income, value added by manufacture, and total electricity production by utilities and industry. Maps II-1 and II-2 illustrate electric-power production levels in the various states.

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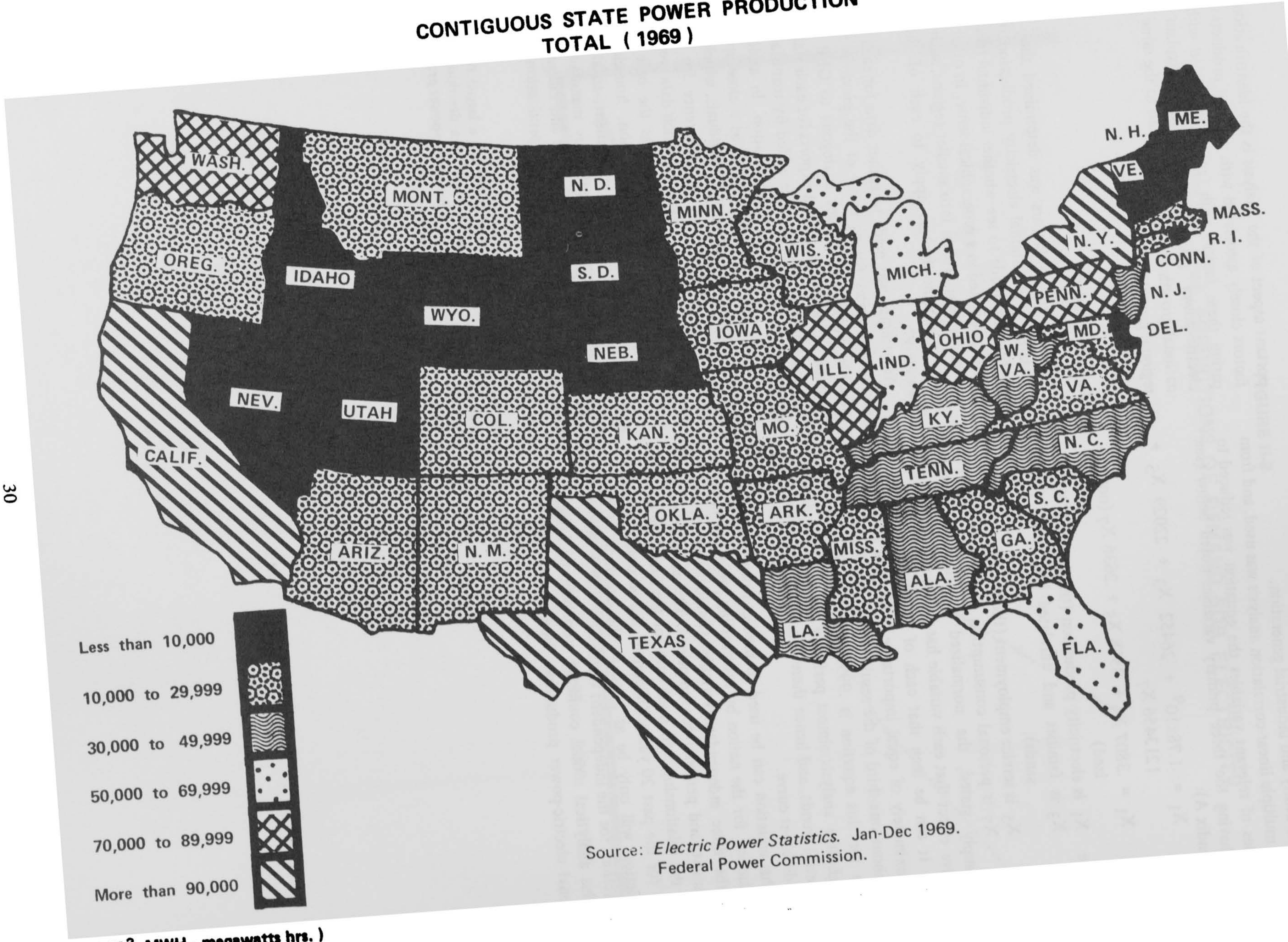
*On the assumption that past production is a lagged function of consumption, this analysis can be seen as a description of the relevant components of the demand for electric-power production.

MAP II-1

CONTIGUOUS STATE POWER PRODUCTION TOTAL (1969)

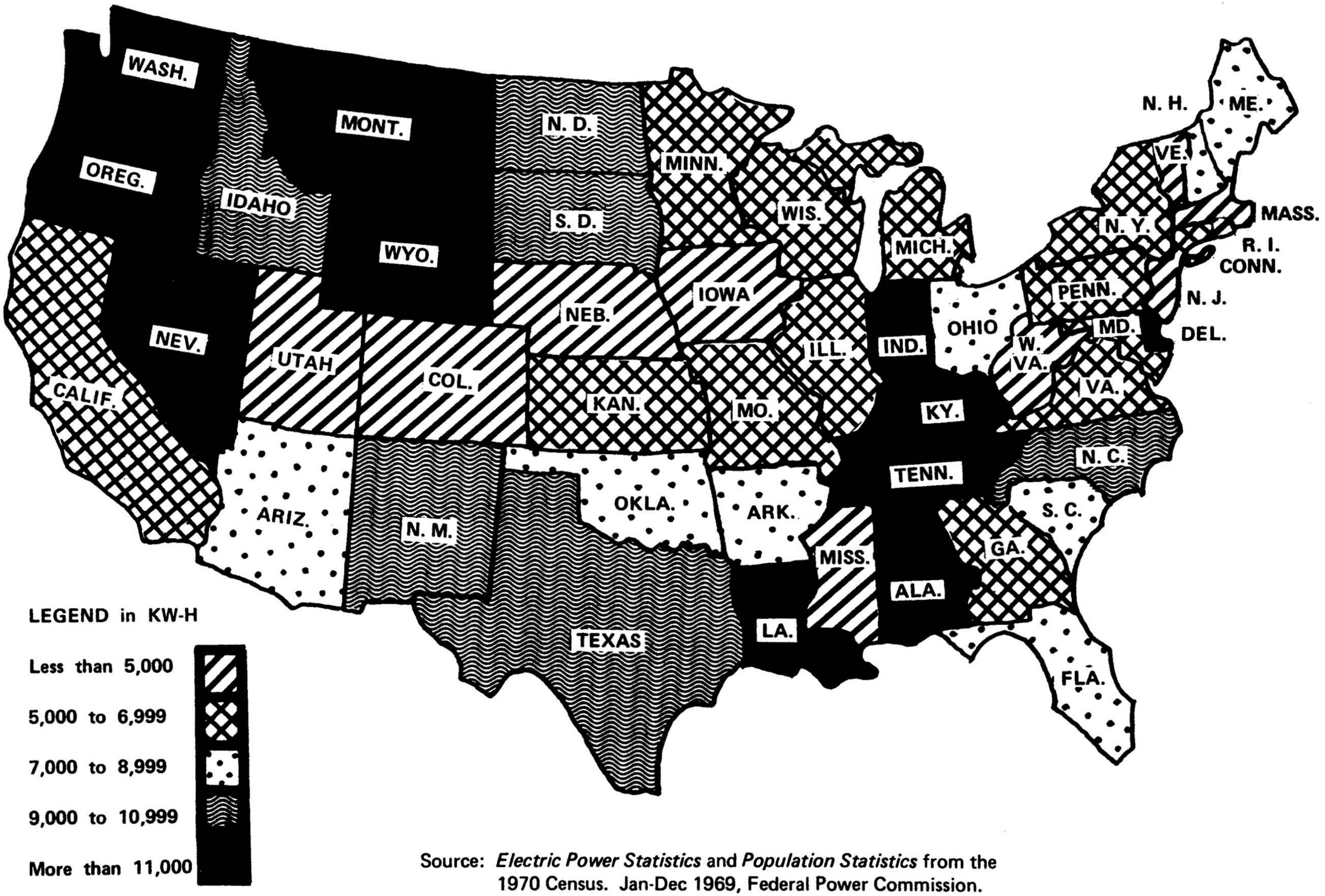


Source: *Electric Power Statistics.* Jan-Dec 1969. Federal Power Commission.

(10^3 MWH-- megawatts hrs.)

MAP II-2

CONTIGUOUS STATE POWER PRODUCTION
PER CAPITA (1969)



Source: *Electric Power Statistics* and *Population Statistics* from the 1970 Census. Jan-Dec 1969, Federal Power Commission.

Again, using a multiple linear-correlation analysis, we arrived at the following equation for state electrical energy production (see Appendix A):

$$X_1 = 5.56 \times 10^6 + 19182\ X_3 + 136\ X_8$$

or, $X_1 = .8550\ X_3 + .0346\ X_8$ (normalized)

where X_1 is electricity production (thousands of KWH);

X_3 is households (thousands);

X_8 is value added by manufacture (millions of dollars).

The multiple correlation value for this equation was .8877 (compared to .9996 for the time series) which, when the residuals are mapped, suggests that the relationships are not linear. In addition, the number of households accounts for about 85 percent of the result, while value added by manufacture only accounts for about 3 percent. The remaining 11 percent or so cannot be accounted for by a linear combination of the variables selected.

This analysis, in addition to providing a descriptive model, has demonstrated that the factors associated with national electricity demand are not the same as those associated with regional electricity demand. This implies that the national energy crisis may not necessarily be shared by all regions; some states may not experience the crisis, whereas others may be severely affected. Since the national rate of growth of electricity demand cannot be used for a particular state it is thus necessary to forecast electricity demand specifically for Texas.

ELECTRICITY-DEMAND PROJECTIONS FOR TEXAS

Electricity continues to be a relatively inexpensive and readily available commodity. Since World War II the cost of electricity has declined relative to overall price indices. This relative stability in electricity prices and the general "double-every-ten years" trend of electricity demand have resulted in many projections based on the assumption that price can be considered to be independent of demand. Most of these projections (*e.g.*, FPC demand estimates) are based, at least implicitly, on extrapolations of previous trends in overall economic and population growth, not on any detailed model based on changes in these and other variables that affect the demand for electric power. Needless to say, these estimates are likely to be accurate only to the extent that these trends continue essentially unchanged into the future.

General observations reveal, however, that population and economic trends are changing. In 1974, for example, average electricity prices increased relative to overall price indices. Many analysts believe the factors influencing the demand for electricity are themselves departing from long established patterns; they believe that higher electricity prices will slow the growth in the use of electricity. A two-year study of the demand for electricity by Chapman, Mount, and Tyrrell evaluated the relations between variables that might influence the growth of demand for electricity, region by region, for each class of consumer-residential, commercial, and industrial. (Chapman, *et al.*, 1972) This study suggested that the most important determinant of growth in electricity use for all types of consumers is the price of electricity, followed by population growth, personal income, and the price of natural gas.

It was decided to use the Chapman model to estimate demand for electricity in Texas for the next 20 years. The causal factors taken into account included: the quantity of electricity consumed in the previous time-period, the price of electricity, the price of natural gas, per capita income, and population. The economic concept of elasticity was used to describe the magnitude of the causal factors. Independent estimates of Texas population, income, prices, and elasticities were utilized, with additional projections developed for alternative assumptions of population, electricity, and natural gas prices (Appendix B.).

Table II-2 provides an overall picture of the structure of the demand estimates as well as the sources used as the basis for the projections. Tables II-3 and II-4 summarize the demand data in both GKWH and index values.

Appendix B describes the methodology as well as the values and the units of all the variables and elasticities.

The analysis and forecasts indicate that if the prices increase over the next decades, the demand for electricity is not likely to increase as much as it did in the past. Indeed, the growth rate of total electricity demand for the nation from 1970 to 1971 was below the 7.2 percent annual increase on which the "double-every-ten-years" demand projection by the FPC is based. A significant fraction of this growth reduction is probably caused by changes in the causal variables discussed above. It is obvious from this analysis that the "high" or "low" projections of population do not make a significant difference in the projected demand of electricity in Texas over the next 20 years. Thus a fertility-rate increase or decrease would not significantly affect demand. Price variations, on the other hand, appear to be a crucial factor in determining future demand for electricity in Texas.

A constant price of electricity (in current dollars) will result in a 13 times greater demand for electricity in the next 20 years. However, the FPC price estimates will result in a 1990 demand 8 times the 1970 demand, while "double-by-2000" price estimates will make the 1990 demand only 2.2 times by the 1970 level. The possible doubling of the price of electricity may be caused by fuel scarcities, the rising cost of power plants, pressure to incorporate the social and environmental costs of electricity

Table II-2

TEXAS ELECTRICITY-DEMAND ESTIMATES

(trillions of KWH)

Case	Asumptions Concerning			Electricity Demand in				
	Population (1)	Electricity Price	Natural Gas Price	1970	1975	1980	1985	1990
				(trillions of KWH)				
A1	High	Constant[2]	Constant[5]	96.135	167.417	309.837	613.701	1,341.479
A2			Med. Increase[4]	”	”	309.775	680.942	1,633.274
A3			Large ”[4]	”	”	343.717	794.080	2,149.542
B1	High	Federal	Constant[5]	96.135	158.180	263.479	450.428	818.734
B2		Power	Med. Increase[4]	”	”	263.478	499.780	996.837
B3		Commission[3]	Large ”[4]	”	”	292.347	582.823	1,311.975
C1	High	Double	Constant[5]	96.135	134.455	169.212	200.556	236.885
C2		by	Med. Increase[4]	”	”	169.211	222.531	288.426
C3		2000	Large ”[4]	”	”	187.752	259.513	379.643
D1	Low	Constant[2]	Constant[5]	96.135	165.435	296.239	563.278	1,162.939
D2	”	”	Med. Increase[4]	”	”	296.242	624.995	1,415.905
D3	”	”	Large ”[4]	”	”	328.701	728.839	1,863.487
E1	Low	Federal	Constant[5]	96.135	156.308	251.925	413.473	409.983
E2	”	Power	Med. Increase[4]	”	”	161.808	204.343	250.315
E3	”	Commission[3]	Large ”[4]	”	”	179.537	238.303	329.482
F1	Low	Double[4]	Constant[5]	96.135	132.865	161.808	184.165	205.583
F2	”	by	Med. Increase[4]	”	”	161.808	204.343	250.315
F3	”	2000	Large ”[4]	”	”	179.537	238.303	329.482

*Electricity sales to ultimate consumers

(1) Population Research Center, The University of Texas at Austin (refer to Appendix B)

(2) The 1970 price of electricity is maintained up to 1990

(3) Federal Power Commission estimates (refer to Appendix B)

(4) Lyndon B. Johnson School of Public Affairs, The University of Texas at Austin, 1975 (refer to Appendix A)

(5) National Petroleum Council

TABLE II-3

Texas Electricity-Demand Projections (in GKWH)

A – High Population Projection and Constant Electricity Price Assumption

	Consumer	1970	1975	1980	1985	1990
Gas Price:	Residential	32.8353	58.5071	107.4184	203.0046	391.4742
1) Constant	Commerical	20.2349	33.3748	60.9457	123.9864	292.5255
Increase	Industrial	40.7672	71.5339	134.0066	272.0405	625.4118
	Total	96.1353	167.4180	309.8371	613.7017	1,341.4790
Gas Price:	Residential	32.8353	58.5071	107.4184	225.2477	476.9753
2) Medium	Commerical	20.2349	33.3748	60.9457	137.5715	356.0449
Increase	Industrial	40.7672	71.5339	134.0066	301.8474	761.2146
	Total	96.1353	167.4180	309.7749	680.9424	1,633.2737
Gas Price:	Residential	32.8353	58.5071	119.1882	262.8528	628.8315
3) Large	Commercial	20.2349	33.3748	67.6235	160.3722	468.2424
Increase	Industrial	40.7672	71.5339	148.6896	351.8750	1,001.0898
	Total	96.1353	167.4180	343.7168	794.0801	2,149.5425

B – High Population Projection and FPC Electricity Price Assumption

	Consumer	1970	1975	1980	1985	1990
Gas Price:	Residential	32.8353	55.5613	92.6552	153.0797	249.7624
1) Constant	Commercial	20.2349	31.4435	51.4179	89.7217	175.0812
	Industrial	40.7672	67.3944	113.1077	196.8597	374.3189
	Total	96.1353	158.1803	263.4792	450.4284	818.7340
Gas Price:	Residential	32.8353	55.5613	92.6552	169.8526	304.3125
2) Medium	Commercial	20.2349	31.4435	51.4179	99.5525	213.0987
Increase	Industrial	40.7672	67.3977	113.1077	218.4295	455.5991
	Total	96.1353	158.1803	263.4783	499.7803	996.3867
Gas Price:	Residential	32.8353	55.5613	102.8074	198.2095	401.1975
3) Large	Commercial	20.2349	31.4435	57.0517	116.0520	280.2505
Increase	Industrial	40.7672	67.3944	125.5009	254.6314	599.1682
	Total	96.1353	158.1803	292.3474	582.8232	1,311.9751

TABLE II-3 (continued)

C – High Population Projection and Double-by-2000 Electricity Price Assumption

	Consumer	1970	1975	1980	1985	1990
Gas Price:	Residential	32.8353	47.9182	61.8281	73.0192	80.4529
1) Constant	Commercial	20.2349	26.5076	32.2956	38.4278	48.0469
	Industrial	40.7672	56.8152	71.0430	84.3150	102.7230
	Total	96.1353	134.4551	169.2117	200.5562	236.8854
Gas Price:	Residential	32.8353	47.9182	61.8281	81.0199	98.0245
2) Medium	Commercial	20.2349	26.5076	32.2956	42.6383	58.4799
Increase	Industrial	40.7672	56.8152	71.0430	93.5533	125.0285
	Total	96.1353	134.4551	169.2112	222.5305	288.4265
Gas Price:	Residential	32.8353	47.9182	68.6026	94.5461	129.2329
3) Large	Commercial	20.2349	26.5076	35.8342	49.7051	76.9082
Increase	Industrial	40.7672	56.8152	78.8271	109.0586	164.4276
	Total	96.1353	134.4551	187.7516	259.5127	379.6428

D – Low Population Projection and Constant Electricity Price Assumption

	Consumer	1970	1975	1980	1985	1990
Gas Price:	Residential	32.8353	57.8881	103.1942	188.0253	344.7046
1) Constant	Commercial	20.2349	32.9827	58.2955	113.9265	254.3027
	Industrial	40.7672	70.6100	127.6679	247.8617	536.1323
	Total	96.1353	165.4354	296.2390	563.2783	1,162.9392
Gas Price:	Residential	32.8353	57.8881	103.1942	208.6271	419.9910
2) Medium	Commercial	20.2349	32.9827	58.2995	126.4094	309.5225
Increase	Industrial	40.7672	70.6100	127.6679	275.0198	652.5488
	Total	96.1353	165.4354	296.2422	624.9949	1,415.9053
Gas Price	Residential	32.8353	57.8881	114.5011	243.4574	553.7048
3) Large	Commercial	20.2349	32.9827	64.6873	147.3601	407.0596
Increase	Industrial	40.7672	70.6100	141.6564	320.6006	858.1812
	Total	96.1353	165.4354	328.7012	728.8386	1,863.4868

TABLE II-3 (continued)

E – Low Population Projection and FPC Electricity Price Assumption

	Consumer	1970	1975	1980	1985	1990
Gas Price: 1) Constant	Residential	32.8353	54.9734	89.0116	141.7843	219.9231
	Commercial	20.2349	31.0940	49.1820	82.4419	152.2042
	Industrial	40.7672	66.5239	107.7094	179.3629	320.8837
	Total	96.1353	156.3078	251.9251	413.4730	709.9829
Gas Price: 2) Medium Increase	Residential	32.8353	54.9734	59.3967	75.0415	86.3135
	Commercial	20.2349	31.0940	30.8913	39.1788	50.8386
	Industrial	40.7672	66.5239	67.6523	85.2383	107.1802
	Total	96.1353	156.3078	161.8078	204.3428	250.3153
Gas Price: 3) Large Increase	Residential	32.8353	54.9734	65.9048	87.5697	113.7934
	Commercial	20.2349	31.0940	34.2760	45.6721	66.8589
	Industrial	40.7672	66.5239	75.0649	99.3655	140.9550
	Total	96.1353	156.3078	179.5370	238.3033	329.4824

F – Low Population Projection and Double-by-2000 Electricity Price Assumption

	Consumer	1970	1975	1980	1985	1990
Gas Price: 1) Constant	Residential	32.8353	47.4112	59.3967	67.6312	70.8412
	Commercial	20.2349	26.1962	30.8913	35.3099	41.7688
	Industrial	40.7672	56.0813	67.6523	76.8211	88.0589
	Total	96.1353	132.8648	161.8083	184.1646	205.5833
Gas Price: 2) Medium Increase	Residential	32.8353	47.4112	59.3967	75.0415	86.3135
	Commercial	20.2349	26.1962	30.8913	39.1788	50.8386
	Industrial	40.7672	56.0813	67.6523	85.2383	107.1802
	Total	96.1353	132.8648	161.8078	204.3428	250.3153
Gas Price: 3) Large Increase	Residential	32.8353	47.4112	65.9048	87.5697	113.7934
	Commercial	20.2349	26.1962	34.2760	45.6721	66.8589
	Industrial	40.7672	56.0813	75.0649	99.3655	140.9550
	Total	96.1353	132.8648	179.5370	238.3033	329.4824

TABLE II-4

Index of Texas Electricity-Demand Projections

(Using 1970 = 1.000 as the base year.)

A – High Population Projection and Constant Electricity Price Assumption

	Consumer	1970	1975	1980	1985	1990
Gas Price:	Residential	1.000	1.782	3.271	6.183	11.922
1) Constant	Commercial	1.000	1.649	3.012	6.127	14.457
	Industrial	1.000	1.755	3.289	6.673	15.341
	Total	1.000	1.741	3.223	6.384	13.954
Gas Price:	Residential	1.000	1.782	3.271	11.132	11.700
2) Medium	Commercial	1.000	1.649	1.856	6.799	8.734
Increase	Industrial	1.000	1.755	4.081	14.917	18.672
	Total	1.000	1.741	3.222	7.083	16.989
Gas Price:	Residential	1.000	1.782	3.630	12.990	15.425
3) Large	Commercial	1.000	1.649	2.059	7.926	11.485
Increase	Industrial	1.000	1.755	4.528	17.390	24.556
	Total	1.000	1.741	3.575	8.260	22.359

B – High Population Projections and FPC Electricity Price Assumption

	Consumer	1970	1975	1980	1985	1990
Gas Price:	Residential	1.000	1.693	2.822	4.662	7.607
1) Constant	Commercial	1.000	1.554	2.541	4.434	8.652
	Industrial	1.000	1.653	2.774	4.829	9.182
	Total	1.000	1.645	2.741	4.685	8.516
Gas Price:	Residential	1.000	1.693	2.822	8.394	7.464
2) Medium	Commercial	1.000	1.554	1.566	4.920	5.227
Increase	Industrial	1.000	1.653	3.445	10.795	11.175
	Total	1.000	1.645	2.741	5.199	10.369
Gas Price:	Residential	1.000	1.693	3.131	9.795	9.841
3) Large	Commercial	1.000	1.554	1.738	5.735	6.874
Increase	Industrial	1.000	1.653	3.822	12.584	14.697
	Total	1.000	1.645	3.041	6.063	13.647

TABLE II-4 (continued)

C – High Population Projection and Double-by-2000 Electricity Price Assumption

	Consumer	1970	1975	1980	1985	1990
Gas Price:	Residential	1.000	1.459	1.883	2.224	2.450
1) Constant	Commercial	1.000	1.310	1.596	1.899	2.374
	Industrial	1.000	1.394	1.743	2.068	2.520
	Total	1.000	1.399	1.760	2.086	2.464
Gas Price:	Residential	1.000	1.459	1.883	4.004	2.404
2) Medium	Commercial	1.000	1.310	0.984	2.107	1.435
Increase	Industrial	1.000	1.394	2.164	4.623	3.067
	Total	1.000	1.399	1.760	2.315	3.000
Gas Price:	Residential	1.000	1.459	2.089	4.672	3.170
3) Large	Commercial	1.000	1.310	1.091	2.456	1.887
Increase	Industrial	1.000	1.394	2.401	5.390	4.033
	Total	1.000	1.399	1.953	2.699	3.949

D – Low Population Projection and Constant Electricity Price Assumption

	Consumer	1970	1975	1980	1985	1990
Gas Price:	Residential	1.000	1.763	3.143	5.726	10.498
1) Constant	Commercial	1.000	1.630	2.881	5.630	12.568
	Industrial	1.000	1.732	3.132	6.080	13.151
	Total	1.000	1.721	3.081	5.859	12.097
Gas Price:	Residential	1.000	1.763	3.143	10.310	10.302
2) Medium	Commercial	1.000	1.630	1.776	6.247	7.592
Increase	Industrial	1.000	1.732	3.888	13.591	16.006
	Total	1.000	1.721	3.082	6.501	14.728
Gas Price:	Residential	1.000	1.763	3.487	12.032	13.582
3) Large	Commercial	1.000	1.630	1.970	7.238	9.935
Increase	Industrial	1.000	1.732	4.314	15.844	21.050
	Total	1.000	1.721	3.419	7.581	19.384

TABLE II-4 (continued)

E – Low Population Projection and FPC Electricity Price Assumption

	Consumer	1970	1975	1980	1985	1990
Gas Price: 1) Constant	Residential	1.000	1.674	2.711	4.318	6.698
	Commercial	1.000	1.536	2.431	4.074	7.522
	Industrial	1.000	1.632	2.642	4.400	7.871
	Total	1.000	1.626	2.621	4.301	7.385
Gas Price: 2) Medium Increase	Residential	1.000	1.674	2.711	7.775	6.593
	Commercial	1.000	1.536	1.498	4.521	4.544
	Industrial	1.000	1.632	3.280	9.835	9.580
	Total	1.000	1.626	2.621	4.772	8.992
Gas Price: 3) Large Increase	Residential	1.000	1.674	3.008	9.073	8.665
	Commercial	1.000	1.536	1.662	5.270	5.976
	Industrial	1.000	1.632	3.6397	11.465	12.599
	Total	1.000	1.626	2.908	5.565	11.835

F – Low Population Projection and Double-by-2000 Electricity Price Assumption

	Consumer	1970	1975	1980	1985	1990
Gas Price: 1) Constant	Residential	1.000	1.444	1.809	2.060	2.157
	Commercial	1.000	1.295	1.527	1.745	2.064
	Industrial	1.000	1.376	1.659	1.884	2.160
	Total	1.000	1.382	1.683	1.916	2.138
Gas Price: 2) Medium Increase	Residential	1.000	1.444	1.809	3.709	2.117
	Commercial	1.000	1.295	0.941	1.936	1.247
	Industrial	1.000	1.376	2.060	4.212	2.629
	Total	1.000	1.382	1.683	2.126	2.604
Gas Price: 3) Large Increase	Residential	1.000	1.444	2.007	4.328	2.791
	Commercial	1.000	1.295	1.044	2.257	1.640
	Industrial	1.000	1.376	2.286	4.911	3.458
	Total	1.000	1.382	1.867	2.479	3.427

production in the rate structure, and rising prices in other segments of the economy. Such a doubling of price would definitely slow down the rate of growth of electric-power demand; in Texas, for example, the electric-power demand would rise from 96,135,342 KWH in 1970 to 236,885,411 KWH in 1990, even assuming constant gas prices. This is much less than the FPC has projected.

This analysis indicated that changes in the price of electricity are more important than population-trend variations in determining future electricity demand. Assuming that the elasticity rates are reasonable, electric-power planning in the next few decades is not likely to be significantly changed as a result of different population-growth assumptions.

For the next five years, all the projections are quite close to one another. Thus, for short-term planning, neither the price of electricity nor population trends will make a significant difference. For long-term planning, however, the price of electricity does appear to influence growth of electricity demand. Inflation, increasing environmental concern, fuel scarcity, and rising costs of plant construction and operating could be instrumental in increasing the price of electricity, consequently slowing the future growth in electrical energy usage.

CONSERVATION OF ENERGY

Another important factor that could slow the growth of electricity demand is energy conservation.

The term "conservation" implies the rationing of a resource. Resources can be rationed for a number of reasons, but the rationing process can be described by three distinct mechanisms. In the *economic* sense, all resources which are not free are rationed by their prices relative to substitutes. Thus the use of plastics in modern automobiles can be viewed as the rationing of steel and other metals by means of substitution. In the *political* sense, resources for which there are no substitutes available are rationed by regulation when the price mechanism will not adequately meet some arbitrary criteria for distribution. The most obvious example here would be the rationing of gasoline, rubber, and leather during a time of war. From a *biological* and *environmental* perspective, externalities or perceived side-effects associated with the use of a resource are rationed on the basis of the capacity of the human and biological environment to absorb them with little or no damage, leading to a rationing of the resource itself. Common examples in this category would be exposure to drugs, X-rays, or pollution of the air and water. Thus our patterns for use of various resources, and subsequently our attitudes toward using them, are determined by three forces:

- economic cost,
- political regulation, and
- voluntary restraint based on fear of externalities.

It is easy to trace the evolution of American attitudes toward the consumption of energy resources in these terms. First, energy in America has always been relatively inexpensive. U.S. gasoline prices are about one-half the European equivalent, and the average household electric bill has represented only a small fraction of total family expenditures. Second, public policy has traditionally stayed away from coercive rationing of energy resources, except in times of national emergency. In fact, President Nixon, in his 1970 energy message to Congress, urged the adoption of an energy policy that would provide all the cheap, clean energy that Americans demanded. Third, only within the last few years has there been serious concern with the environmental and biological side-effects of an over-dependence on energy. The effect of the basic rationing forces is revealed by the fact that the United States consumes 33 percent of world energy-production, while accounting for only 6 percent of the population. The result has been a traditionally carefree attitude toward the use of energy, which affects daily lives in ways that are frequently overlooked. Self-cleaning ovens and frost-free refrigerators require twice the amount of electricity as standard models, for example. American automobiles consume two to three times the amount of gasoline required by many foreign models, and the new antipollution devices increase consumption by an additional 7 percent. With the exception of large industrial processes, energy efficiency has never been a critical parameter in the design of American artifacts.

It follows, then, that technological development is not a sufficient answer to the question of energy conservation because the directions that our technologies follow depend upon our acceptance of prevailing forces of rationing. Consider the engineering efforts of the industrial sector, where economic cost of energy resources does in fact serve as a powerful rationing force. In January, 1973, Alcoa announced that it had developed a new process for making aluminum that would require 30 percent less electricity than present methods. Compare this effort with the case of air conditioners, where the average unit on the market today is only half as efficient as the most energy efficient models *already possible*. Another glaring example can be found in housing construction. It has been estimated that a house with enough insulation to meet the homeowner's optimum economic point would require 40 percent less energy for space heating than does one meeting the 1970 Federal Housing Administration standards. If all homes in the U.S. had this optimum level of insulation, the total energy need would decrease by almost 4 percent. These examples serve to illustrate that technology does not in itself solve anything, for more efficient technologies in housing and air conditioning already exist. However, there are no rationing forces strong enough to induce further technological development or to encourage the use of existing energy-saving techniques.

Holding the rationing forces constant, demand is projected to outstrip supply in the near future unless drastic improvements in supply technology are realized. The fallacy in this assumption is that there is no reason why the rationing forces *should* remain constant.

This is not to say that supply technologies and incentives should not be pursued; rather, any attempt to hold the rationing forces constant would place untenable pressures on our capability to produce energy in the long run. Reasonable government policies must be aimed at both the supply and the demand sides of the energy equation. What is commonly referred to as the "energy crisis" is a function of our dependence on energy as well as its supply, and strengthening the rationing forces would only serve as an impetus for technologies directed at reducing that dependence.

Government Action

In October, 1972, the Office of Emergency Preparedness (OEP) issued a report on the conservation of energy; the recommendations of that report are included in Appendix C. Most of the measures recommended by OEP were well beyond the power of that agency to enact, although it did undertake an advertising effort aimed at informing the public on energy conservation and potential energy shortages. Additional action will have to come from legislatures and government agencies, where policy changes are currently being proposed and debated. The following measures are among those that have been advanced by various individuals and groups to accommodate various rationing forces. While by no means complete, the list offers a representative cross-section of conservation alternatives.

Economic Measures

- The price of interstate shipments of natural gas, which has been kept artificially low by the Federal Power Commission, could be raised substantially. This would have greatest impact in the industrial sector (including electric-power generation), and tend to redirect end-use to the residential sector. At present, almost one-half the growth in residential electricity use is accounted for by direct heating—that is, space-heating, water-heating, cooking, and clothes-drying. For these four functions, natural gas is two to three times as efficient as electricity in terms of total energy consumed.
- Taxes on gasoline could be raised to discourage inefficient transportation by automobile. It is estimated that approximately 30 percent of the energy devoted to transportation could be saved through the use of transportation modes which use energy more efficiently. This potential saving of energy represents almost *eight* percent of the U.S. energy budget.
- A tax could be levied on the end-use of all energy forms, especially in the industrial sector, which consumes 41 percent of all energy. Such a tax could be progressive, thereby greatly increasing the incentive to develop processes which use energy efficiently.
- A "super daylight-saving time" has been suggested—moving the clocks ahead one hour in the summer and two hours in the winter, in order to take best advantage of natural lighting during business hours.
- The price structure of the electric-utility industry could be modified. At present, the largest users pay the cheapest rates. The differences between residential and industrial prices could be reduced, and a progressive rate-structure used in both sectors.
- A truth-in-energy bill has been proposed that would force manufacturers of appliances to state the total amount of energy required to operate each product. As an example, up to one-third of the total energy required to operate a gas stove can be consumed by the pilot lights alone. Thus, the consumer would have the opportunity to shop and make decisions based on the cost of operation as well as on the cost of the product itself.
- Increased subsidies for low-cost mass-transit would help discourage the use of automobiles. The aim would be not only to provide an alternative but also to make the automobile a relatively expensive method of commuting. Local governments could also increase road tolls and institute taxes for downtown parking as further incentives to use mass transit.

Political Measures

- Energy efficiency for intercity passenger service is lowest for the airlines. The FAA could place a minimum-occupancy rate for airline service, especially the shuttle services that depart every one or two hours.
- FHA and VA housing standards for federally guaranteed mortgages could be changed to provide for increased insulation and mandatory use of flourescent lighting in kitchens and bathrooms. Fluorescent lighting uses much less electricity than standard incandescent lamps.
- Local building codes could be adapted to increase energy efficiency in commerical buildings. Changes could be made in insulation, fluorescent lighting, decorative lighting, and window requirements. (The precedent for windows is already established since most building codes already require either a window or an air vent in all bathrooms.)
- Maximum horsepower ratings could be placed on auto-

mobile engines. The economic counterpart of this measure would be to place a heavy excise tax on all engines over a certain size.

- As noted earlier, natural gas is most efficient for use in the household sector. End-use priorities could be placed on natural gas; this would be a more direct method of assuring efficient allocation than would a change in price.
- As a last unpalatable resort, the government could turn to rationing or limiting imports to levels below demand. Southern California is presently facing the possibility of gasoline rationing in order to meet the Environmental Protection Agency's clean air standards for 1976.

Voluntary Measures

- The government could take a more active role in insuring that new energy technologies are fully disclosed and publicly debated before they are instituted. As an example, the problems associated with radioactive wastes of a nuclear power plant have not been entirely resolved. This is an area where the public should be given the choice of "limited power generation" or "nuclear power and the potential effects of nuclear-waste build-up." If the public chose limited power, they would be forced to consider the individual's role in terms of public awareness and voluntary restraint.
- Mass-media promotional techniques similar to those initiated by OEP could be used to further stimulate public awareness of energy conservation. Such promotions could take many forms, using the economic appeal of "lowering the family electric bill" as well as deploring the pollution of the environment. An example would be promoting the re-cycling of aluminum beer cans, which indirectly lowers the power requirements of the energy-intensive aluminum industry.

Energy Conservation and Electric Utilities

Electric utilities constitute the most rapidly expanding market for primary sources of energy. Of the four major energy-consuming groups, electric utilities are expected in the next 20 years to increase their share of the market from 25 to 38 percent (*Science*, April, 1973). Hence, improving the efficiency of power generation and transmission could be of major significance.

Historically, the electric-utility industry has sought to economize its use of fuels in an effort to reduce operating expenses. In 1900 the generation of electricity was about 5 percent efficient; today, the newest coal-fired plants can achieve almost 40 percent and the average for all existing power plants (including light-water nuclear reactors) is around 32 percent (*Science*, December, 1972). In response to growing concerns for a systematic effort to reduce the wasteful conversion of fuels to electricity, the electrical utility industry has recently created a national research corporation, funded on a shared basis, to organize research on crucial electrical power problems. Some of the energy-conserving techniques being studied by this group include:

(1) *Combined gas and steam turbines*, capable of burning natural gas, oil distillates or products produced from coal gasification. By using combined cycle systems greater efficiencies can be achieved than by operating a gas or steam turbine alone.

(2) *Magnetohydrodynamics*, a process that directly converts energy to electricity by squirting hot, ionized (electrically charged) gas through a magnetic field. MHD techniques promise greater generating efficiencies as well as lower maintenance and cooling requirements.

(3) *Turbulent fuel mixing*, an experimental technique for mixing air with oil to achieve 99 percent combustion. At some future time this method may contribute to the reduction of fuel waste as well as air pollution.

(4) *Cryogenic transmission*, a laboratory method that uses low-temperature technologies to increase the transmission efficiency of electricity. On a laboratory scale exceedingly high-distribution efficiencies can be achieved, but many problems stand in the way of practical application.

(5) *Waste-heat utilization*, the collection and use of waste heat dissipated from electric-power plants to supply the heating requirements of local residential and commercial structures.

(6) *Total-energy systems*, the design and construction of integrated utility packages that would supply electric-power heating and cooling, and liquid and solid waste disposal to residential complexes and shopping centers.

Summary

There is no doubt that some of the rationing forces for energy use will be strengthened in the coming years without government intervention. For example, most oil companies predict that gasoline prices will rise rapidly whether or not the government raises the gasoline tax. But the government is clearly in a position to influence these changes: it can attempt to stall or cushion them, or it can encourage and complement them. Between 1950 and 1970, total U.S.

energy-use doubled, but only about 40 percent of this rise is attributable to population growth. The remaining 60 percent is generally attributed to increased affluence, but a significant fraction of this increase results from waste. If we could decrease this waste, the growth of electricity demand would be dampened. Slowing down the rate of growth of electricity demand would thus help reduce the proportions of the "energy crisis".

CONCLUSIONS AND POLICY IMPLICATIONS

From the time-series analysis, national electricity production can be viewed as a linear function of families and unrelated individuals, service employment, and personal consumption. It may be that these three factors reflect residential, commercial, and industrial uses of electricity, but the only positive conclusion to be drawn is that no one factor explains all three uses.

Our regional analysis made it clear that the only significant common denominator among the 48 contiguous states that can be associated with electricity production is the number of households. Unlike the time-series analysis, personal income and service employment share no relationship with electricity production over all geographical regions.

The time-series analysis implies that increases in regional service employment and personal consumption will be accompanied by a national increase in demand for electricity. However, the increase in demand may not necessarily occur in the same region as do increases in the other factors, because service employment and personal consumption showed no association with state electricity production. Since increases in service employment and personal consumption are indicators of a rising standard of living, clearly a region may experience the benefits of an increase in its standard of living without having to pay directly the associated social, aesthetic, and environmental costs of increased electricity production. It is possible that these burdens may be transferred to other sectors of the economy and other regions of the country.

It should be apparent that national projections cannot be generalized for all the states because states differ considerably in their commercial and industrial makeup. This would mean that the only relation to the "energy crisis" that any particular region could be sure of would be through factors correlated with the use of electricity. If this were the case, then a state would be incorrect in assuming that projected demand for the nation would mean a proportional increase in state demand.

Our causal analysis model makes this very clear. The demand forecast shows that variation in the price of electricity is the most important variable in projecting the electric-power demand. Hence, electric-power planning in Texas in the next few decades is not likely to be changed because of population trends or in-migration patterns. In the next five years all the projections are reasonably close to one another. Thus, for short-term planning, neither the price of electricity nor population trends will make a significant difference. Long-range planning, however, can be substantially affected by pricing policies. The price of electricity, identified as an important and adjustable factor, can be used to conserve energy as well as to influence the growth of electricity demand.

Not everyone would agree with this analysis. In fact, the major electric utilities in Texas do not believe that the price of electricity is as important as our model assumes. They argue that the consumption of electricity accounts for only a fraction of an average household's budget and that a gradual increase in price would not alter present consumption patterns.

Although it is generally believed that discouraging growth of demand for electric power will result in a declining rate of economic growth, a recent study conducted by the RAND Corporation for the California State Legislature concludes that energy-conservation policies could reduce the number of new electric power plants needed in California from 127 to about 45 with only relatively minor economic impacts and dislocations. This finding has led some federal officials to question whether increases in energy use and economic growth are necessarily correlated. In fact, they are not correlated at the regional and state level, although they have been closely associated nationally. On the other hand, generation, transmission, and waste-energy problems associated with increasing energy usage have definitely caused the quality of the environment to deteriorate.

If a state's economy remains unaffected by decreases in the rate of electricity consumption, then it is certainly desirable to encourage energy conservation. The Texas electric utilities agree that significant economies of energy can be achieved through such conservation measures as better home insulation, improved building codes, and increased power-generation efficiencies. This would not only lengthen the life-span of available fuels but provide additional time for the development of safer, more economical, and less environmentally damaging sources of electric power.

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APPENDIX A

NATIONAL AND REGIONAL DEMAND-ANALYSIS

The basic purpose of this multiple-correlation analysis is to produce a linear combination of independent variables which will correlate as highly as possible with the dependent variable. This linear combination can then be used to describe values of the dependent variable. The linear-correlation equation can be written as follows:

$$D = b_1I_1 + b_2I_2 + \ldots\ldots\ldots + b_nI_n + C,$$

where D is the dependent variable, the I's are the independent variables, the b's are the regression coefficients (unnormalized), and C is a constant (or intercept).

Multiple linear-correlation could be used to understand the nature of electricity demand. This involves obtaining the regression equation and for forecasting purposes the values of all the independent variables as well as the equation itself.

Understanding the phenomenon of electricity demand involves a time-series analysis, taking aggregate national demand over the period from 1951 to 1970, and a regional analysis, based on electricity demand in each of the 48 contiguous states in one particular time-period.

TIME-SERIES ANALYSIS

In the time series analysis, the aggregate national demand for electricity was made dependent on other aggregate national variables: population (X_2), families and unrelated individuals (X_3), industrial employment (X_4), service employment (X_5), total employment (X_6), personal consumption (X_7), personal consumption of durable goods (X_8), residential investment (X_9), total services (X_{10}), total goods (X_{11}), total GNP (X_{12}). Using the data in Table 5, the equation obtained as a first step was:

$$X_1 = -2.012\text{x}10^9 - 3177\,X_2 + 34680\,X_3 + 41740\,X_4 + 64720\,X_5 - 36400\,X_6 + 2847000\,X_7 - 323600\,X_8 + 1600000\,X_9 - 2330000\,X_{10} - 554100\,X_{11} + 13530\,X_{12}\,, \ldots\ldots\ldots \quad (1)$$

where X_1 is the national production of electricity.

Since the independent variables in this equation are measured in different scales (e.g., population in millions, GNP in billions of dollars), the regression equation has to be normalized to determine which independent variable is the most important predictor of electricity demand and to determine if any of the variables can be omitted without losing much descriptive ability.

The general form of the normalized equation is:

$$D = B_1I_1 + B_2I_2 + \ldots\ldots + B_nI_n\,,$$

where the B's, the weights (coefficients) attached to the independent variables (the I's), are in the standard form and satisfy the criterion of least squares. (Each of these coefficients is conventionally denoted by the letter "beta".) A "beta" is the average change in the criterion variable per unit change in the independent variable with which the "beta" is associated, with the influence of the other n-1 independent variables removed. Thus a $B_{12} = 0.1$ would mean that if all other variables were held constant and if I_{12} changed by 50%, then D would change by 5%.

When the normalization operation was applied to equation (1), the normalized equation obtained was:

$$X_1 = -.138\,X_2 + .499\,X_3 + .100\,X_4 + 1.051\,X_5 - .618\,X_6 + .618\,X_7 - .016\,X_8 + .009\,X_9 - .361\,X_{10} - .078\,X_{11} + .005\,X_{12} \ldots\ldots\ldots \quad (2)$$

Since the coefficients for X_4, X_8, X_9, X_{11}, and X_{12} are less than 0.1, these variables (industrial employment, personal consumption of durable goods, residential investment, total goods, and total GNP, respectively) have little impact on electricity demand. Also, such small coefficients might be the result of statistical sampling error or other external factors, and it is reasonable to remove them. This does not, however, mean that there is an insignificant correlation between these variables and the dependent variable. For example, X_8 has 98.09% correlation with X_1 and 98.9% correlation with X_7. The greater the relationship between two independent variables (e.g., X_8 and X_7), the more desirable it is to eliminate one of them from the analysis. This is because only one of them can make any appreciable contribution to the over-all relationship; the net effect of the other variable is likely to be extremely small. The normalized equation obtained by removing these five variables was:

$$X_1 = -.141\,X_2 + .542\,X_3 + .324\,X_5 + .058\,X_6 + .493\,X_7 - .278\,X_{10} \qquad (3)$$

The coefficient of X_6 is .058. Since it was insignificant, X_6 (total employment) was also removed from the calculation. With the reduced set of independent variables, the (normalized) equation became:

$$X_1 = -.164\,X_2 + .518\,X_3 + .414\,X_5 + .530\,X_7 - .302\,X_{10} \qquad (4)$$

In the normalized equation, X_2 and X_{10} have negative coefficients and were dropped. The resulting (normalized) equation was:

$$X_1 = .3807\,X_3 + .3758\,X_5 + .2636\,X_7 \qquad (5)$$

where X_3 is families and unrelated individuals, X_5 is service employment, and X_7 is personal consumption (in thousands, thousands, and billions of dollars, respectively).

REGIONAL ANALYSIS

The regional analysis was done for the year 1970 over the 48 contiguous states, with electricity demand in each state related to the independent, variable values in that state. (In the time-series analysis, 20 data points in time were taken, whereas in the regional analysis 48 data points over space were used.) Variables considered were production of electricity (X_1), population (X_2), households (X_3), manufacturing, mining, and construction employment (X_4), service employment (X_5), total employment (X_6), personal income (X_7), and value added by manufacture (X_8). Table II-6 gives the values of these variables.

The spatial, multiple-correlation analysis, after going through the same elimination steps used in the time-series analysis, provided the equation:

$$X_1 = 5565300 + 1918200\,X_3 + 1365200\,X_8; \qquad (6)$$

the normalized equation obtained was:

$$X_1 = 0.855\,X_3 + 0.0346\,X_8 \qquad (7)$$

The equations (5) and (7) explain the electric demand as related to other aspects of national and regional activity and relative impacts of these activities on the electricity demand in the nation or a state, respectively. If all these activities (or independent variables) are forecast for a time-period, then the demand for electricity can be forecast for the same time-period.

TABLE II-5

Data for Variables Considered in Multiple Regression Analysis

Year	Production of Electricity in Thousands of KWH by Utilities and Industries 1	Population of U.S. Times 100 2	Families and Unrelated in Individuals Times 1000 3	Industrial Employment Times 1000 4	Service Employment Times 1000 5	Total Employment (Sum of 4 and 5) 6	Personal Consumption Billions of Dollars 7	Durable Goods Personal Consumption Billions of Dollars 8	Residential Investment Billions of Dollars 9	Total Services Billions of Dollars 10	Total Goods Billions of Dollars 11	Total GNP Billions of Dollars 12
1950	—	151,267	49,295	25,635	26,747	52,382	230.5	34.7	23.5	117.5	192.6	355.3
1951	433,357,910	153,374	49,720	26,651	27,924	54,575	232.8	31.5	19.5	130.5	208.4	383.4
1952	463,054,694	155,782	50,537	26,665	28,660	55,325	239.4	30.8	18.9	136.3	214.0	395.1
1953	514,169,131	158,330	50,716	27,299	29,195	56,494	250.8	35.3	19.6	140.3	225.4	412.8
1954	544,645,484	161,242	51,675	25,903	29,306	55,229	255.7	35.4	21.7	141.8	215.1	407.0
1955	629,009,799	164,399	52,778	26,931	30,199	57,130	274.2	43.2	25.1	147.5	236.1	438.0
1956	689,894,054	167,388	53,276	27,347	31,344	58,691	281.2	41.0	22.8	153.0	239.0	446.1
1957	715,705,826	170,452	54,131	26,872	31,967	58,841	288.2	41.5	20.2	160.1	239.8	452.5
1958	724,013,312	173,382	55,116	25,010	31,890	56,900	290.1	37.9	20.8	163.4	230.8	447.3
1959	794,505,449	166,338	55,990	25,882	32,807	58,689	307.3	43.7	24.7	171.2	247.7	475.9
1960	840,457,452	179,154	56,537	25,851	33,651	59,502	316.1	44.9	21.9	176.6	256.0	487.7
1961	878,530,235	182,127	57,504	24,960	34,025	58,985	322.5	43.9	21.6	184.0	257.3	497.2
1962	943,052,693	184,861	58,011	25,298	35,986	61,284	338.4	49.2	23.8	193.7	277.3	529.8
1963	1,007,896,779	187,534	58,618	25,225	35,897	61,122	353.3	53.7	24.8	200.9	289.7	551.0
1964	1,078,956,751	190,134	59,892	25,427	37,153	62,580	373.8	59.1	24.6	211.2	307.2	580.0
1965	1,153,072,668	192,474	60,411	26,185	38,702	64,987	396.2	66.4	24.1	221.1	325.5	614.4
1966	1,244,037,473	194,496	61,336	27,035	40,591	67,029	418.1	71.7	21.3	253.7	336.3	658.1
1967	1,809,825,341	196,336	62,948	27,056	42,326	69,382	430.3	72.8	20.3	269.2	338.7	674.6
1968	1,434,015,046	192,256	64,313	27,431	43,167	71,398	452.7	81.3	23.2	283.4	345.4	706.6
1969	1,546,909,456	200,243	65,689	27,765	45,750	73,515	469.3	84.8	23.1	294.4	356.7	727.7
1970	1,632,127,803	202,667	67,305	26,755	46,985	73,740	475.9	81.4	21.3	303.3	346.1	720.0

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4. Source same as #2. Alaska and Hawaii not included. Subtracted mining, construction, and manufacturing for 1959-1970, and also agriculture for 1960-1970.
5. and 6. Source same as #2. Alaska and Hawaii subtracted from total.
7. U.S. Office of Business Economics. *National Income and Products Accounts for the U.S. 1929-1965: Statistical Tables.* Washington, D.C., GPO. For years 1950-1965.
   ______. *Survey of Current Business*, Washington, D.C., GPO, February, 1970. For years 1966-1967. U.S. Bureau of Economic analysis. *Survey of Current Business.* Washington, D.C., GPO, February, 1972. For years 1968-1970. All figures for all 50 states in 1958 constant dollars.

8., 9., 10., 11., 12. Source same as #7.

TABLE II-6

STATE / DATA DESCRIPTION	1 Production of Electricity in Thousands of KWH By Utilities and Industries 1969	2 Population Times 1000 For 1969	3 Household Times 1000 for 1968	4 Manufacturing, Mining, and Construction Employment Times 1000 For 1969	5 Service Employment Times 1000 for 1969	6 Total Employment Times 1000 For 1969 (Sum of Above) (Exc. Agriculture)	7 Personal Income (Billions) 1969	8 Value Added By Manufacture 1969 (Millions)
MAINE	7,199,465	978	291	131	199	330	3.0	1,225
N.H.	5,293,158	717	212	111	147	258	2.5	1,006
VT.	1,033,715	439	126	55	90	145	1.4	555
MASS.	26,602,817	5,467	1,648	776	1,463	2,239	22.6	9,572
R.I.	1,587,528	911	278	141	202	343	3.4	1,472
CONN.	19,307,943	3,000	883	531	664	1,195	13.6	7,172
N.Y.	94,624,015	18,321	5,749	2,144	5,037	7,181	81.0	28,384
N.J.	34,341,116	9,148	2,102	1,018	1,564	2,582	30.6	14,362
PENN.	70,274,289	11,803	3,586	1,058	3,312	4,370	43.2	22,136
OHIO	78,677,300	10,740	3,187	1,668	2,223	3,891	40.6	24,192
IND.	59,012,720	5,118	1,544	843	1,028	1,871	18.9	11,857
ILL.	72,008,787	11,047	3,383	1,623	2,745	4,368	47.6	22,642
MICH.	60,835,125	8,766	2,540	1,297	1,767	3,064	34.6	20,253
WIS.	28,240,660	4,233	1,246	588	933	1,521	15.4	8,106
MINN.	19,611,245	3,700	1,096	412	886	1,298	13.4	4,942
IOWA	13,135,779	2,781	879	269	611	880	9.8	3,729
MD.	25,060,395	4,651	1,486	541	1,127	1,668	16.1	6,766
N.D.	6,192,300	615	180	19	139	158	1.9	144
S.D.	6,440,119	659	198	26	145	171	2.0	213
NEB.	7,394,127	1,449	457	114	357	471	5.3	1,415
KAN.	15,312,992	2,321	734	194	490	684	8.2	2,456
DEL.	5,221,127	540	152	86	122	208	2.2	151
MO.	22,983,079	3,765	1,041	368	907	1,277	15.4	4,188
VA.	29,985,974	4,669	1,290	478	956	1,434	15.4	4,816

SOURCES: Listed next page

TABLE II-6 (continued)

STATE / DATA DESCRIPTION	1 Production of Electricity in Thousands of KWH By Utilities and Industries 1969	2 Population Times 1000 For 1969	3 Household Times 1000 For 1968	4 Manufacturing, Mining, and Con struction Employ- ment Times 1000 For 1969	5 Service Employment Times 1000 For 1969	6 Total Employment Times 1000 For 1969 (Sum of Above) (Exc. Agriculture)	7 Personal Income Billions) 1969	8 Value Added By Manufacture 1969 (Millions)
W. VA.	39,242,437	1,819	550	204	309	513	4.7	2,288
N.C.	49,822,394	5,205	1,441	814	921	1,735	15.0	8,186
S.C.	18,220,035	2,692	721	390	422	812	6.9	3,672
GA.	28,021,850	4,641	1,287	566	956	1,522	14.1	5,413
FLA.	55,037,679	6,354	2,015	502	1,577	2,079	21.8	4,398
KY.	38,044,285	3,232	944	329	566	895	9.2	4,438
TENN.	48,079,247	3,985	1,169	545	767	1,312	11.2	5,982
ALA.	48,586,269	3,531	1,006	386	613	999	9.1	4,315
MISS.	10,056,401	2,360	638	221	348	569	5.2	1,912
ARK.	13,513,788	1,995	604	203	329	532	5.0	2,025
LA.	44,814,330	3,745	1,047	316	728	1,044	10.4	3,250
OKLA.	20,246,626	2,568	845	207	547	754	7.9	1,595
TEXAS	118,500,043	11,187	3,300	547	2,525	3,611	35.4	12,922
MONT.	10,458,743	694	218	40	157	197	2.2	359
IDAHO	6,442,605	718	220	54	145	199	2.1	577
WYO.	6,083,165	320	102	26	81	107	1.1	98
COL.	10,104,782	2,100	648	165	544	709	7.5	1,880
N. MEX.	10,373,412	994	272	54	231	285	2.9	207
ARZ.	14,112,133	1,693	487	143	371	514	5.6	1,275
UTAH	4,858,272	1,045	293	80	268	348	3.1	1,054
NEV.	5,588,713	457	140	23	166	189	2.0	161
WASH.	72,160,767	3,402	1,073	340	785	1,125	13.0	5,132
ORE.	28,418,543	2,032	665	213	491	704	7.2	2,612
CALIF.	119,760,802	19,443	6,232	1,983	4,926	6,909	83.1	27,016

SOURCES–TABLE II-6

1. U.S. Federal Power Commission, *Electric Power Statistics*, Washington, D.C., GPO, Jan. - Dec., 1969.
2. through 7. U.S. Bureau of the Census. *Statistical Abstract of the United States: 1970*. Washington, D.C., GPO, 1970.
3. U.S. Office of Business Economics. *Survey of Current Business*, 1969, v. 49. Washington, D.C., GPO, 1969.

APPENDIX B

CAUSAL ANALYSIS FOR TEXAS PROJECTIONS

The projection model employed here is a modification of one developed by Cornell University and Oak Ridge National Laboratory under a National Science Foundation's RANN (Research Applied to National Needs) grant. (Chapman, *et al.*, 1972) This model uses causal analysis to forecast the demand for electricity, rather than simply examining statistical trends, as demand models frequently do. The causal factors considered in the model (in order of importance) are: price of electricity, population, personal income, price of natural gas, wholesale price index, and consumer price index. In addition to these causal factors, the economic concept of elasticity is used to describe the relative magnitude of influence of these factors. The elasticity of a causal factor represents the precentage change in the demand for electricity associated with a 1 percent change in that causal factor; for example, an elasticity of -1.3 for residential electricity price implies that a 1 percent increase in the price of residential electricity would, in the long run, result in a 1.3 percent decrease in the demand for residential electricity.

Table II-7 shows the values of elasticities used for all the causal factors. It is assumed that these values do not change significantly over the different geographical regions, and that the elasticity values arrived at in the Cornell-Oak Ridge study are applicable to Texas. Also indicated in Table II-7 are the values of θ, a time response factor. The percent of response in the first year is equal to $100(1-\theta)$; for example, if θ is 0.9, then the first year response is 10%.

This model was used to predict demand for electricity in Texas for all three consumer classes—residential, commercial, and industrial. Table II-8 provides the values of the causal factors used for this prediction. Two different estimates were used for the population and the price of electricity. The population figures are the authorized state estimates developed recently by the Population Research Center, The University of Texas at Austin. High population figures are based on the U.S. Bureau of the Census (1972) Series I-C projections (a slightly increasing fertility-rate and a continuation of interstate migration at 1960 to 1970 levels), while low-population figures are based on the Bureau's Series I-E projections (a slightly decreasing fertility-rate and a continuation of interstate migration at 1960 to 1970 levels). The Federal Power Commission (FPC) price estimates are projections made by the Federal Power Commission for the South Central Region, which contains Texas. (FPC, 1970) The "double-by-2000" price estimates assume that the price of electricity will double (in real dollars) between 1970 and the year 2000. Low gas-price estimates are obtained from the recent National Petroleum Council energy study. (National Petroleum Council, 1971).

It was assumed that the percentage change in the price of gas (in real dollars) over the next 20 years would be relatively similar for all three consumer-classes. A similar assumption was made regarding the price of electricity for the three consumer-classes. The rates of change of prices, rather than the prices themselves, are required for the

TABLE II-7 ELASTICITIES OF CAUSAL FACTORS

	Elasticity				First	Time
Consumer	Electricity Price	Population	Income	Gas Price	Year Response	Response Parameter
Residential	-1.3	+0.9	+0.3	+0.15	10%	0.90
Commercial	-1.5	+1.0	+0.9	+0.15	11%	0.89
Industrial	-1.7	+1.1	+0.5	+0.15	11%	0.89

Source: Chapman, D., T. Tyrrell, and T. Mount, "Electricity Demand Growth and the Energy Crisis," *Science*, Vol. 178, No. 4062, November 17, 1972.

forecast; hence no attempt was made to obtain the exact prices of gas and electricity. Projections of the Consumer Price Index (CPI) were extrapolated from past trends. The price of gas was deflated by the Consumer Price Index for residential consumers and by the Wholesale Price Index for commercial and industrial consumers. The price of electricity (FPC), already in 1968 constant dollars, was used as given for residential consumers. For commercial and industrial consumers it was deflated by the Wholesale Price Index. All the values of the causal factors were converted to indices using 1970 as a base. The new values are given in Table II-9.

TABLE II-8

VALUES OF CAUSAL FACTORS FOR THE TEXAS ENERGY DEMAND ESTIMATES

	1970	1975	1980	1985	1990
Population					
High Assumption	11,196,730	12,000,700	13,068,600	14,256,300	15,450,000
Low Assumption	11,196,730	11,859,700	12,632,500	13,628,300	14,481,800
Price of Electricity in mills/KWH					
FPC*	1.48	1.54	1.60	1.66	1.72
Double-by-2000*	1.48	1.726	1.971	2.217	2.460
Price of Natural Gas in cents/MCF @					
Constant	26	27	28	29	30
Medium Increase	25	50	75	83	100
Large Increase	25	63	100	150	200
Wholesale Price Index 1970=100.000#	100.000	114.140	130.400	148.980	165.000
Consumer Price Index 1970=100.000	100.000	116.500	133.000	149.500	156.000

Sources: FPC–Federal Power Commission, *The 1970 National Power Survey*, Part I, U.S. Government Printing Office, Washington, D.C., 1970.

NPC–National Petroleum Council, Committee on U.S. Energy Outlook, *U.S. Energy Outlook*, Vol. 2, Washington, D.C., 1971.

TABLE II-9

VALUES OF CAUSAL FACTORS CONVERTED TO INDICES (in constant dollars, 1970=1.000)

Variable	1970	1975	1980	1985	1990
Population					
High Assumption	1.000	1.072	1.167	1.273	1.380
Low Assumption	1.000	1.059	1.128	1.217	1.293
Price of electricity					
FPC					
: residential	1.000	1.041	1.081	1.122	1.162
: commercial	1.000	1.062	1.103	1.126	1.099
: industrial	1.000	1.062	1.103	1.126	1.099
Double-by-2000					
: residential	1.000	1.166	1.332	1.498	1.664
: commercial	1.000	1.190	1.359	1.503	1.573
: industrial	1.000	1.190	1.359	1.503	1.573
Personal Income	1.000	1.109	1.219	1.328	1.438
Price of Gas					
Constant					
: residential	1.000	0.891	0.810	0.746	0.740
: commercial	1.000	0.910	0.826	0.749	0.699
: industrial	1.000	0.910	0.826	0.749	0.699
Medium Increase					
: residential	1.000	0.500	0.333	0.301	0.250
: commercial	1.000	0.511	0.339	0.302	0.253
: industrial	1.000	0.511	0.339	0.302	0.253
Large Increase					
: residential	1.000	0.393	0.250	0.166	0.126
: commercial	1.000	0.401	0.255	0.167	0.124
: industrial	1.000	0.401	0.255	0.167	0.124

Some variation may occur due to rounding.

Note that the price of electricity (gas) is not the same for commercial and industrial consumers; however, the rate of change of the price is the same for each sector. Thus, the percentage increase in the price of electricity (gas) will be the same in the two sectors.

The present model is defined as:

$$Q_{it} = A_i (Q_{i,t-1})^{\theta_i} (PE_{it})^{\alpha_i} (N_t)^{\beta_i} (Y_t)^{\gamma_i} (PG_{i,t-1})^{\sigma_i} \ldots. (1)$$

where Q: demand for electricity
PE: price of electricity
N: population
Y: personal income
PG: price of gas
A: constant
θ: time response parameter
β: elasticity for population
α : elasticity for price of electricity
γ : elasticity for real income
σ: elasticity for price of gas
i: denotes the consumer class
t: denotes time period (year)

The interval chosen for this analysis was five years, i.e., (t+1)-t = five years. In order to use the variable index values with 1970 values as base values, equation (1) above is rewritten as:

$$Q_{it} = A_i' (Q_{i,t-1})^{\theta_i} (PE_{it}/PE_{i,1970})^{\alpha_i} (N_t/N_{1970})^{\beta_i} (Y_t/Y_{1970})^{\gamma_i} (PG_{i,t-1}/PG_{i,1970})^{\sigma_i} (PE_{i,1970})^{\alpha_i} (N_{1970})^{\beta_i} (Y_{1970})^{\gamma_i} (PG_{i,1970})^{\sigma_i} \ldots\ldots\ldots\ldots (2)$$

Since $(PE_{i,1970})^{\alpha_i}$, $(N_{1970})^{\beta_i}$, $(Y_{1970})^{i}$, and $(PG_{i,1970})^{i}$ are all constants, we have:

$$Q_{it} = A_i'(Q_{i,t-1})^{\theta_i} (PE_{it}')^{\alpha_i} (N_t')^{\beta_i} (Y_t')^{\gamma_i} (PG_{i,t-1}')^{\sigma_i} \ldots. (3)$$

where $A_i' = A_i (PE_{it}/PE_{i,1970})^{\alpha_i} (N_{1970})^{\beta_i} (Y_{1970})^{\gamma_i} (PG_{i,1970})^{\sigma_i}$

$PE_{it}' = PE_{it}/PE_{i,1970}$
$N_t' = N_t/N_{1970}$
$Y_t' = Y_t/Y_{1970}$
$PG_{it}' = PG_{it}/PG_{i,1970}$

and where A_i' = new constant
PE' = electricity price-index (1970=1)
N' = population index (1970=1)
Y' = personal income-index (1970=1)
PG' = gas price-index (1970=1)

Using equation (3) and the values from Table II-9 projections were made for each class of consumers for different assumptions and different combinations of electricity price and population growth. (These projections were given earlier in Tables II-3 and II-4.) The electricity demand-projections are external-electricity demand-requirements; they do not include internal energy-consumption related to pumping, station use, and transmission and distribution losses. The external demand-requirements, or the sale of electricity to ultimate consumers, is typically on the order of 80 percent of the total production of electricity. These demand figures are the average-load requirements, and do not take peak loads into account. The sale of electricity to ultimate consumers other than residential commercial, and industrial is on the order of 2.4 percent of total electricity production.

These projections represent an attempt to forecast electricity demand with the specification of assumptions and methodology which introduce maximum objectivity into the process and give the user a basis for appraising the validity of projections. The specification of assumptions facilitates consideration of alternative projections based on different assumptions and provides a foundation for the evaluation of "what if" questions.

APPENDIX C

POTENTIAL FOR ENERGY CONSERVATION

In October, 1972, the Office of Emergency Preparedness issued a report entitled, *The Potential for Energy Conservation–A Staff Study.* The report included a summary of recommendations and an estimate of the impact each would have on total national consumption of energy. The completeness and clarity of the summary warrant its inclusion here.

Short-Term Measures (1972-1975)

Transportation—Conduct educational programs to stimulate public awareness of energy conservation in the transportation sector; establish government energy-efficiency standards; improve airplane load factors; promote development of smaller engines/vehicles; improve traffic flow; improve mass transit and intercity rail and air transport; promote automobile energy-efficiency through low loss tires and engine tuning.

Savings–1.9 QBTU*/yr. (10 percent)

Residential/commercial—Provide tax incentives and insured loans to encourage improved insulation in homes; encourage use of more efficient appliances and adoption of good conservation practices.

Savings–0.2 QBTU/yr. (1 percent)

Industry—Increase energy price to encourage improvement of processes and replacement of inefficient equipment; provide tax incentives to encourage recycling and reusing of component materials.

Savings–1.9-3.5 QBTU/yr. (6-11 percent)

Electric Utilities—Smooth out daily demand-cycle by means of government regulation; facilitate new construction; decrease electricity demand.

Savings–1.0 QBTU/yr. (4 percent) (already assumed in the projections)

Mid-Term Measures (1976-1980)

Transportation—Improve freight-handling systems; support pilot implementation of most promising alternatives to internal combustion engine; set tax on size and power of autos; support improved truck engines; require energy-efficient operating procedures for airplanes; provide subsidies and matching grants for mass transit; ban autos within the inner city; provide subsidies for intercity rail-networks; decrease transportation demand through urban refurbishing projects and long-range urban/suburban planning.

Savings–4.8 QBTU/yr. (21 percent)

Residential/commercial—Establish upgraded construction standards and tax incentives and regulations to promote design and construction of energy-efficient dwellings including the use of the "total energy concept" for multi-family dwellings; provide tax incentives, R&D funds and regulations to promote energy-efficient appliances, central air-conditioning, water heaters, and lighting.

Savings–5.1 QBTU/yr. (14 percent)

Industry—Establish energy-use tax to provide incentive to upgrade processes and replace inefficient equipment; promote research for more efficient technologies; provide tax incentives to encourage recycling and reusing component materials.

Savings–4.5-6.4 QBTU/yr. (12-17 percent)

Electric Utilities—Restructure rates for heavy uses to smooth out demand-cycle; facilitate new construction.

Savings–1.1 QBTU/yr. (4 percent) (already assumed in the projections)

Long-Term Measures (beyond 1980)

Transportation—Provide R&D support for hybrid engines, non-petroleum engines, advanced traffic control systems, dual-mode personal rapid-transit, high-speed transit, new freight systems, and people movers; decrease demand through rationing and financial support for urban development and reconstruction.

Savings–8 QBTU/yr. (25 percent)

Residential/commercial—Provide tax incentives and regulations to encourage demolition of old buildings and

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* Quadrillion BTU.

construction of energy-efficient new buildings; R&D funding to develop new energy sources (solar, wind power).

Savings—15 QBTU/yr. (30 percent)

Industry—Establish energy-use tax to provide incentive for upgrading processes and replacing inefficient equipment; promote research in efficient technologies; provide tax incentives to encourage recycling and reusing component materials.

Savings—9-12 QBTU/yr. (15-20 percent)

Electric Utilities—Smooth out daily demand-cycle through government regulation; facilitate new construction; support R&D efforts.

Savings—1.4 QBTU/yr. (3 percent)

CHAPTER THREE

FUELS: COSTS, RESERVES AND FUTURE PROSPECTS

The electric-power industry in Texas operates under a number of technological, economic, and physical limitations. The growth potential of the industry, including its ability to meet future electricity demands depends on a realistic assessment of these constraints. To assist in this evaluation, this chapter provides analyses of:

- available methods of power generation,
- fuel costs,
- usage rates,
- fuel reserves in Texas, and
- policies affecting fuel resources in Texas.

METHODS OF POWER GENERATION

The process of electric-power generation involves the conversion of power sources. Currently, all power is produced by generators which, in simplified language, use the rotation of a magnetic field within a coil to produce a flow of electrons or electrical energy. Some power source must be used to rotate this magnet to release the electron flow. In the old-fashioned telephone a small crank was turned by hand to rotate the magnet and produce a small electrical charge, ringing a bell at the other end of the line. The problem of electric-power generation is to find some method of turning a big enough "crank" fast enough to produce electricity in the quantity needed.

In the United States today three methods are used to turn the generators that produce electric power: internal combustion engines, hydro power, and steam turbines. These categories may be further divided into gas turbine and diesel internal combustion engines, conventional and pumped-storage hydro-power, and geothermal, nuclear, and fossil-fuel steam turbines. About 71 percent of the electrical power currently produced in the United States is generated by fossil-fuel steam plants; hydro power accounts for about 15 percent of the total; internal combustion 8 percent; and nuclear 5 percent. (See Figure III-1). Geothermal energy plays a small role at present, although it may be the answer to the power needs in some areas in the future.

Internal Combustion Engines

Internal combustion engines, diesel and gas turbines, account for a very small percentage of the generating capacity of the United States.

The diesel engine used for electric-power generation is a larger version of the engine used to power trucks, buses, and other vehicles. Diesels are used primarily as standby and backup units and as supplemental units in peak-demand periods. Despite the fact that diesels are much more efficient than steam or gas turbines, from an economic and engineering standpoint they are impractical at sizes greater than six megawatts.

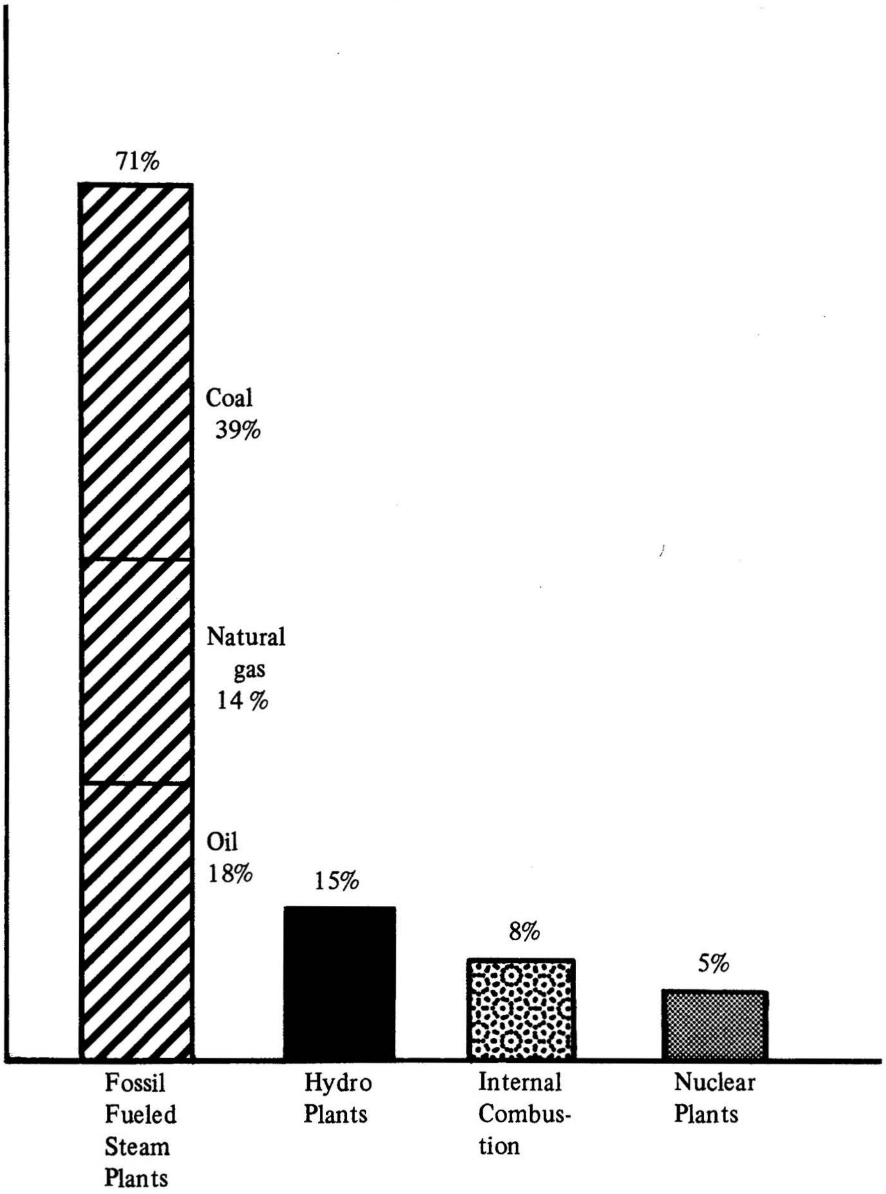
The gas-turbine engine operates on much the same principle as the jet-aircraft engine. (In fact, aircraft-type engines are often used.) In operation, air is drawn into the engine along with compressed air from some outside source. Within the combustion chamber fuel is injected and ignited, creating a tremendous expansion of hot gas which is used to turn additional turbines as it exists from the chamber. About 75 percent of the power produced by the exhaust turbines is needed to turn the compressing turbines, and the rest is used to generate electricity. Almost any volatile gas or liquid may be used for fuel; most turbines are easily converted from gas to liquid, some even while operating under full load. While they may be produced in larger sizes than diesels and are capable of being connected in a series to a single driveshaft, economic-efficiency considerations prevent their use as a main power-source in most large-scale plants.

Hydro Power

Hydro power was one of the earliest forms of power used to produce electricity. In conventional hydro power, the water pressure built up behind a dam is released through turbines that generate the electricity. In pumped storage, water is pumped to a higher level during periods when the supply of electricity exceeds the demand. There it is stored until peak demand occurs, at which time it is released through turbines that produce electric power in the

FIGURE III-1

ELECTRIC-POWER PRODUCTION BY METHOD IN THE UNITED STATES, 1973



Source: Federal Energy Administration, *Project Independence Report,* 1974.

same manner as conventional hydro power.

For various reasons, including its nonexistent fuel costs and simplicity of operation, hydro power was the major source of electrical energy until after World War II. Today, however, the demand for electrical energy has greatly risen and most of the more suitable dam sites have been utilized so that hydro power accounts for only about 15 percent of the power generated in the United States. Hydroelectric generation is likely to rise slightly in the future as the remaining suitable dam sites are utilized. This increase, however, will not take place as fast as the total increase in power production.

Steam Turbines

The principle behind the steam turbine is the use of steam power to turn a turbine. Different sources of heat are used to produce this steam to drive the turbine.

In geothermal production, natural geysers are used as the source of steam. Pacific Gas and Electric's Sonoma County (California) plant is the only geothermal plant in the United States, although the geothermal method is considered feasible in other areas in the West. (See *Energy in Texas: Volume II* for geothermal potential in Texas)

A recent development is the use of controlled nuclear fission as a heat source. Pipes passing through a nuclear reactor carry steam to the turbine, where the steam is condensed and recycled through the reactor. Environmental and engineering questions have retarded the rapid development of nuclear power plants, but many believe nuclear energy will become the major source of electric-power generation in the future. Breeder reactors that produce more fuel than they consume and fusion reactors that utilize water as a fuel are not expected to play a major role for at least 25 years.

Fossil fuels (coal, oil, and natural gas) are by far the most widely used means of producing steam for the generation of electricity. The fuels are burned in a boiler and the steam which is provided drives a turbine. Coal in the form of liqnite, anthracite, and bituminous coal is the most abundant of the fossil fuels, but it is also the "dirtiest" in environmental terms. Moreover, it is the hardest to transport, since in its natural form coal cannot be shipped by pipeline; and the slurry method of pipeline transportation (pulverized coal in an oil or water medium) is expensive. Natural gas is probably the easiest of all the fossil fuels to use and transport, but it is being used up at a much greater rate than the others. There is hope that an increase in its price and/or the emergence of new technologies will make possible the use of presently unreclaimable deposits as well as the discovery of new fields. Oil accounts for 18 percent of the fossil fuels used for generation, but many feel that its use will be curtailed sharply in view of current and projected price increases.

FUEL COSTS

Fuel costs depend not only on the price of the raw resource, but also on processing costs, transportation costs, storage costs, pollution abatement costs, and, in some cases, reprocessing costs.

Natural Gas Costs

Natural gas was originally flared (burned off) in many oil fields because there was no use or market for it. When a domestic and industrial market emerged after World War II, contracts by pipeline systems for natural gas were as low as three to five cents per thousand cubic feet (Mcf). In the summer of 1974, the average wellhead price of natural gas used in Texas was 37.9 cents per Mcf. To a large degree, this price reflects the influence of long-term contractual arrangements rather than the current market value of natural gas. In 1975, the price of interstate pipeline gas was set at 52 cents per Mcf by the Federal Power Commission (FPC), while nonregulated intrastate buyers were willing to pay prices ranging from 80 cents to $1.50 or even higher. In Texas, electric utilities that now wish to purchase natural gas in quantities exceeding their contractual stipulations must pay as much as $2 per Mcf.

Texas natural gas companies believe prices are going to rise significantly in the coming years as demand increases faster than supply, and as the FPC comes under pressure to raise interstate prices in order to close the gap between supply and demand. The impact that such changes will have on the electric-power industry is clear: alternative boiler fuels must be sought and planned generating capacity for the foreseeable future will have to rely upon a mixture of coal (or lignite) and nuclear power.

Coal Costs

In 1970, coal provided about 4.56 percent of the fuel for electric-power generation in the South Central Region of the U.S. and this was expected to grow to 10.09 percent by 1990 (See Table III-1).

Without large deposits of bituminous and anthracite coal in the state, Texas utilities have historically been interested in other energy sources. But with growing demands placed upon natural gas and petroleum, a good deal of attention has been given to the mining and use of lignite (low-grade coal) deposits that are concentrated in east Texas. The revival of interest in lignite as a fuel has been a significant practical development in the Texas utility industry. Texas Power and Light, Dallas Power and Light, and Texas Electric Service Company are operating a lignite-fired plant southeast of Dallas and are jointly planning to build eleven additional plants by 1985 with a total generating capacity of 7,580 megawatts (ERCOT, 1975).

TABLE III-1

South Central Region

Total Thermal Generation for All Systems Reporting[1]

	Years					
	1966	1970	1975	1980	1985	1990[2]
Thermal Generation (millions of kwhr)	116,033	172,118	264,824	405,662	608,463	933,799
% Coal	4.56	4.28	9.18	10.61	11.52	10.09
% Oil	.03	.07	.32	.20	.11	.07
% Gas	95.22	95.47	85.15	71.14	55.69	46.36
% Nuclear			5.24	17.98	32.63	43.45
% Internal Combustion	.19	.18	.11	.07	.05	.03

[1] These estimates depend on availability, deliverability, and price.

[2] 1990 figure on thermal generation incorporates the higher Gulf States Utilities Company energy estimates.

Source: Federal Power Commission, *National Power Survey, 1970.*

Costs for lignite-fired plants will depend to some extent on whether environmental side-effects and costs can be absorbed by the utilities. Since lignite is a "dirty" fuel extracted by strip mining, at least two environmental expenses must be assimilated: the cost of scrubbing stack gases at the generating site to meet emissions standards, and the cost of reclaiming the land from which the fuel has been taken.

According to the 1970 *National Power Survey,* The South Central Region of the United States has sufficient coal reserves to cover its needs beyond 1990. Most experts agree that the cost of this coal will rise due to increasing demand and the upward trend of operating costs. But by how much is not altogether clear. In 1974, *Project Independence* estimated the 1990 average minimum selling price of coal in the Gulf Coast Region (from new surface mines) to be 32 cents per million BTU. If this figure is used, by 1990 the cost of coal in Texas will have increased 52 percent over current prices.

Fuel Oil Costs

Due to declining petroleum reserves in the United States and the artificially high prices established by the Organization of Petroleum Exporting Countries (OPEC) cartel, the costs of fuel oil have sharply escalated in recent years. Today, it is simply unrealistic to anticipate a growth role for fuel oil in the electric-power industry. In 1974, the national average price of oil as a boiler fuel was $2 per million BTU. Unless circumstances change drastically, the U.S. Department of the Interior predicts that the percent of oil used for power generation will drop from its current level of 18 to 8 percent. (U.S. Department of the Interior, *Energy Perspectives,* 1975)

Fuel-Cost Comparison

A major operating cost for all electrical generation plants, with the exception of hydroelectric plants, is that associated with the procurement, transportation, storage, and handling of fuel. This is very significant in terms of the final mills per KWH cost of electricity because fuel costs make up between 75 and 80 percent of average annual production expenses. This indicates that changes in the price of fuel should significantly affect the price of electricity to the consumer.

Table III-2 and Figure III-2 show current cost comparisons among alternative power generating plants with varying capacity factors.* At a 40 percent capacity factor, power plants burning coal have a lower average total cost than do plants that rely upon nuclear fission, oil, or gas turbines. At a 55 percent capacity factor, or higher, nuclear power represents the lowest cost fuel source.

Nuclear Fuel-Cycle Costs

At present there are no nuclear power plants operating in Texas. Nevertheless, the 1970 *National Power Survey* anticipates that nuclear power in the South Central Region of the United States will account for 17.98 percent of all thermal generation by 1980 and 43.45 percent by 1990. It it likely that Texas' percentages will be somewhat lower, since other states in the South Central region are in more advanced stages of nuclear planning and construction (See Map III-1).

In 1969 ownership of nuclear fuel material was transferred from the government to the private sector. By 1973, 43 uranium-bearing mining tracts on government-controlled land in the Uravan Belt in Colorado, Utah, and New Mexico had been opened up for private development (U.S. Atomic Energy Commission, 1973). The long-term effect of this transfer on price remains to be shown. The use of nuclear fuels requires utilities to develop the expertise to assume management responsibility for all economic, technical, and scheduling decisions. This cost and the costs associated with mining, milling, conversion, enrichment, fabrication, shipping, reprocessing, and waste storage must be considered together as nuclear fuel-cycle costs. (Figure III-3 shows the relationships of the various fuel processes more clearly.)

Although some countries use natural uranium in their power reactors, enriched uranium is used in the United States. Enrichment results in fewer constraints on design, more compact cores, longer fuel life, and economic recovery of the plutonium discharge.

Uranium-fuel production begins with mining and milling—processes that produce uranium-ore concentrate (U_3O_8), or yellowcake. (See Table III-3 for the location of uranium-ore reserves.) (Present mining of yellowcake is being done at about $8/lb.) The ore concentrate is then converted to a uranium-hexaflouride gas (UF_6). This operation is currently performed by two privately owned plants in the United States and represents a minor part of the total fuel cost. The uranium gas is then delivered to one of the three gaseous-diffusion plants of the Atomic Energy Commission where the amount of uranium U-235 isotope is increased or enriched. *The enrichment process amounts to about 40 percent of the total fuel cost.*

At this point the enriched gas in converted to a uranium dioxide (UO_2) powder, which is then fabricated into fuel assemblies. *The cost of fabrication is almost 40 percent of the total fuel cost.*

After the fuel has been spent, reprocessing occurs in order to concentrate the radioactive waste for disposal and to recover unused uranium and plutonium for recycling. Reuse of these fuel materials is currently considered essential for fuel economy. But in the future this may become less important since advanced reactors will produce higher levels of radioactive waste which, in turn, will create higher reprocessing costs. Even at present levels the cost of shipping spent-uranium fuel is five or six times that of shipping new fuel.

Other factors than the direct cost components may have a significant effect on total fuel-cycle costs of uranium. Examples are the value of recycled bred-plutonium as a water-reactor fuel and the rate of introduction of the fast-breeder reactor with its anticipated lower fuel costs. Table III-4 shows projections for total fuel costs. (The intermediate conversion to BTU's is not available.) The projected costs for the light-water reactor assumed the following fixed costs: ore at $8/lb., plutonium at $7.50/gram, fabrication at $70/kilogram of uranium (KgU), and shipping and reprocessing at $45/KgU.

In 1973, total average costs, including operation and maintenance costs, for nuclear power plants, with an efficiency factor of 70 and 40 percent was, respectively, 18.84 and 29.97 mills per KWH (See Table III-2).

Fuel-Transportation Costs

The transport of fuel in one form or another constitutes a significant part of the total cost of electricity and therefore has considerable bearing on the type of fuel chosen for a particular plant.

In the past, fuel transportation has not been a problem in Texas because its primary fuel source, natural gas, is easily transported. However, Texas utilities must look to alternative fuel-sources that in general have higher transportation costs. For example, the use of coal to produce thermal generation will more than double between now and 1990 in the South Central Region of the United States.

In the future, for plants located near major-load centers, unit-train deliveries of coal will probably prove most economical. Movement by barges along the Texas coastal zone is also likely. Another type of technology for coal transport is the pipeline-slurry method. Under this method, coal is crushed, mixed with oil or other fluids, and pumped via pipe to the power plant. Pipeline-slurry systems are competitive only when large, annual volumes of coal are involved (above 6 million tons annually) and the contractual period is relatively long.

As a result of increased coal use, future transportation

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*A capacity factor is the proportion of total energy capacity utilized during a period of time.

TABLE III-2

COMPARATIVE COSTS OF POWER-GENERATING PLANTS

Cost Comparisons of Alternative
Power-Generating Plants, 1973 Dollars
(Mills Per KWH at Generating Plant)

ITEM	TYPE OF POWER-GENERATING PLANT			
	NUCLEAR	COAL	OIL	GAS TURBINE
FUEL COST	2.50	5.56	15.83	23.54
OPERATING AND MAINTENANCE EXPENSES[1]	1.50	2.75	2.65	2.50
FIXED CHARGES				
CAPACITY FACTOR = (.7)	14.84	11.48	10.45	5.12
CAPACITY FACTOR = (.4)	25.97	20.10	18.30	8.96
TOTAL COSTS				
CAPACITY FACTOR = (.7)	18.84	19.79	28.93	29.88
CAPACITY FACTOR = (.4)	29.97	28.41	36.78	32.76

[1] Includes environmental costs.

Source: U.S. Department of the Interior, *Energy Perspectives,* February, 1975.

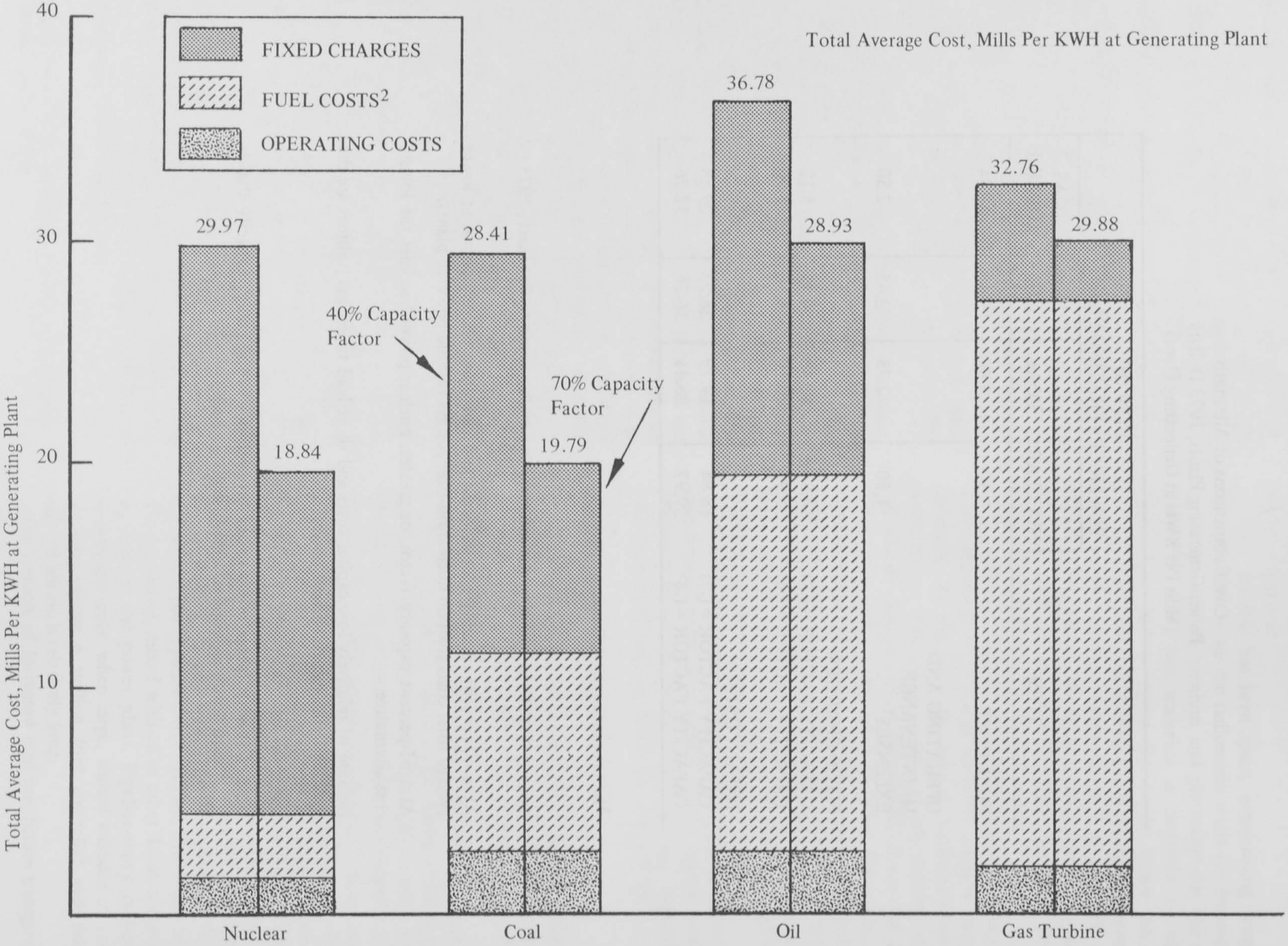
At a 40-percent capacity factor, coal-fired generating plants operate at lower average total costs than do nuclear,oil-fired, or gas-turbine-powered plants.

At a 55-percent capacity factor, or greater, nuclear power becomes the lowest cost alternative.

Because of relatively low capital costs and short lead times, gas turbines are the most desirable source of peak power.

Note: Capacity factor refers to the proportion of total energy capacity that is used during a period of time (usually a year).

FIGURE III-2
COMPARATIVE COSTS[1] OF POWER-GENERATING PLANTS



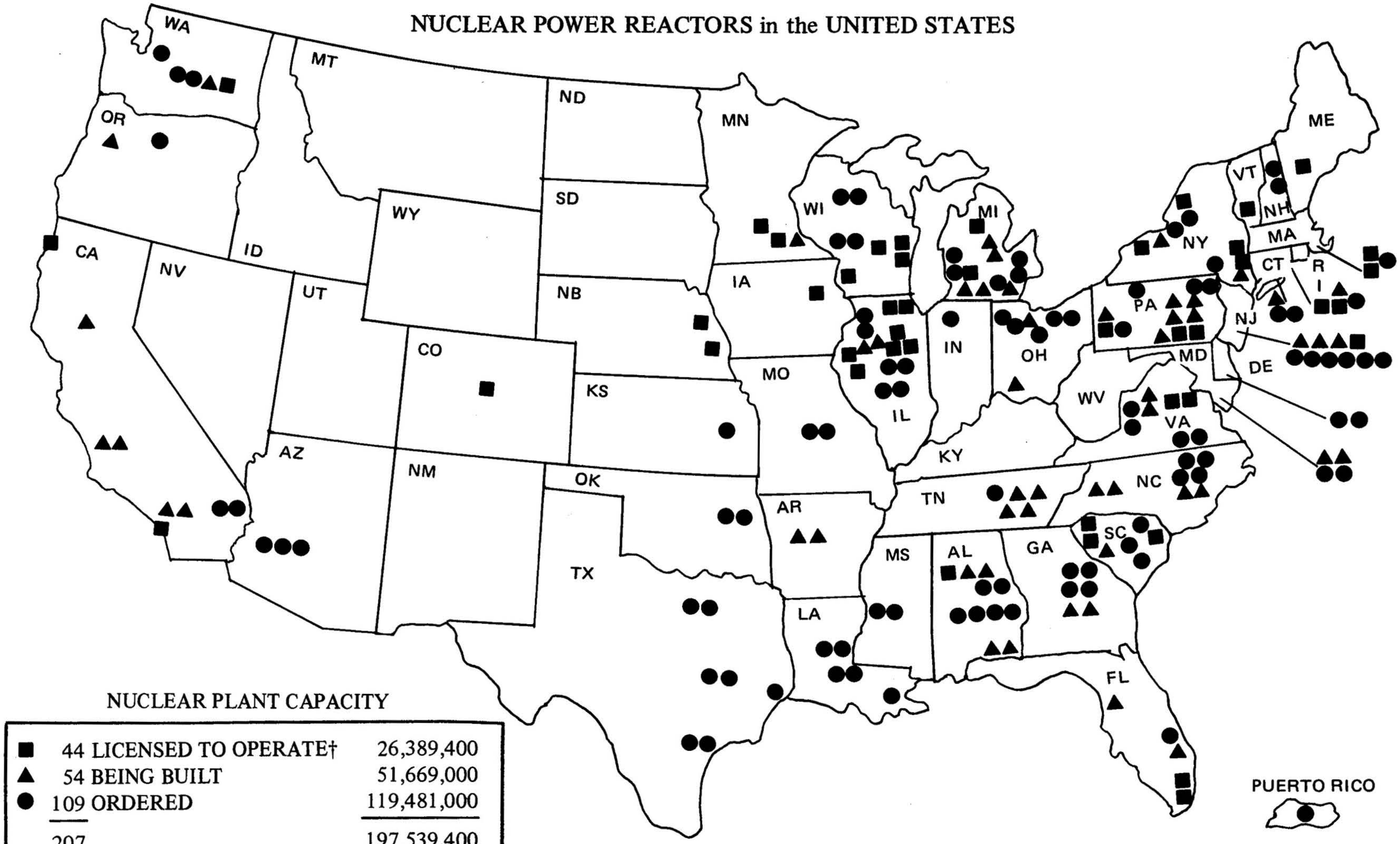
[1] Costs are expressed in 1973 dollars.

[2] Fuel costs are $14.52 a ton for coal, $10.59 per barrel for residual oil, and $11.77 for distillate.

Source: FEA, *Project Independence Report*, 1974, page 286.

MAP 1

NUCLEAR POWER REACTORS in the UNITED STATES



NUCLEAR PLANT CAPACITY

■	44 LICENSED TO OPERATE†	26,389,400
▲	54 BEING BUILT	51,669,000
●	109 ORDERED	119,481,000
	207	197,539,400

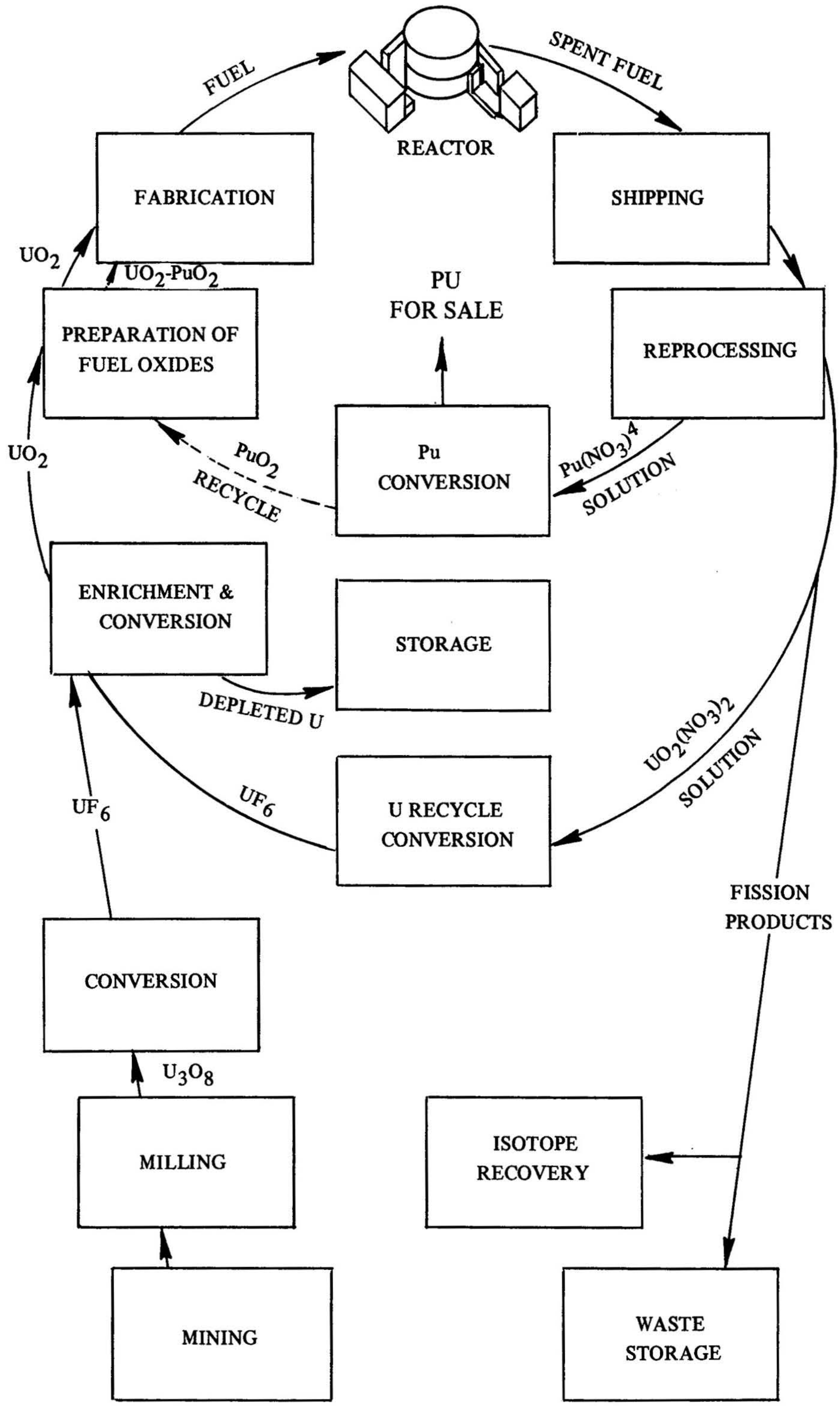
*22 additional generating units are planned for which reactors have not been ordered representing 25,038,000 kilowatts.

Because of space limitations, symbols do not reflect precise locations.

†Includes 2 U.S. owned plants operated by utilities.

U.S. Atomic Energy Commission
March 31, 1974

FIGURE III-3
NUCLEAR FUEL CYCLE
FOR LIGHT-WATER REACTOR



Source: Federal Power Commission, *National Power Survey, 1970.*

TABLE III-3

Estimated Ore Reserves of U_3O_8 By End of 1972
At $8.00/Pound

State	Tons of Ore	% U_3O_8	Contained Tons U_3O_8
1) New Mexico	51,700,000	.27	137,000
2) Wyoming	51,100,000	.19	94,900
3) Texas	10,200,000	.14	14,600
4) Colorado	3,300,000	.27	8,900
5) Utah	2,600,000	.33	8,600
6) Others	8,000,000	.11	9,000
TOTAL	127,000,000	.22	273,000

Source: U.S. Atomic Energy Commission, 1972

Note: Recoverable reserves would increase significantly if price increased to $10.00/pound

TABLE III-4

Fuel-Cycle Costs for a 1,000 -MW Plant[1]

Charge Date	Reactor Type	Fuel Cycle Costs Mills/KWH
1975	LWR	1.7–1.9
1980	LWR	1.5–1.7
1985	LWR	1.4–1.6
1990	LWR	1.4–1.6
1980	HTGR	1.2–1.4
1990	HTGR	1.0–1.2
1985/1990	LMFBR	0.6–0.9

[1] From Report of the EEI Reactor Assessment Panel, April 1970. In 1975 dollars.

costs for coal will make attractive the alternative of locating generation plants at the fuel source and transmitting the electric power rather than the fuel to the load area. Mine-mouth, lignite-fired plants are planned for north central Texas. An important factor in selecting mine-mouth sites will be the extensive system of Extra High Voltage (EHV) transmission lines available. Where they are available, additional transmission investments are minimal.

According to the 1970 *National Power Survey* many of the transmission problems that have affected the competitive status of coal-fired plants in the past will disappear in the next decade as utilization of the EHV grid permits location of plants near the fuel source rather than the load center.

With regard to liquefied natural gas (LNG), the principal advantage is that it can be transported under certain circumstances more economically than natural gas. The four basic processes in an LNG liquefaction plant are purification, liquefaction, storage, and vaporization. One cubic foot of LNG results in a volume of approximately 632 cubic feet of methane at 70 degrees and 14.73 psia (one atmosphere).

The transport of natural gas requires a continuous pipeline between the source and the consumer. In Texas alone, it takes more than 100,000 miles of pipeline to serve the industry's 2.8 million customers (Ryan, 1972). Most of the nation's transmission mains originate in the major producing-states of Texas, Louisiana, New Mexico, Oklahoma, and Kansas. Of the 248,000 miles of transmission mains in the United States, 72 percent are subject to the jurisdiction of the Federal Power Commission.

FUEL-USAGE IN THE UNITED STATES AND TEXAS

More than 70 percent of all electric energy produced in the United States today comes from the burning of the so-called fossil fuels: coal, oil, and natural gas. All three are used in boilers to produce steam to drive turbines. Gas and some oils are also used in connection with gas turbines and internal combustion engines. (See Figures III-4 and 5; Table III-5.)

Coal is the most widely used of the fossil fuels in the generation of electrical power, and most projections show an increase in the amount and the ratio of coal that will be used for generating power in the next 20 years (See Figure III-5).

TABLE III-5

PRODUCTION OF ELECTRIC ENERGY IN THE UNITED STATES 1972, 1973 AND PERCENT CHANGE 1973/1972 BY TYPE OF PRODUCER.

(in billion KWH)

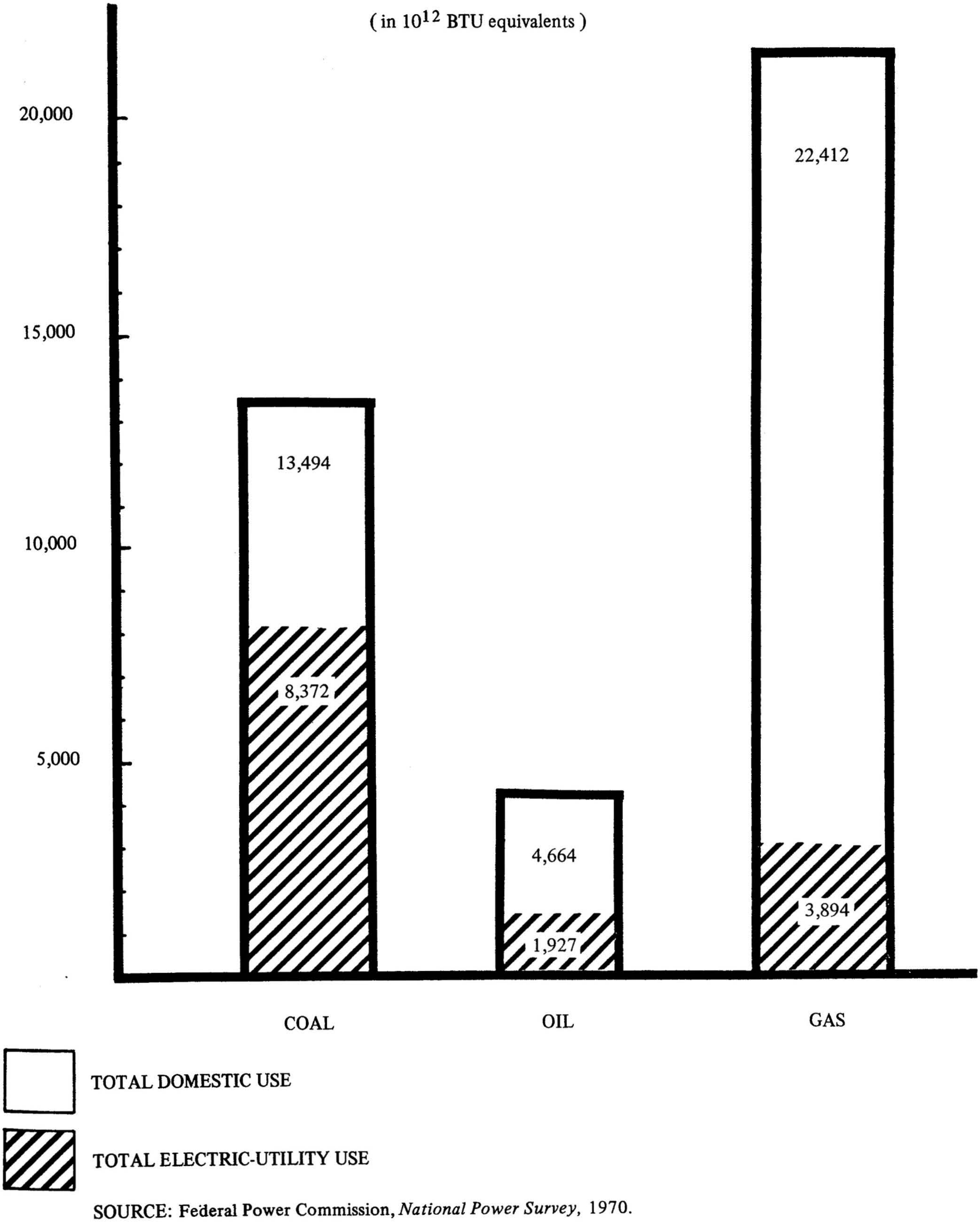
	1973		1972		% Charge 1973/1972
Utility	1,791,984		1,664,937		7.6
Hydro Plants		277,325		268,727	3.2
Conventional Fuel Plants		1,448,964		1,352,093	7.2
Nuclear Plants		65,695		44,117	48.9
Industrial	105,878		103,846		2.0
Total	1,897,862		1,768,783		7.3

Source: FPC *NEWS*, 9-6-74

FIGURE III-4

1970 NATIONAL CONSUMPTION OF FOSSIL FUELS

(in 10^{12} BTU equivalents)

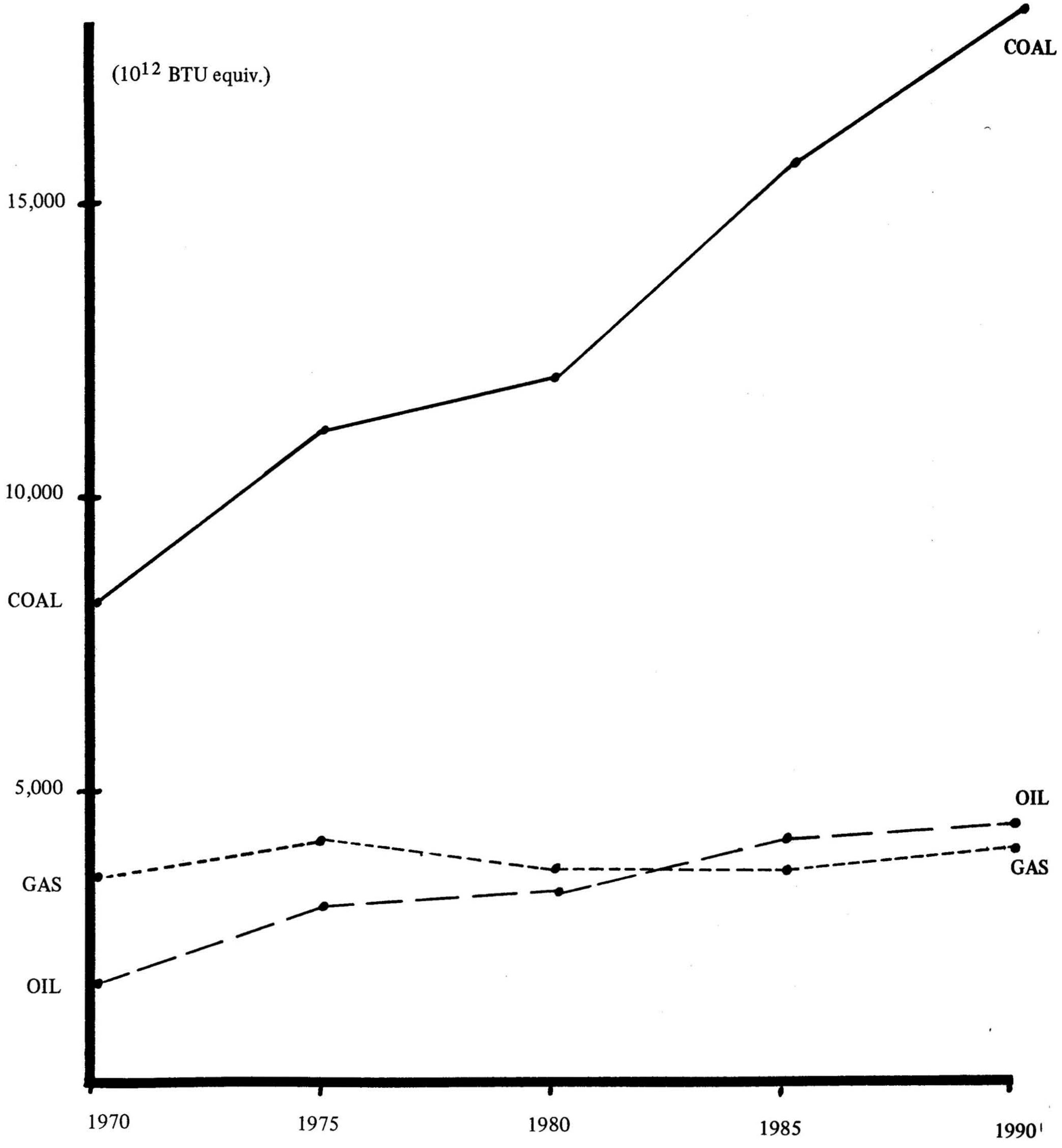


SOURCE: Federal Power Commission, *National Power Survey,* 1970.

FIGURE III-5

ANNUAL CONSUMPTION OF FOSSIL FUELS BY ELECTRIC POWER PLANTS

Projected to 1990



SOURCE: Federal Power Commission, *National Power Survey,* 1970.

In 1970, 605.8 million tons of coal were produced in the United States. Of this amount, 519 million tons were consumed in this country, with 322 million tons (or 62 percent of United States consumption) used to generate electrical power. (FPC, *National Power Survey,* 1970.) However, in Texas utilization of coal for generation occurs at the Alcoa aluminum smelting plant near Rockdale and at the Texas Utilities' generating plant near Fairfield in north Texas; each plant uses lignite. Several other lignite-burning plants are scheduled to begin operation in the near future in the state.

The second most widely used fossil fuel in the United States is natural gas. As a fuel source for electric-power generation, natural gas is in high demand because of its low sulfur content and the ease with which it can be transported and regulated. But natural gas is in short supply, and projections of consumption rates indicate that its role as an energy source for electric-power generation will diminish in the coming years. In 1970, 22,412x10^6 Mcf of natural gas were consumed in the United States, with 3,894x10^6 Mcf (or 17.4 percent of the total United States consumption) used for the production of electrical power. By far the most widely used fuel in Texas, natural gas was burned in the amount of approximately 1,060x10^6 Mcf in the production of electricity in 1970.

The use of oil, the third fossil fuel, has increased almost fourfold since 1960. In 1970, 41.3 percent of the 804.2 million barrels of oil produced in the United States (i.e., 332.3 million barrels) was used in electric-power production. This figure compares with only 85.7 million barrels used for this purpose in 1961. However, due to falling domestic reserves and extremely high international prices (more than $13 a barrel for crude in 1975), the future use of oil is expected to decline sharply. As noted earlier, the most recent estimates foresee a precipitous drop in oil used for power generation by 1985. (U.S. Department of the Interior, *Energy Perspectives,* 1975).

Conventional hydroelectric developments use dams and waterways to harness the energy of falling water in streams to produce electric power. Pumped storage developments use the same principle, but all or part of the water is recycled by pumping.

Hydroelectric plants that now account for 15 percent of total generating capacity in the United States are expected to provide about 12 percent of total capacity of 1990. (Figure III-6 shows the low availability of hydro-power sources in the South Central portion of the United States.) In fact, Texas has only seven hydroelectric plants. Production expenses, in mills per KWH, range from 1.57 up to 8.0 but average about 3.0 which is lower by 0.5 than the average for fossil-fuel or nuclear fuel plants. Generating capacity from hydroelectric plants in Texas is 224.8 MW, which is about 1 percent of the total electricity-generating capacity in Texas.

Texas presently has only one pumped-storage power station—the Buchanan station of the Lower Colorado River Authority, which has a generating capacity of 33.8 MW. One type of pumped storage installation is used solely to provide peaking capacity. This type may be feasible for Texas, since it requires only that water be recirculated between an upper and a lower reservoir.

All types of hydroelectric plants have these favorable operating-characteristics:

- rapid start-up and loading,
- long life and low rates of depreciation,
- low operation and maintenance costs,
- low unscheduled outage rates (time when plant is not producing power), and
- minimal air and thermal pollution.

Hydroelectric plants do, however, occupy large areas of land and often necessitate changes in stream regimens.

The cost per kilowatt of installed capacity of constructing a conventional hydroelectric project varies considerably depending on size, location, land cost, and the necessity to relocate existing facilities such as bridges and roads. On the average, investment costs per kilowatt are substantially higher than for thermal electric plants or pumped-storage projects. However, operating expenses are much lower because there is no fuel requirement. Consequently, as fuel costs increase, conventional hydroelectric-power sites may become more favorable economically. As an over-all ratio, the FPC figures total production expenses for hydroelectric plants at 64 percent for operation and 36 percent for maintenance.

Presently, designation by PL 90-542 includes the Rio Grande in Texas as suitable for future inclusion in a hydroelectric system. The 1970 *National Power Survey* lists two possible hydroelectric projects before 1990 on the Red River for a capacity addition of 200 MW.

For the South Central Region of the country, hydroelectric capacity represented about 5 percent of the peak generating-capacity in 1970. Projected additions in hydroelectric capacity beyond 1970 are for the most part pumped-storage project (See Table III-6). There has, however, been a lack of congressional approval of federal construction of offstream-storage projects. Nevertheless, if all hydroelectric projects that have been projected are installed, hydroelectric power capacity as a percentage of peak load in 1990 will be less than the present 5 percent.

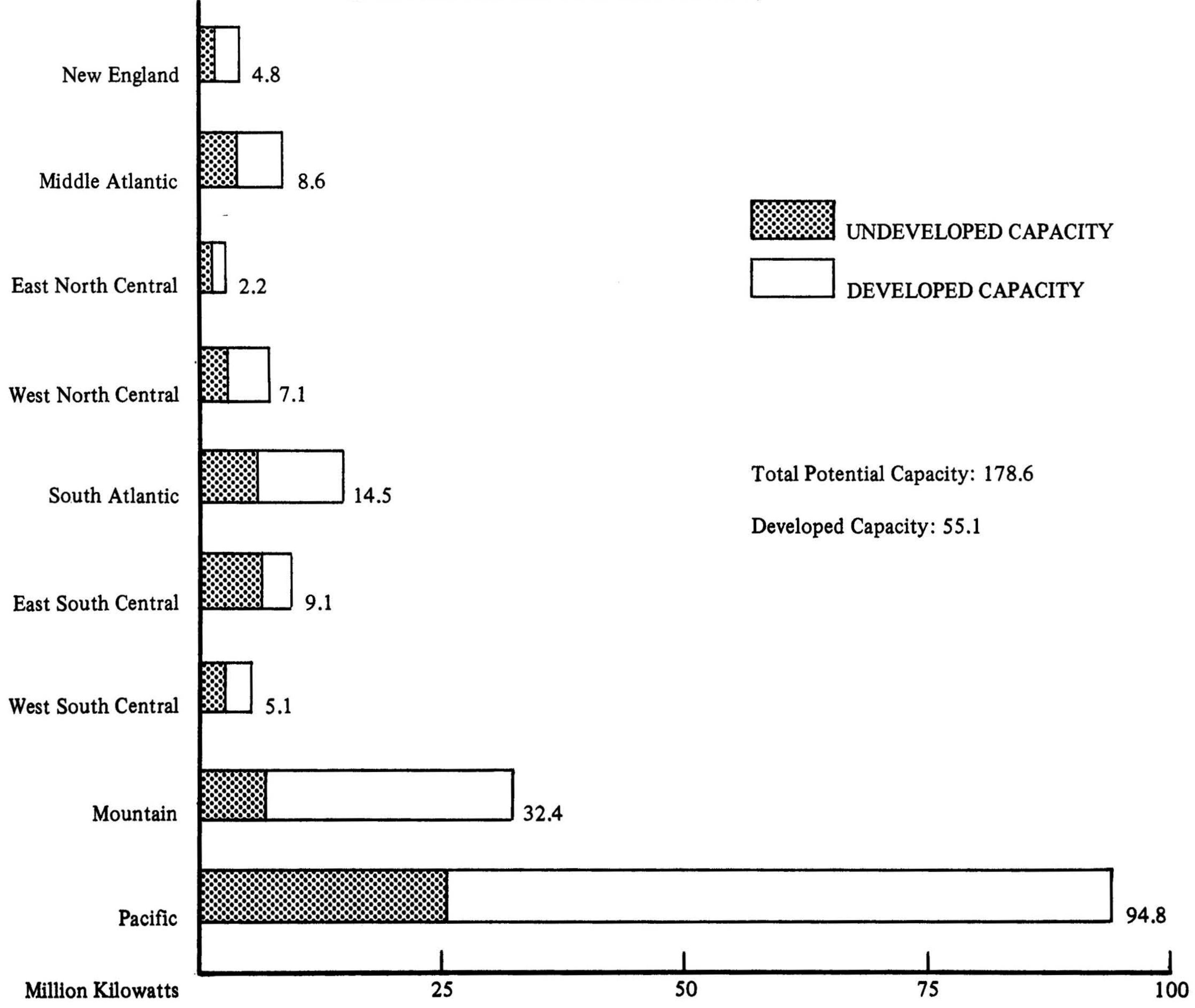
FOSSIL-FUEL RESOURCES IN TEXAS

Natural Gas

As of 1969, virtually all steam-powered, electric-power generation in Texas utilized natural gas for fuel. The two

FIGURE III-6

U.S. HYDROELECTRIC POWER BY REGION, 1973



Source: Federal Power Commission, 1974.

TABLE III-6

SOUTH CENTRAL REGION–HYDRO RESOURCES	Capacity (MW)		
	Existing and under construction	Potential for 1980	Potential for 1990
Hydro	2,221	578	936
Pumped Storage	130	2,666	1,985
TOTAL	2,351	3,244	2,921

SOURCE: Federal Power Commission, *National Power Survey,* 1970.

factors which have made gas the predominant fuel in the Southwest are its relatively cheap price and its natural abundance in the area. Only in the last few years have Texans had to face the fact that the supply of natural gas is indeed exhaustible.

The total, proved natural gas reserves in Texas recoverable under known economic conditions were estimated in 1972 to be 106 trillion cubic feet. In a recent study, the Colorado School of Mines estimated that about four times this amount remains to be discovered in the three-state area of Texas, Arkansas, and Louisiana, but a large portion of this estimate was labeled "speculative". During 1971, total production of natural gas within the state of Texas was 9.57 trillion cubic feet, or about 9 percent of proven reserves. It is significant to note that during this same year Texas consumed about 5.84 trillion cubic feet, or over 61 percent of total state production. This also means that Texas used more than 22 percent of all the natural gas produced in the entire United States. (See Table III-7.)

The electric utilities account for about 20 percent of natural gas consumption in Texas, although indications are that such a heavy dependence cannot continue much longer. Indeed, a number of alternatives have been offered to reduce the immediate pressure on the gas supply. Some have argued that the ratio of proved reserves to production is low due to FPC pricing policies; that if pricing were completely a function of market value, exploration would be more profitable, and the level of proved reserves would increase. Others have argued that Texas production could easily be supplemented with imported liquid natural gas.

An alternative solution might be found in the production of synthetic natural gas from coal, naptha, or other hydrocarbons. The real promise in this field seems to lie with a form of coal gasification such as the "Kellogg process" (*Chemical and Engineering News*, December, 1972). Other attempts have been made to utilize the vast United States coal reserves in this manner, but the Kellogg process might be the first to demonstrate the economic feasibility of coal gasification. (For a discussion of other gasification processes see *Energy in Texas Vol. II.*)

While these strategies might serve to temporarily ease the pressure on natural gas reserves, it is difficult to imagine them as long-range solutions. If Texas experiences the predicted growth in demand for electricity, power companies will have to look to alternative fuel supplies.

Coal

Texas has two types of coal that are potential sources of fuel: bituminous coal and lignite. The bituminous deposits were mined from 1895 until 1943, but none has been mined since that time. There are an estimated 6,100 million short-tons in beds more than 14-inches thick which have yet to be extracted, but the high sulfur-content of these particular deposits makes this coal unacceptable for burning at present. The director of research at Texas Electric Service Company has noted that although no acceptable method has been established for removal or control of the sulfur by-products of combustion, a breakthrough in this area could make it possible to use the Texas bituminous deposits as a fuel source. These resources are still potential sources of processed fuels and chemicals.

TABLE III-7

RESERVES AND CONSUMPTION OF NATURAL GAS IN TEXAS

		Amount (trillion cu. ft.)
Colorado School of Mines estimate of undiscovered natural-gas reserves in the Southwest (Texas, Arkansas, Louisiana) as of December 31, 1972	Probable**	136
	Possible	207
	Speculative	110
	Total	453
Total proved natural-gas reserves in Texas as of December 31, 1971		106
1971 production of natural gas in Texas		9.57
1971 consumption of natural gas in Texas		5.84
1970 volume of natural gas consumed by electric utilities in Texas		1.06

** Colorado School of Mines defines their terms as follows:

"Probable" is that future supply from known accumulations and new pool discoveries associated with existing fields.

"Possible" is that supply from new field discoveries associated with productive formations.

"Speculative" is that supply from new field discoveries associated with formations not previously productive.

(Colorado School of Mines, 1971)

As of 1970, Texas lignite deposits were being mined in only three locations: Milan County (for use by an Alcoa plant), Harrison County (for use in preparing activated carbon by Atlas Chemical Industries, Inc.), and Freestone County (for the use of a newly constructed power plant jointly owned by Texas Power and Light, Dallas Power and Light, and Texas Electric Service Co.). The power plant went into operation in 1971 and 1972, and is the only one of its kind in the state. While the United States Geological Survey estimates that there are over 3,200 million short-tons of lignite remaining in the ground in Texas, it is not known exactly how many power plants these deposits could support, since they are spread over a wide geographic area. The director of research of the Texas Electric Service Co. has estimated that Texas lignite deposits could only be expected to support four or five plants. This makes it seem doubtful that Texas coal could serve as a long-range substitute for natural gas, but there is no question that the state could more fully exploit its lignite deposits and thereby relieve some of the pressure created by an overdependence on one fuel source.

In addition to developing its own coal resources, Texas could consider importing coal from other regions of the country. Schurr has shown that there is no foreseeable shortage of coal nationwide, and has predicted that United States net exports will increase in the coming years (Schurr and Homan, 1971). In the past, the four-state area of Texas, Arkansas, Oklahoma, and Louisiana has imported millions of tons of coal from other parts of the country, but it has been used exclusively for coke and gas plants; none has been used for utilities since 1963 (Bureau of Mines, 1970).

There are also problems associated with coal importation, primarily transportation and storage of the enormous volumes of coal required by a power plant. Single-purpose or "unit train" contracts with the railroads presently offer a viable transportation alternative, and Houston Lighting and Power is investigating the problems of inventory and storage. In the future, however, the likelihood of continuous, large-volume use of coal will make the construction of slurry pipelines economically attractive.

Serious consideration of coal as a fuel in Texas is relatively recent, although a trend may be developing. For example, the 1970 *National Power Survey* explains the prospects this way:

> Although coal does not supply a major portion of the requirements of fuel for power generation at this time in the South Central region, it appears that it will play an increasing role beginning in the late 1970's. This is evidenced for (sic) the majority of systems seriously considering the use of coal and lignite as a fuel for units projected during the period.

Petroleum

Approximately 18 percent of all electricity generated in the United States is produced by using petroleum as an energy source. The major form of oil used by utilities is residual fuel oil, and Texas refineries alone produced 41 million barrels of residual fuel oil in 1970.

While utilities in Texas might look toward petroleum as an emergency fuel source, the real potential for residual fuel oil rests on international developments that affect the price of crude oil.

FUEL PERSPECTIVES FOR THE FUTURE

The foregoing analysis of fuels used for power generation in Texas has emphasized the problems of a single-fuel economy. Until recently, natural gas was burned to the virtual exclusion of other boiler fuels to produce electricity. This was due partly to price and partly to the abundance of the resource–conditions that no longer prevail. It would seem therefore, that for the short-term, boilers must be adapted to burn lignite, coal, and, on a temporary basis, fuel oil. During this period, the most effective boiler technology will be one that can utilize a combination of coal, fuel oil, and natural gas, depending upon their price and availability. The long-term future is more difficult to anticipate, but the economic advantage would appear to favor coal and nuclear power. However, the extent to which these fuels will displace natural gas is undetermined.

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CHAPTER FOUR

ENVIRONMENTAL CONSIDERATIONS OF ELECTRIC-POWER GENERATION

INTRODUCTION

The previous chapter emphasized the importance and availability of various fuels for power production. This chapter focuses on an additional resource limitation: the preservation of a safe, healthy, and clean environment. As a matter of national policy, everyone would appear to favor continued social growth and economic advancement. But for many years the negative environmental effects of growth have been rapidly accumulating as the rate and magnitude of growth have increased. Now many kinds of environmental degradation can no longer be ignored. Growth has forced environmental considerations to the fore, and we must begin to determine the acceptable tradeoffs between growth and maintenance of the environment.

Increasingly, environmental considerations such as air and water pollution, site-location, and fear of nuclear power plants will be the most important factors in deciding whether a particular power plant will be built, what energy system it will use, and when it will be available.

In the long run, one hope for resolving conflicting desires for energy and a clean environment lies in possible technological breakthroughs, but the advances in technology that will be applied to commercial power plants in the next 20 years are probably not sufficient to resolve the conflict. As a result, present and future short-range decisions on the production of electric power must carefully weigh the environmental effects and determine whether the costs are justified in terms of other social benefits.

Fossil-Fuel Plant Emissions

The principal pollutants of fossil-fuel plants are sulfur dioxides, nitrogen oxides, carbon dioxides, carbon monoxides, smoke soot, and fly ash.

A modern fossil-fuel plant without controls can discharge through its stacks on the order of 1,000 tons of SO_2 (sulfur dioxide) and several tens of tons of NO_x (nitrogen oxides) per 1,000 megawatt capacity per hour at full operation (Barth, *et al.*, 1970). In the United States, current estimates of annual emissions from power plants are 19 million tons of SO_2 and 4.2 million tons of NO_x. These values represent about 62 percent of SO_2 emissions and 24 percent of NO_x emissions from all sources. Among stationary sources including industrial processes, power plants contribute about 41 percent of the total particulate emissions, 65 percent of the total SO_2 emissions, and 55 percent of the total NO_x emissions (EPA, February, 1972).

In Texas 97 percent of the total electric-power generating capacity during 1970 came from steam fossil-fuel plants. With only a few exceptions, these plants were built to burn natural gas (the cleanest fossil fuel). Nationwide in 1969 only 28.7 percent of all electricity was produced in natural-gas-fired steam plants; 59 percent came from coal and 12.3 percent from oil. Estimates are that the heat derived from each of these sources will almost double by 1980 and will at that time comprise an estimated 63 percent of total generated electric power. Unless improved control technologies are developed and applied by the year 2000, SO_2 emissions from power plants will probably increase 5 times and NO_x emissions 3.5 times. Likewise, emissions of fine particulate matter in the optical range of stable aerosols are expected to increase fourfold from the present 3.4 million tons per year.

The past concern with stack effluents from power plants has focused on maximum ground-level concentrations in the vicinity of the plant. As plant size has grown in the last 10 years, the electric-power industry has tried to hold down ground-level concentrations resulting from the increased emissions by increasing the height of the stack. The average height has gone from 74 meters in 1960 to 186 meters in 1969. As a result the ground area that is subject to air pollutants has been greatly increased while the chance of observing high concentration at any one point has been reduced (Barth, *et al.*, 1970).

The effects of pollution outputs vary considerably depending on the air-pollution potential of a site. The site must be evaluated in terms of possible emissions, meteorological-climatological factors, topography, and the effects of decay or removal of pollution by natural processes. At the present time, the task of defining the behavior of plumes from the power-plant boilers and cooling towers with respect to meteorology and topography is far from complete, and an intensified study is needed. Likewise, the task of defining the chemistry and physics of such plumes in the atmosphere is in a rudimentary stage. Perhaps most important, a more definite determination of possible effects of the original or transformed pollutant is needed.

A 500-megawatt plant using 12,000 BTU-per pound coal containing 3 percent sulfur and 8 percent ash (80 percent up the stack) would have potential emissions of 12.5 tons of SO_2 and 13.3 tons of particulate matter per hour. With a 99 percent efficient electrical precipitator, particulate emissions would still be 266 pounds per hour (Faith and Atkisson, 1972). Table IV-1 compares the pollutant emissions of natural gas, fuel oil, and coal per 10^6 BTU input.

Natural gas is in great demand because it burns relatively cleanly. Its hydrocarbon output is negligible with proper combustion. A high-usage rate of natural gas in Texas for electric-power production is the primary reason the state has avoided severe air pollution problems often associated with electric-power generation. Yet increased emissions due to increasing coal and lignite usage is a problem Texas will face in the future. Table IV-1 also shows that coal produces by far the highest quantity of pollutants.

TABLE IV-1

SPECIFIED EMISSIONS BY TYPE FUEL
PER 10^6 BTU INPUT

	SO_2 Sulfur Dioxide	NO_2 Nitrogen Dioxide	Particulates	HC Hydro Carbons	Aldehydes
Natural Gas	.0004	.39	.015	No	.001
Fuel Oil	1.839 range .40-4.60	.747 range .49-1.12	.06 range .05-.11	.02	.004
Coal	3.8 range .8-7.2	1.3 range .3-2.4	4.5 range 1-8	.20 range .008-.4	.0002

Source: Joe O. Ledbetter, *Air Pollution,* M. Dekker, New York, 1972.

Characteristics of Pollutants

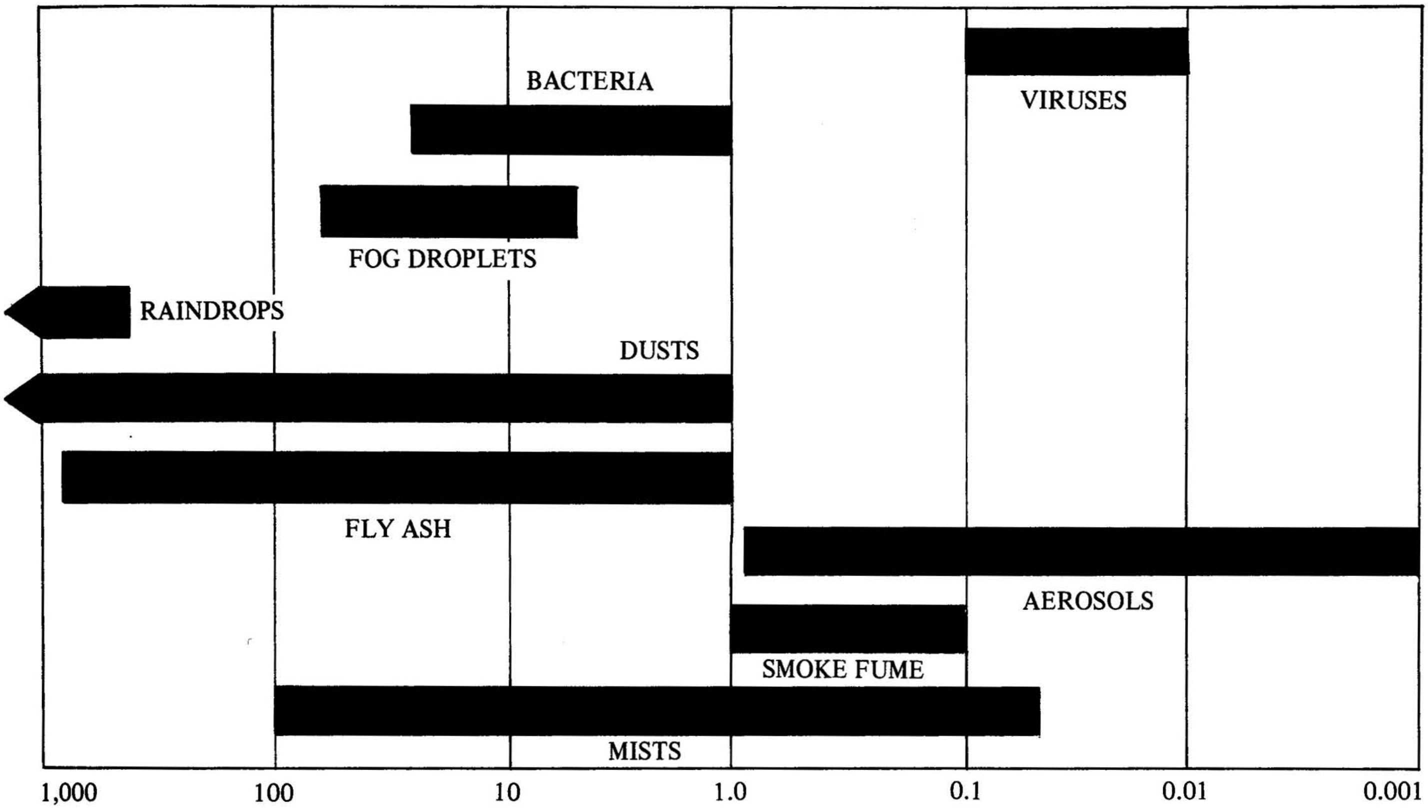
Pollutants can exist as solid matter, liquid droplets, or gas. Both the solid and liquid matter are called particulates. The relative sizes of particulates are shown in Figure IV-1. Very small aerosols can act as nuclei on which vapor condenses relatively easily. Thus fogs, ground mists, and rain may be increased and prolonged. About one-half the particulates in the urban air are estimated to be less than 2 or 3 microns in size. These particulates can penetrate deep into the lungs, carrying such harmful chemicals as sulfur dioxide with them. Particulates also act as catalysts. An example of this characteristic is the change of sulfur dioxide to sulfuric acid, aided by moisture and catalytic iron oxides.

Over 50 percent of the sulfur oxide emissions to the air each year come from fuel combustion in stationary sources. The major oxide of sulfur that is produced in combustion is sulfur dioxide (SO_2), a heavy, pungent, colorless gas that combines easily with water to form sulfurous acid (H_2SO_3). Sulfurous acid easily joins with oxygen in the air to become an irritating mist, sulfuric acid (H_2SO_4). Sulfur oxides can yellow the leaves of plants, dissolve marble, and eat away iron and steel. They can cut down light from the sun and limit visibility, and in sufficiently high concentrations can affect one's breathing by irritating the upper respiratory tract. There also exists concern over the global effects of sulfate particles, which are the most commonly occurring particles.

The combustion process gives off a great deal of carbon, either as unburned or partly burned particles or as carbon monoxide or carbon dioxide. Carbon particulate matter is known as soot. Carbon monoxide is primarily a product of the automobile, although power plants do add a small increment to the atmosphere.

Hydrocarbons are a class of compounds containing carbon and hydrogen in various combinations. Power plants

FIGURE IV-1
THE SIZES OF PARTICULATES IN MICRONS
(1 micron equals 1/1,000 of a millimeter, or 1/25,000 of an inch)



Source: *Air Pollution Primer*, National Tuberculosis and Respiratory Disease Association, New York, New York, 1969.

are not a major source of hydrocarbons. Some hydrocarbons take part in the photochemical reaction that creates smog and some are believed or known to be carcinogenic.

Only two of many possible combinations of nitrogen and oxygen are considered pollutants–nitric oxide (NO) and nitrogen dioxide (NO_2). Power plants emit about 38 percent of all nitrogen-oxide pollutants. Nitric oxide itself is relatively harmless, but when emitted to the atmosphere, varying amounts are converted to nitrogen dioxide. In Texas, because of the higher temperature and greater amounts of sunlight, more nitrogen dioxide is formed from a given amount of nitric oxide than would be formed in a cooler and less sunny climate. Nitrogen dioxide, a yellow-brown gas, can limit visibility and has a pungent, mildly sweet odor that can be detected at 1 to 3 parts per million. It reacts with water or raindrops to produce nitric acid, which can corrode metal surfaces even at small concentrations.

Photochemical smog is created by the sun's energy being absorbed by nitrogen dioxide in the presence of some hydrocarbons. In the process the compound separates into nitric oxide and atomic oxygen. Atomic oxygen reacts with a number of other constituents to form ozone. Ozone can cause coughing, headaches, and severe fatigue. Moreover, it can damage the leaves of plants, crack rubber, deteriorate fabrics, and fade colors. Ozone is also a participant in a highly complex series of continuing reactions which produce other pollutants. Another smog product is PAN (peroxyacyl). It is known to make the eyes burn, irritate the lungs, and damage agricultural products. Still another group of photochemical smog products are the aldehydes. Aldehydes are produced in a photochemical reaction and are present in the direct emissions of automobiles and fossil-fuel electric power plants. They are powerful irritants of the eyes, skin, and respiratory tract.

Emission Standards

Although emissions of pollutants vary considerably depending on the fuel used, federal and state air-quality standards require that actual emissions not raise the ambient air quality above specified limits. This means a plant using high-sulfur coal must invest in pollution-abatement equipment to bring stack emissions in line with air quality standards.

The state uses the federal criteria and control technique documents, which set standards for air pollution, to devise implementation plans to achieve the standards within a reasonable period of time. The Environmental Protection Agency (EPA) reviews and approves the state plans. Criteria documents have been issued on all the major pollutants from fossil-fuel power plants. EPA performance standards for selected emissions from new fossil-fuel steam generators are listed in Table IV-2.

TABLE IV-2

Standards of Performance for New Stationary Sources

Source	Emission standard (max. 2-hr. average, except opacity)
Fossil-Fuel Fired Steam Generators	
Particulate matter	0.1 lb/MM BTU heat input 20% opacity
Sulfur dioxide	
Liquid fuel	0.8 lb/MM BTU heat input
Solid fuel	1.2 lb/MM BTU heat input
Nitrogen oxides	
Gaseous fuel	0.2 lb/MM BTU heat input
Liquid fuel	0.3 lb/MM BTU heat input
Solid fuel	0.7 lb/MM BTU heat input

Source: Title 40, *Code of Federal Registration*, Part 60, December, 1971.

Texas has submitted a plan to implement control of air pollution that will bring the state into compliance with federal air-pollution standards. In meeting these standards, Texas' major pollutant problem will be keeping hydrocarbon emissions and NO_x emissions (both of which are produced to some extent by fossil-fuel power plants) within the ambient air concentrations specified by EPA.

Abatement Costs

Abatement costs associated with controlling emissions vary considerably depending on the fuel burned, emission standards that must be met, and the type of abatement equipment purchased. Table IV-3 estimates the annual cost of meeting air-quality standards for the nation to be over 1 billion dollars per year.

SO_2 emissions can be controlled through the use of low-sulfur fuel, removal of sulfur from fuel prior to combustion, or removal of SO_2 from the stack gases. Costs for each of these processes range from 3 cents to 8 cents per million BTU. According to the Battelle Memorial Institute, the average cost of sulfur control for a 1,000-MW plant is 0.8 mills per KWH if the load factor is 50, and 0.5 if the load factor is 80. This represents an increase in the cost of electricity of 10 to 16 percent.

Other studies place the cost even higher. In 1973, for example, an interagency committee of the federal government reported that the costs of stack-scrubbing devices and treatment facilities would run from 12.2 cents to 16.7 cents per million BTU (Sulfur Oxide Control Technology Assessment Panel, 1973). These figures were challenged by the Federal Power Commission, whose projections indicated a range of 20.33 cents to 27.55 cents per million BTU (Gakner and Jimeson, 1973). Both of these estimates, however, were low in comparison to a study by Commonwealth Edison that placed scrubber costs between 50 cents and 63 cents per million BTU (Commonwealth Edison, 1973).

TABLE IV-3

STATIONARY FUEL COMBUSTION SOURCES – ESTIMATES OF POTENTIAL AND REDUCED EMISSION LEVELS AND ASSOCIATED COSTS

		Quantity of Emissions 1/ (Thousands of Tons per Year)			Associate Emission Control Level 1/ (Percent)			Control Costs (Millions of Dollars)	
Source	Year	Part	SO_X	NO_X	Part	SO_X	NO_X	Investment	Annual
Steam-Electric Power Plants	1967	3,400	15,400	4,300	78	0	0		
	FY 77 W/O 2/	5,600	27,600	7,200	78	0	0		
	FY 77 W 3/	2,800	2,760	7,200	98.5	90	0	4,660	1,360

1/ Emission abbreviations are: particulates (Part), sulfur oxides (SO_X), and nitrogen oxides (NO_X).

2/ Estimates without (W/O) implementation of the Clean Air Act are shown.

3/ Estimates with (W) implementation of the Clean Air Act are shown.

Source: Environmental Protection Agency, *The Economics of Clean Air*, Annual Report to the Congress, February, 1972.

Concluding Comments

Both scientific evidence on the contribution of power plant chemical emissions to air pollution problems and the acceleration of world electric-power needs indicate the importance of preventing emissions of such pollutants to the limit of feasibility, rather than relying on procedures (e.g., tall stacks) that are directed only to the reduction of local ground-level concentrations. The increasing demand for energy and therefore the increasing use of fossil fuels, particularly coal, may result in the imposition of stricter pollution controls on fossil-fuel users in order to insure a cleaner environment. But as the cost of environmental protection is rolled into the price of electricity, it is likely that renewed efforts will be made to relax air and water quality standards. If energy shortages become acute and stagflation continues to characterize the economy, these forces will be difficult to resist.

THERMAL DISCHARGES TO THE ENVIRONMENT

Thermal discharges and electric power plants go hand in hand. Over the years, waste heat as a percentage of the power capacity of an average plant has decreased. However, concern over waste heat has increased as the number and size of power plants has grown, since the total heat emitted has increased. As a result, the press, the scientific community, electrical and environmental engineers, and the public have made heat a seriously considered issue, even though most experts do not understand all the consequences of such emissions.

At one extreme, the electric-power industry gives defensive arguments for thermal discharges by focusing on the need to avoid brownouts and power failures, and to improve the standard of living. At the other extreme, environmentalists argue that damage to the ecosystem and aquatic life may result from even small heat discharges from man-made sources.

Pollution and Magnitude of the Problem

Thermal discharges are usually designated as "polluting" when they lower or raise water temperatures to levels that make it unusable by other water-use interests. Whether heat discharges into water constitute "pollution" or not is a matter of prevailing legislative or administrative definition. This section does not propose to resolve those issues. Its purpose is rather to review the effects of heat discharges.

In an electric power plant, the energy of nuclear fission or the energy of burning fossil fuels is used to generate steam; steam turns the turbine, and the turbine powers the generator. Once the steam goes through the turbine, it has to be recondensed into water in a condenser. The condensers are cooled with water taken from a lake, cooling pond or tower, river, estuary, bay, or ocean.

Theoretically, due to fundamental limitations arising from the second law of thermodynamics, all heat from fossil-fuel combustion or nuclear fission cannot be converted into electricity. In practice, more than 60 percent of it is dispersed as waste heat, which makes electricity-generating plants less than 40 percent efficient. Well-maintained fossil-fuel plants have been about 38 percent to 40 percent efficient, whereas nuclear-fission power plants have been about 30 percent to 32 percent efficient. Thus, for every KWH of electricity produced in a conventional plant, about one and one-half KWH of energy (about 2.3 KWH, in the case of a nuclear power plant) enter the environment as waste heat. In terms of the quantity of water required, this means that 30 gallons of water (around 46 gallons of water for a nuclear power plant) per KWH of electricity are needed to meet the federal heat-dispersion guidelines.

Of the 60 billion gallons of water per year now used by steam condensers in American industries for cooling, about three-fourths is used in electric power plants. Thus far, the thermal effects of this waste heat have become a problem only in some limited areas. But power development is growing rapidly, without waiting for technology to provide solutions for its thermal effects. Present projections indicate that by the year 2000, a volume of water equivalent to half the available fresh water runoff in the U.S. will be withdrawn to cool power plants.

Effects of Thermal Discharge

A body of water is divided into three thermal layers: a) the epilimnion; b) the thermocline; and c) the hypolimnion. Waste heat can disrupt the layers and inhibit the intermixing which is essential if all are to receive oxygen. The effect of a withdrawal from a body of water or the discharge of waste heat into that body could be defined by any one or a combination of factors:

- volume of water discharged or withdrawn in relation to mean streamflow;
- surface area of discharged or withdrawn water;
- depth of water;
- shading;
- elevation;
- temperature difference between the discharged water and the stream;
- downstream flow-rates.

There are several harmful effects of thermal discharge:

- The capacity of the streams to assimilate other wastes is decreased, forcing other stream-users to increase the quality of their effluents if water-quality standards are to be met for the stream as a whole.
- The temperature increase in the water stimulates the growth of oxygen-consuming algae and other plants, thus reducing the vital supply of oxygen available for fish and the lower organisms on which they feed. Increased temperature also increases an aquatic organism's metabolic rate and need for oxygen.
- The temperature changes alter, and may disrupt, the ecology of aquatic organisms, with perhaps an impact on reproduction capabilities.
- The temperature change may disturb the equilibrium of plant and animal life (spawning and other critical activities). A plant, animal, or fish unable to live in the changed conditions will leave or die, or be replaced by competitive, more tolerant species, perhaps endangering the food chain on which all aquatic biota are dependent.
- The high temperatures may be lethal to fish if the distribution of heated water in the stream is not proper and adequate.

Again, it should be emphasized that the effects of waste heat discharges are not fully understood. Given the constraint that the efficiency of electric power plants is not going to increase significantly in the near future, waste heat must be released into the environment. This will surely affect the environment, but its effects could be minimized by proper heat-dissipation systems.

Dissipation of Heat

The National Technical Advisory Committee on Water Quality Criteria, in its interim report of June, 1967, suggested guidelines for thermal dispersion:

—maximum temperature increase for rivers:	5.0°F
—maximum temperature increase for lakes:	3.0°F
—maximum temperature increase for coastal waters:	1.5°F (summer) 4.0°F (fall - spring)

These standards can be achieved through various dispersion methods, including:

Once-through cooling

1. Dilution of the heated stream by mixing it with a large quantity of ambient water prior to discharge. This requires an additional pumping system and a place to do the mixing.

2. Use of a large volume flow of cooling water, thereby achieving a smaller temperature rise. This requires a larger condenser and larger pumps and water conduits.

3. Discharge in a fast jet, to promote rapid mixing of the heated discharge with the receiving water, or the use of

a large number of discharge points. This requires low temperature and rapid movement of the receiving body of water.

4. Withdrawal of water from locations deep enough that its natural temperature is cooler than the surface water temperature by about the same amount as the temperature rise through the condenser. This requires a cool, deep, and large body of water which may eventually become a marsh.

Once-through cooling systems can have the greatest impact on the environment, especially when discharge is into lakes where the cooling capacity is at a minimum because of lack of water movement. Waste-heat discharges into rivers are often less serious due to the cooling effects of stream-flow and turbulence. The dynamic nature of rivers and coastal waters precludes detailed knowledge of how they are affected by warm-water emissions. Studies are underway using infra-red light photography to determine the patterns of warm-water dispersion.

Other methods (when once-through cooling systems cannot be used due to the absence of sufficient water or adverse effects on aquatic life)

1. Cooling pond—this involves the controlled recirculation of the cooling water in a natural or man-made pond or lake, with natural heat transfer to the atmosphere. This may require about 1,000-2,000 acres of land for a 1,000-MW plant. It has been estimated that for every MW of generating capacity an electric-power plant requires one acre of cooling reservoir, 10 to 60 feet deep, at a building cost of $2,500 per MW. A cooling pond may be used as an intermediate step before returning water to a river or a lake. Such a pond may remove a large quantity of water from the total water available to the area which is significant in the summer when scarcity of water forces a tradeoff between commercial, industrial, and residential usages.

2. Spray pond—the heated cooling-water is sprayed into the air to promote heat transfer and cooling. It is then caught in a reservoir and recirculated to the condenser. This may increase the frequency and severity of fog, rainfall, and high-humidity conditions, creating hazards for highway and airport traffic.

3. Combined spray and cooling pond—this combination allows for a smaller pond but the fog problems associated with the spray pond remain.

4. Natural- or forced-draft, wet-cooling tower—this is essentially a spray-pond-in-a-building. The building prevents excessive loss of water to the atmosphere, since the water is allowed to fall down instead of spraying up. The operating cost is quite high, although the initial capital cost is lower.

5. Natural—or forced-draft, dry-cooling towers—these towers rely on the transfer of heat by conduction and convection. The circulating coolant is sealed into the system. It is not presently economically competitive with other methods and systems, and so is not used unless water for cooling purposes is unavailable. This system does not raise significant thermal-pollution issues, does not require water circulation, and does not create fog problems.

Figure IV-2 illustrates various cooling-cycle flows diagrammatically. Table IV-4 gives heat rejection data for thermal power plants, while Table IV-5 shows cost estimates of different types of cooling systems for fossil-fuel and nuclear fuel electric power plants. Cost alone, however, cannot determine the type of plant or cooling system installed; without adequate long-range planning (including environmental and economic considerations), the utilities and the community may incur excessive financial and environmental costs.

Conclusion

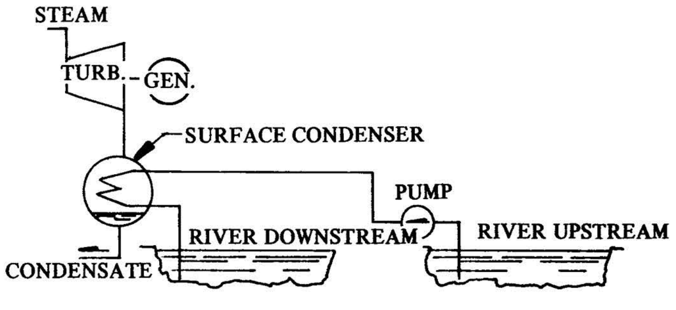
Of utmost importance to the electric-power industry is the availability of water for condenser cooling. The expected growth of nuclear power plants will raise the potential for higher thermal discharges and increase the need for cooling water. The water requirement considerations are important because allocation of water is becoming a critical matter for the entire nation, especially in arid regions such as south and west Texas. Misuse of water through inadequate planning may cause a shortage for both local and downstream consumers.

Table IV-6 summarizes heat-rejection data concerning land, water, and investment costs of all types of cooling systems for both fossil-fuel and nuclear-fuel power plants.

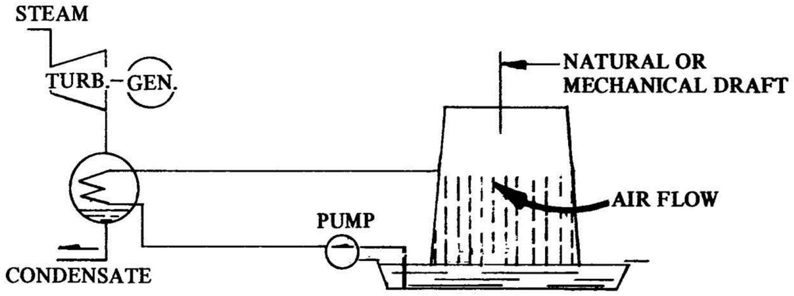
The concept of "ecosystem" is based on the fact that any change in surroundings can affect life. Man, being part of the ecosystem, is affected by whatever affects the system. It is difficult to evaluate the effects of heat on aquatic life. But it is even more difficult to determine the effects on man himself.

FIGURE IV-2

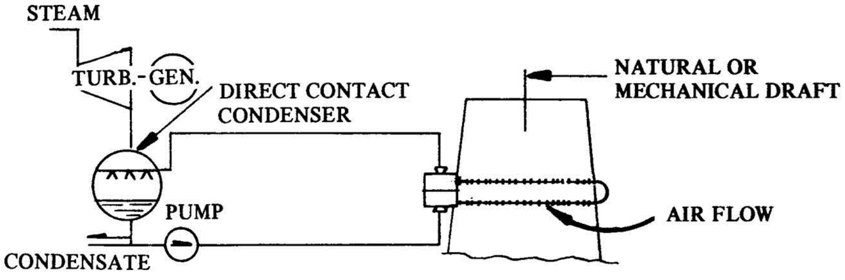
COOLING-CYCLE FLOW DIAGRAMS



A. ONCE-THROUGH COOLING CYCLE



B. EVAPORATIVE ("WET") COOLING TOWER CYCLE



C. DRY COOLING TOWER CYCLE

Source: William H. Steigelmann, "Alternative Technologies for Discharging Waste Heat," *Power Generation and Environmental Change*, ed. by David A. Berkowitz and Arthur M. Squires, The MIT Press, Cambridge, Massachusetts, 1971.

TABLE IV-4

THERMAL POWER PLANT HEAT-REJECTION DATA

	Nuclear-fueled	Fossil-fueled
Planet net generating capability	1000 MW	1000 MW
Plant thermal efficiency	~32.5%	~40%
Plant heat rate	10,500 BTU/KWH	8,600 BTU/KWH
Total heat losses	7.1 X 10^9 BTU/h	5.2 X 10^9 BTU/h
Heat discharged directly to atmosphere[a]	~10^3 BTU/h	~1.3 X 10^9 BTU/h
Heat discharged from condensers and auxiliary heat exchangers	7.0 X 10^9 BTU/h	3.9 X 10^9 BTU/h
Cooling water flow rate for 15°F temperature rise	~930,000 gpm (56 gal/KWH)	~520,000 gpm (31 gal/KWH)

[a] Heat losses through insulation around piping and equipment and from stack in fossil-fueled unit.

Source: William H. Steigelmann, "Alternative Technologies for Discharging Waste Heat," *Power Generation and Environmental Change*, ed. by David A. Berkowitz and Arthur M. Squires, The MIT Press, Cambridge, Massachusetts, 1971.

TABLE IV-5

COMPARATIVE COST OF COOLING-WATER SYSTEMS FOR STEAM-ELECTRIC PLANTS

	Investment cost ($/KW)		
	Fossil-fuel	Nuclear plants	
Type of System	plant	LMFBR[a]	LWR[b]
Once-through	2-3	2-3	3-5
Cooling ponds[c]	4-6	4-6	6-9
Wet cooling towers			
Mechanical draft	5-8	5-8	8-11
Natural draft	6-9	6-9	9-13
Dry cooling tower	17-21	17-21	25-32

[a] Liquid-metal-cooled fast breeder reactor.

[b] Light-water-cooled reactor.

[c] For 1,200-2,000-MW generating capacity.

Source: Walter G. Belter, "Thermal Effects–a Potential Problem in Perspective," *Power Generation and Environmental Change*, ed. by David A. Berkowitz and Arthur M. Squires, The MIT Press, Cambridge, Massachusetts, 1971.

TABLE IV-6

HEAT-REJECTION SYSTEM DATA SUMMARY (1,000 MW unit)

Type of system	Nuclear-fueled[a]	Fossil-fueled
Once-through		
Turbine back pressure (in. Hg)[b]	1.2-1.8	1.2-1.8
Land area (acres)	<1	<1
Water requirement (gpm)[c]	930,000	520,000
Investment cost ($/KW)	2-6	2-5
Cooling pond[d]		
Turbine back pressure (in. Hg)	1.5-2.0	1.5-2.0
Total area (acres)	1,500-3,000	1,000-2,000
Water requirement (gpm)	15,000	9,000
Investment cost ($/KW)	6-12+	4-10+
Natural-draft evaporative-cooling tower		
Turbine back pressure (in. Hg)	1.5-3.0	1.5-3.0
Land area (acres)	~7	~3.5
Water requirement (gpm)	13.000	9,000
Investment cost ($/KW)	9-14	6-10
Forced-draft evaporative cooling tower		
Turbine back pressure (in. Hg)	1.5-3.0	1.5-3.0
Land area (acres)	~5	~2.5
Water requirement (gpm)	13,000	9,000
Investment cost ($/KW)	8-11	5-8
Forced-draft dry-cooling tower		
Turbine back pressure (in. Hg)	4-8	4-8
Land area (acres)	~8-15	~4-7
Water requirement (gpm)	~0	~0
Investment cost ($/KW)	18-30	14-25

[a] Pressurized water or boiling water reactor.

[b] The units of pressure are inches of mercury (Hg).

[c] The water requirement is expressed in gallons per minute (gpm).

[d] Data are strongly dependent upon site location, topography, hydrology, and cost of land.

Source: William H. Steigelmann, "Alternative Technologies for Discharging Waste Heat," *Power Generation and Environmental Change,* ed. by David A. Berkowitz and Arthur M. Squires, The MIT Press, Cambridge, Massachusetts, 1971.

The study of thermal effects should not be approached with the predetermined conclusion that the addition of heat, properly controlled, to some particular water source will necessarily produce all the dire consequences generally predicted. A positive approach is to utilize heat constructively. In some cases, heated water could be used for irrigation to get year-round crops. Excess heat from the power plants can be used to heat nearby structures, desalinate sea water, and for chemical processes in industries. The availability of sufficient energy is essential to the economic development of any nation, and a closer look at the tradeoffs is a necessity.

RADIATION

Three of the basic types of radiation emissions are alpha and beta particles, and gamma rays. An alpha particle is made up of two neutrons and two protons, and thus is identical in mass to the nucleus of a helium atom. As the largest particle emitted during nuclear decay, it can be stopped easily (for example, by a sheet of paper). However, upon entering the body of living organisms, it may be extremely dangerous biologically because of its destructive ability.

Beta particles are also emitted by the nucleus of atoms undergoing radioactive decay, but have a mass equal only to that of an electron. Beta particles can be stopped by a sheet of metal but may cause skin burns and are also harmful upon entering the body.

Gamma rays are high-energy, short-wave length electromagnetic radiation that frequently accompany alpha and beta emissions but are always present in nuclear fission. Gamma rays are similar in many ways to x-rays, but are usually more energetic. When ionizing radiation passes through matter, the amount of energy absorbed per unit mass of irradiated material is called the absorbed dose. Generally speaking, radiation is measured in units of "millirem" (mrem). This unit takes into account both the absorbed dose and the relative effect of the three types of radiation.

There are two kinds of biological effects of radiation: *somatic effects* (those that impair the health or shorten the life of those exposed to radiation) and *genetic effects* (those that are transmitted to the offspring of the exposed individual by mutations in the genes). The average American receives a dose of between 145 and 200 mrem per year from such sources as natural radioactivity, television, and medical and dental x-rays.

TABLE IV-7

AVERAGE ANNUAL RADIATION EXPOSURE FROM DIFFERENT SOURCES

Type of Radiation	Source	Average Annual Exposure (mrem/yr)
Alpha	• Natural radioactivity (uranium) in soils, rock, minerals	30
Beta	• Natural radioactivity (potassium-40) in soils, rocks, minerals	20
	• Television (an average of 1 hr/day)	1-2
	• Luminous dial wrist watch	2
	• Natural radioactivity in the air (tritium)	2
Gamma	• Medical and dental x-rays	50-100
	• Cosmic radiation at sea level	40
Total		145 to 200

Source: "Questions and Answers, Nuclear Power and the Environment", American Nuclear Society, San Diego Section, Gulf General Atomic Company, San Diego, California, 1972.

Table IV-7 gives a comparison of radiation exposure from different sources. In addition to natural background radioactivity and the radioactive releases of nuclear power plants, coal-fired power plants emit measureable amounts of radiation due to the presence of radioactive materials (mostly radium isotopes) in the coal.

Radioactive materials produced in a nuclear power plant are in solid, liquid, and gaseous forms. The solid materials, such as old pieces of radioactive machinery and gloves, have a very low level of activity; these materials are sealed and shipped for burial. Liquid materials are corrosion products, some fission products, and tritium. Radioactive corrosion products are the result of chemical action on metal parts in the reactor.

Nuclear power reactors in operation today are fission reactors. In the fission process, uranium splits into two smaller atoms called fission products. Although these products are contained in zirco alloy fuel rods, some may escape to the primary cooling system because of fuel cladding failure. This failure is usually less than 1 percent. Gaseous fission products such as isotopes of xenon, krypton, and iodine are also created within the fuel rods and sometimes escape through cladding failure to the primary coolant.

Ion exchange systems are used to remove most of the ionic elements present in the coolant system. These resins, when spent, represent the highest level of operational waste material and are shipped to waste disposal areas. Gaseous fission products purged from the system are delayed and contained in charcoal filter systems for as long as practicable to minimize the activity released. Gaseous wastes, after temporary storage, are discharged into the atmosphere.

Highly radioactive wastes are converted to solids of small volume and are shipped for waste disposal. Low level wastes are stored temporarily, permitting some of the radioactivity to decay, and then are diluted with large quantities of water and discharged into lakes, rivers, and oceans. Gaseous wastes, after temporary storage to permit some decay, are discharged into the atmosphere. (Solid waste disposal is a special problem and is treated separately in another section.)

The Nuclear Regulatory Commission (NRC) is required by law to establish limits on radioactivity releases from commercial nuclear power plants. Under pressure from environmentalists, the NRC has further stated that the radiation releases to the environment must be "as low as practicable" (ALAP) and must not exceed specified limits. (Some environmentalists argue that the "food chain" will concentrate these "tiny" releases into dangerous accumulations. For example, radioactive elements released in water are absorbed by plants; the plants are eaten by larger animals, the zooplanktons; the zooplanktons, in turn, are eaten by crustaceans; the crustaceans are food for small fish; and so on. This process may result in a thousandfold increase in concentration. Sometimes this food chain may not stop at the fish but may be carried on to birds and other animals. In effect, the "food chain" concentrates the highly diluted wastes dumped into the water and then "packages" this concentrate for consumption by mankind.

John Gofman and Arthur Tamplin, formerly of the Lawrence Radiation Laboratory (Livermore) have argued for the reduction of the NRC limits on gaseous radiation to about one-tenth their present levels. They claim that exposure at the presently allowed 170 mrem per year could result in 32,000 additional deaths from leukemia and other cancers. A National Academy of Sciences panel on radiation standards estimated in 1972 that a more likely figure was in the range of 3,000 to 15,000 cases with a "most probable" figure of 6,000. (It should be noted that the 170 mrem per year standard, which applies to exposure in addition to natural and medical sources, is considerably greater than present exposure.)

In 1972 the NRC did tighten its standards. The exposure experienced by a person sitting 24 hours a day, 365 days a year on a fence at the boundary of a nuclear plant site is limited to less than about 5 mrem annually; the average neighbor of such a plant usually receives less than 1 mrem per year (American Nuclear Society, 1972) (average exposure to natural background radiation is 100 to 150 mrem/year; one chest X-ray is 200 mrem). Using the current values for average population dose from nuclear power plants as reported by the Environmental Protection Agency, the increased cancer death rate was estimated to be about one death in 20 years (American Nuclear Society, 1972). The current maximum permissible radioactivity-release levels from nuclear power plants have been estimated to produce 24 genetic mutations per year in the U.S., as against the spontaneous genetic-mutation rate of 800,000 per year (American Nuclear Society, 1972).

Besides radiation exposure from power generation, there are radiation hazards due to activities that are peripheral to actual plant operation. These operations include a series of activities beginning with uranium mining, the processing of ore and fuel element fabrication, the shipment of spent-fuel elements to a reprocessing plant, and releases during the reprocessing operation. The 5 mrem per year exposure standard does not apply to these facilities.

The first human exposure to radiation in the nuclear fuel cycle occurs to the uranium miners. The radionuclides may be deposited in the respiratory tract and create lung cancer. Enrichment and fuel element fabrication plants generate relatively low levels of airborne and liquid wastes. By using proper equipment, releases to the environment can be held to extremely low levels. An accident in the shipment of spent fuel elements (described in a later section) is a concern in the transportation stage of the fuel cycle. Upon arrival at the fuel processing plant, chemical reprocessing becomes the major source of radioactivity released to the environment. In these plants millions of curies of fission products generated in the reactor core are separated from the remaining fuel. Long-lived fission products resulting from reprocessing accumulate in the environment and are distributed, through natural processes, over very large georgraphic areas. The importance of these factors is not in the magnitude of the dose, but in the large number of people exposed.

In our opinion, the present low limits on radioactive releases from nuclear power plants provide adequate safeguards to normal radiation hazards associated with plant operations. However, radiation from the processing of nuclear fuel rods may become a significant problem in the future if emphasis on nuclear power increases.

NUCLEAR WASTE STORAGE

The disposal of high-level, long-lived radioactive waste is a matter of considerable controversy. Those concerned with nuclear waste disposal point out that, as yet, only interim procedures for disposing of the high-level radioactive wastes produced by nuclear power plants have been developed. The NRC concurs with this point but feels that interim procedures are adequate to safely store high-level wastes until a decision is made upon the best way to neutralize or permanently dispose of them.

The fission (splitting) of each uranium atom produces two or three new atoms (fission products) that remain in the fuel rods. As these fission products build up they absorb more and more neutrons and slow down the reaction so that after about one year the efficiency of the rod has decreased, and it must be replaced. The spent-fuel-rod assembly is reprocessed to recover most of the one-third unused uranium-235 as well as most of the newly-created plutonium. (This recovery process reduces the cost of power production by 5 percent, or about $3 million per year, for a 1000-MW plant.) The recovery process involves chopping the fuel rods into segments, dissolving them in nitric acid, and separating the fuel from the fission products. The heat from the radioactive decay of the fission products is enough to boil the solution, hence cooling must be provided.

Since these fission products are initially stored in highly acidic solutions, tank leaks present some problems. Liquid wastes from past NRC operations now amount to 80 million gallons and are stored at four separate large-scale waste-storage facilities (Hambleton, 1972). Fifteen of 151 tanks developed leaks over a 20-year period at the NRC storage facility at Hanford, Washington (American Nuclear Society, 1972). Presently all old wastes and new wastes are being transferred to more modern double-walled tanks.

Wastes from nuclear power plants are reprocessed at the Richland, Savannah River, and Idaho operations of the NRC, as well as at the commercial plant of Nuclear Fuel Services, Inc., at West Valley, New York. The NRC requires that these plants solidify the liquid wastes five years after they produce it. At the end of an additional five years these solid wastes must be delivered to the NRC interim-storage facility.

The potential hazard from these wastes derives from the basic characteristics of the radioactive contaminants. The isotopes that are of greatest concern are those that are highly toxic and have long half-lives, including strontium-90 and cesium-137, with half-lives of 30 years, and plutonium-239, which has a half-life of 24,000 years and the highest radiotoxicity of any known element. Plutonium-239 requires upwards of 250,000 years to decay to a safe level, thus presenting a disposal problem without precedent in human history.

If nuclear power develops as projected, by the end of this century the United States will have produced about one-half million cubic feet of high-level wastes. This will be solid waste housed in 80,000 canisters 1 foot in diameter and 10 feet long. Each canister, because of its radioactive contents, will produce about 5 kilowatts of heat. A single 1000-MW plant will generate about 10 such canisters per year.

The essence of the waste-storage problem is what to do with these 80,000 canisters for the next quarter of a million years or until we develop a technology to render the wastes harmless. In 1959 the NRC began to study the possibility of burying the wastes in salt beds in Kansas. Salt is abundant, can heal its own fractures by plastic flow, transmits heat readily, and exhibits compressive strength and radiation-shielding properties. However, studies for a salt-storage area in Lyons, Kansas, were abandoned by the NRC as a result of public pressure and the discovery of conflicting geologic traits in the area (specifically, that water might enter the salt deposits through natural aquifers or through the more than 200 oil wells drilled through the salt).

As a result, the NRC is looking for a location to build an above-ground storage facility for use until a "fail-safe" method of disposal is developed. Such a storage facility will immerse the canisters in pools of water. The water will be continually run through a cooling mechanism. The cost of such a storage system will be $25-50 thousand per canister. This cost, as part of the price of electricity, may represent as little as .03 of a mill per KWH or as much as 2 percent of the cost of nuclear power.

The possibility of a major failure or a minor leakage at the storage site exists. However, the risk is relatively small. If the cooling system failed it would take one week for the coolant to boil away. On the seventh day the canisters would melt, releasing the radiation to the atmosphere. Dr. Pittman, director of the NRC Division of Waste Storage and Transportation, feels this possibility is nil, since the plant is under continual surveillance. In addition, he points out that if for some reason no one was there to correct the cooling problem, the circumstances leading to this situation would have to be of a magnitude to cause man greater harm than the release of the stored radioactive waste (Symposium on the Implications of Nuclear Power in Texas, The University of Texas at Austin, March, 1973). The 60 million gallons of waste that will be produced by nuclear power plants by the year 2000 have a concentration of strontium-90 of about one hundred (100) curies per gallon. The maximum permissible concentration of strontium-90 in drinking water is a few billionths of a curie per gallon.

The controversy over nuclear storage comes down to two considerations: first, the calculation of the risk involved, and second, the decision whether or not to accept that risk. The NRC is depending on technology to provide a fail-safe method of disposal within the next 40 to 100 years. The agency also feels present interim measures are safe enough to allow the small risk involved in storage until the technology is developed. Those who disagree with the NRC and who are qualified to do so, put considerably less faith in both the ability to develop a fail-safe storage method and present interim procedures. They are not willing to take the risk and feel society should not be burdened with storage responsibilities for high-level nuclear wastes for thousands of years to come.

SAFETY OF NUCLEAR POWER PLANTS

Although injuries and deaths have occurred in uranium mining, in fuel processing, and in research reactor accidents, no accidental injuries or radiation exposures beyond permissible limits to members of the public are known as a result of nuclear power generation in the U.S. Still, a number of disquieting indications have turned up in recent years to suggest that a vital safety feature of nuclear power reactors may be far less capable of preventing a catastrophic accident than has long been assumed.

The safety concerns of most people fall into three categories:

- that the reactor might explode like a bomb;
- that an accident, such as an earthquake, might break the protective shell;
- that abnormal operation might result in an accident, thus releasing harmful radiation.

The first worry, that a plant might explode atomically, can be disposed of quickly: it is simply not possible. The reactors employ relatively dilute fuel, they are designed along different principles, and they operate differently. The safety of nuclear power plants does not depend on restraining the force of atomic energy but on containing the radioactive material it generates. An accident such as an earthquake could not split a plant, according to the NRC. Further, the NRC argues that a plant could withstand the impact of an airplane crashing into it.

The third prospect of an accident arises from abnormal operation. Great reliance is placed on engineered safety systems to prevent or mitigate the consequences of such accidents. Foremost among the safety systems are the emergency core-cooling systems (ECCS). The ECCS go into operation if normal cooling systems accidentally fail. Whether the result of malfunction or failure, human error, or sabotage, if the coolant water stops circulating (loss of coolant accident—LOCA), the temperatures would rise rapidly and within a minute the fuel itself would begin to melt. If emergency cooling were not effective within this first minute, the entire reactor core, fuel, and supporting structure would begin to melt down. Emergency cooling water injected at this stage might react violently with molten metal and gas pressures; steam explosions would probably break through the containment building, and radioactive material in the form of a cloud could be lethal for dozens of miles (Forbes, *et al.*, 1972).

In August, 1974, the NRC released a draft report (WASH 1400) of a two-year $4-million study of risks present in reactor operations. The study concluded that risks to the public from reactor failures was very small—much smaller, in fact, than many non-nuclear accidents such as fires, explosions, airplane crashes, earthquakes, or hurricanes (see Table IV-8). Moreover, nuclear power plants were found to be 100 to 1,000 times less likely to result in economically costly accidents than many conventional or natural sources (see Table IV-9).

Although criticized by The Sierra Club and The Union of Concerned Scientists (Kendall and Moglewer, 1974) on grounds of faulty methodology and the neglect of short-term consequences, an important conclusion of the WASH 1400 report was given support by an independent study conducted by Professor H.W. Lewis of The University of California at Santa Barbara (Lewis, 1975). On April 28, 1975, The American Physical Society, under whose auspices the research took place, announced that the study had not ". . . uncovered reasons for substantial short-range concern regarding risk of accidents in light water reactors."

TABLE IV-8

INDIVIDUAL RISK OF ACUTE FATALITY BY VARIOUS CAUSES

(U.S. Population Average 1969)

Accident Type	Total Number for 1969	Approximate Individual Risk Acute Fatality Probability/yr[1]
Motor Vehicle	55,791	3×10^{-4}
Falls	17,827	9×10^{-5}
Fires and Hot Substance	7,451	4×10^{-5}
Drowning	6,181	3×10^{-5}
Poison	4,516	2×10^{-5}
Firearms	2,309	1×10^{-5}
Machinery (1968)	2,054	1×10^{-5}
Water Transport	1,743	9×10^{-6}
Air Travel	1,778	9×10^{-6}
Falling Objects	1,271	6×10^{-6}
Electrocution	1,148	6×10^{-6}
Railway	884	4×10^{-6}
Lightning	160	5×10^{-7}
Tornadoes	91[2]	4×10^{-7}
Hurricanes	93[3]	4×10^{-7}
All Others	8,695	4×10^{-5}
All Accidents		6×10^{-4}
Nuclear Accidents (100 reactors)	0	3×10^{-9}

[1] Based on total U.S. population, except as noted.

[2] (1953-1971 avg.)

[3] (1901-1972 avg.)

Source: U.S. Nuclear Regulatory Commission, *Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants: Summary Report*, 1974.

TABLE IV-9

U.S. ECONOMIC LOSSES FROM VARIOUS CAUSES

Source	Estimated Annual Losses (millions of dollars)
Automobile Accidents (1970)	5,000
Fires (Property - 1970)	2,200
Hurricanes (1952-72 average)	500
Fires (Forest - 1970)	70
Tornadoes (1970)	50
Reactor Accidents from 100 Plants	2

Source: U.S. Nuclear Regulatory Commission, *Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants: Summary Report*, 1974.

OTHER ENVIRONMENTAL CONSIDERATIONS

Transportation in the Nuclear Fuel Cycle

The main hazards associated with transportation in the nuclear fuel cycle are with spent fuel and fission-product wastes, both of which are highly radioactive. Until the fuel has been used in the nuclear power plant it is a naturally radioactive material and as such does not usually constitute a significant radiation hazard or transportation problem. A less important hazard associated with transportation is criticality. Criticality is reached when the amount or mass of fuel gathered together is such that a self-sustaining nuclear reaction is started. Until fuel has gone through the enriching process, it cannot sustain a chain reaction except under very special circumstances. After enrichment, when the fuel is shipped to the reactor, the amount of contained fuel is kept well below the minimum critical value and the containers are spaced apart from one another by a framework.

Normally, after three or four years, spent-fuel rods are removed from the reactor and stored at the reactor site for three to four months to allow the decay of short-lived radioactivity. They are then placed in massive, shielded shipping casks for transportation to the reprocessing plant. The casks are designed to minimize the probability of inadvertent criticality of the contents. The probability of the loss of all radiation shielding and criticality occurring is near zero. Of more concern is the possible release of radioactivity as a result of an accident in shipping. Such accidents have occurred at the rate of one per 2 million miles of shipment (American Nuclear Society, 1972). Most accidents have been minor, with little or no damage to the shipping cask. Table IV-10 classifies transportation accidents involving radioactive material.

The transportation of spent fuel in the U.S. is normally by train or truck. Highway load limits, rather than safety reasons, restrict highway shipments. At present there are many different types of package designs for radioactive material that have been authorized, ranging from small packages weighing a few pounds to 80-ton casks holding up to 4 or 5 tons of waste. Casks are designed to withstand a 30-foot drop onto an unyielding surface, followed by a 40-inch drop onto a 6-inch-diameter, 8-inch-high piston, followed by exposure to 1475°F for a 20-minute period, followed by immersion in water for 8 hours. Although it is impossible to design a package to survive every possible accident, the NRC feels its regulations offer a high degree of assurance that a cask will not break under severe accident conditions.

The hazards associated with the transportation of spent fuel are uncertain. However, the risk of an accident exposing the population to relatively large doses of radioactivity is small. Those who oppose the rapid expansion of nuclear power feel the possible magnitude of a severe accident precludes accepting the present level of risk. The NRC, on the other hand, feels its regulations are adequate to minimize the risk. The NRC also says that, although there may be more accidents in the future as more fuel is

TABLE IV-10

CLASSIFICATION OF TRANSPORTATION ACCIDENTS
INVOLVING RADIOACTIVE MATERIALS

Class	Description	Number of Incidents 1949-1970	Relative Frequency	
I	No loss of package integrity	89	0.556	
II	Package breached–no release	22	0.137	
III	Release confined to vehicle	23	0.144	
IV	Release to the ground–no aerial dispersal	22	0.137	
V	Aerial dispersal	3	0.019	25%
VI	Radioactive material enters a watercourse	1	0.006	

Source: G. Yadigaroglu, A.G. Reinking, and V.E. Schrock, "Spent Fuel Transportation Risks," *Nuclear News,* 15:11, November, 1972.

shipped, the casks will be larger (from 50 to 100 tons) to minimize the number of shipments and more resilient to damage as a result of additional shielding.

A final question on transportation safety has to do with security. By the year 2000 there may be as many as 600 shipments of highly radioactive fuel per week. The diversion of plutonium for illegal purposes is a possibility. Plutonium is worth about $10,000 per kilogram. One kilogram of plutonium is enough to kill (by radiation) every person in a large city. The NRC is aware of the difficulties a "plutonium economy" will bring and is seeking ways to avoid or ameliorate them.

Environmental Impact of Mining for Fuel

Either conventional shaft mining or strip mining may be used to recover uranium and coal. Both methods have undesirable social and environmental consequences.

Shaft mining for coal is hazardous because of the dangers of fires and cave-ins. Uranium shaft mining releases radioactive radon gas, which has resulted in a significantly higher cancer-rate for uranium miners.

Strip mining methods create immediate environmental problems and pose a threat to the future utility of the land. The land area being destroyed by strip mining for uranium is smaller than that for coal. However, waste disposal from the on-site, uranium-refining plant requires a surface area equal to that needed if the same area were being strip-mined for coal.

The end product of a strip-mining operation is a ridge, or many closely spaced, parallel ridges, of loose rock resting at an angle of repose of about 33 degrees. These "spoils banks" are often high in sulfuric acid and low in organic material and trace elements needed to support plant life. In mountainous regions where contour stripping is practiced, "spoils banks" may initiate landslides and contribute excessive amounts of silt to the local drainage.

Restoration of the original contour of the land may cost from $900 to $2,700 per acre and is obviously more than the value of the reclaimed land for agriculture or other purposes. Minimum strip-mine reclamations which reduce the angles of the slopes, improve drainage, and plant a cover crop may cost upwards of $100 per acre.

According to the U.S. Department of the Interior, the total disturbed land as of 1970 was about 2,450 square miles. Only about one-third of this total has been reclaimed by man or nature, or has been put to some minimal beneficial use.

At least 17 states have enacted laws requiring reclamation of strip-mined land. Consideration is being given in Congress to a partial ban on strip mining by prohibiting it in areas where reclamation cannot occur. The National Coal Association estimates such a law would increase the cost of coal to the consumer by .05 percent (U.S. Geological Survey, 1970).

Coal Wastes

The burning of coal to produce electric power also produces ash. Because the ash content of coal may vary from 6 percent to 20 percent, a large plant will produce a large volume of ash. It is estimated that an ash pile which would be 40-feet high and cover 20,000 acres will be produced in the U.S. between 1968 and 2000 from the generation of electric power by coal (Joint Committee on Atomic Energy Hearings, 1969). Coal ash may be used for landfill and some work has been done on the feasibility of using it for roads. If it is stored in a pile, however, ash may blow off the piles into the air, rainwater will then act with it to produce acids which, if not collected in a drainage system, will damage the environment.

IMPLICATIONS OF ENVIRONMENTAL CONSIDERATIONS

A fossil-fuel power plant discharges through its stacks a considerable amount of sulfur oxides, nitrogen oxides, and particulate matter. Much research in this area is still in the rudimentary stage. Chemical pollutants in the air can cause effects ranging from irritation of the eyes and headaches to chronic illnesses.

Present limits for sulfur-oxide and nitrogen-oxide emissions have been established between the natural background level and the level of medically perceivable effects. Radiation limits, on the other hand, are well below the natural background level. Chemical discharges from nuclear power plants are essentially nil and their gaseous radiation is less than that of fossil-fuel plants.

Thermal discharges in water not only can reduce the capacity of the streams to assimilate other wastes but can also reduce the oxygen content of the stream, altering the ecology of aquatic organisms. Thermal discharges from a nuclear power plant are about one and one-half times as great as those from a fossil-fuel plant of comparable electric capacity.

Although coal storage and coal wastes pose a considerable problem with regard to land requirements, air pollution, and water pollution, the waste disposal of nuclear wastes is a far more serious problem. These radioactive wastes contain highly toxic and long-lived radioisotopes. As yet only interim procedures for disposing of high level radioactive waste have been developed. However, these interim procedures are claimed adequate to safely store high-level wastes until ways to store them permanently or to neutralize them can be developed.

The most controversial aspect of the operation of nuclear power plants is their safety. Emergency core-cooling systems have emerged as a vital component in the safety system of nuclear plants. This component still needs considerable research. Its widespread usage could conceivably result in an accident with catastrophic consequences.

The problem of high-level wastes from nuclear power plants needs a thorough research and development effort but, radiation, thermal discharges, and fuel-cycle problems are, to a certain extent, shared by both nuclear and fossil-fuel power plants. However, nuclear power plants pose risks that require caution before a widespread, commercial nuclear power program is launched.

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CHAPTER FIVE

GOVERNMENT INVOLVEMENT IN POWER-PLANT SITING

Decisions affecting the siting of electric power plants are made by many different people and involve multiple layers of permits, licenses, and regulations. This chapter describes the regulatory role of government by reviewing pertinent federal legislation and discussing state and federal procedures for power-plant siting.

FEDERAL LEGISLATIVE FRAMEWORK

The regulation of power-generating facilities takes place within a framework developed over more than half a century. The most important laws are: the Federal Power Act (1920); the Atomic Energy Act (1954); the Administrative Procedure Act (1946); the National Environmental Policy Act (1970); and several air and water quality acts (the most important of which are the Clean Air Act of 1970 and the Federal Water Pollution Control Act Amendments of 1972).

Part I of the Federal Power Act provides a comprehensive system of national regulation for hydroelectric plants, while the 1954 amendments to the Atomic Energy Act authorize federal controls for the construction and operation of nuclear reactors. In all cases of power-plant licensing, the federal regulatory staff must conform to the Administrative Procedure Act (except where classified information is involved) and file Environmental Impact Statements (EIS) in accordance with the National Environmental Policy Act. Additional restrictions are imposed by federal air and water quality acts that require permits for plant discharges.

While the licensing process is controlled from Washington, federal environmental legislation has permitted states to develop their own standards, subject to federal administrative approval. Thus, in 1965 and 1967 the Texas Legislature passed two water pollution-control bills modeled after the Federal Water Quality Act. These bills authorized a permit system for regulating discharges into all state waters and created an independent entity—the Texas Water Quality Board—to supervise its implementation. After the national Clean Air Act was passed, similar arrangements were made for control of air pollution with the Texas Air Quality Board, an agency housed within the State Health Department.

The federal Water Pollution Control Act Amendments of 1972 require each state to revise its permit system to meet newer, more rigid EPA requirements. Under this act the EPA has much more control over the states and enforcement of federally approved standards is much easier. If the states fail to meet federal criteria, or if they choose not to submit new plans, then EPA must design new standards for state compliance.

The act itself is a far-reaching revision of federal policies in water pollution control. It applies to *all* navigable waterways, and states as its goal "... that the discharge of pollutants into the navigable waters be eliminated by 1985." Section 316 of this act, relating to thermal discharges, takes a somewhat novel approach to thermal pollution control: it stresses the effects of thermal discharges on the biota, without reference to standards established by the Environmental Protection Agency. Since the effects of temperature changes upon biological systems in various bodies of water change with respect to characteristics of the biota, geological considerations, and meteorological conditions, few generalizations are justifiable. Congress has taken into consideration the necessity to relate thermal pollution control to specific ecosystems.

This systems approach seems to allow operators of nuclear power plants more freedom in the disposal of thermal wastes, but the law is emphatic in its requirement that any thermal discharge "... will assure the protection and propagation of a balanced indigenous population of shellfish, fish, and wildlife in and on that body of water." Whatever the characteristics of specific waterways, thermal discharges are not permitted to disturb the ecology of a marine system.

Section 102 of the National Environmental Policy Act (NEPA) specifies that Environmental Impact Statements must be filed for all actions by government agencies that significantly affect the environment. This has been interpreted to include projects wholly or partially funded, contracted for, or licensed by federal agencies or departments. In view of the magnitude and scope of federal activities it is not surprising that many agencies feel overwhelmed. EPA, for example, has asked the court to narrow requirements for filing EIS to projects of major impact only. If EPA were required to file EIS for all project applications, the total number could exceed 30,000–a number clearly beyond staff capabilities. In response to this problem the Council on Environmental Quality (CEQ) has prepared a guideline that exempts EPA from filing EIS on all protective regulatory activities in which the agency concurs or makes by itself, including rules and regulatory standards. The action taken by CEQ, however, does not appear to be authorized by statute and further legislation may be necessary to clarify exemptions for EPA.

Some measure of relief might be realized through the passage of legislation to amend NEPA by allowing EPA to issue permits under the Refuse Act without filing EIS. If such a bill became law, its provisions would be temporary, allowing limited time for EPA to adjust to its new permit-granting functions.

Other applications of NEPA are less equivocal. The Nuclear Regulatory Commission (NRS) must file EIS on all utility applications for the construction of nuclear power plants; and the Federal Power Commission must do the same for hydroelectric facilities, major transmission lines, and interstate fuel lines.

Two other federal acts offer opportunities for state participation:

The Coastal Zone Management Act (1972) provides grants for the establishment of coastal zone management programs by the states which are administered by the Department of the Interior. Moreover, the law creates a National Coastal Resources Board, chaired by the Vice President, and including several officers of the Executive Branch, to coordinate all federal programs relating to coastal zone management, mediate disputes between federal and state agencies over coastal zone development programs, and provide a forum for appeals against federal action in the coastal zone. The inclusion of the chairman of the NRC on this board indicates that nuclear power plants locating in coastal areas will be under review by this panel. This should minimize harm, if any, to beaches, harbors, bays, estuaries, or other coastal ecosystems.

The Fish and Wildlife Coordination Act, enables state fish and wildlife agencies to comment on EIS for projects affecting state surface waters.

PROCEDURES FOR SITING ELECTRIC POWER PLANTS

The procedures an electric utility must follow in constructing an electric power plant vary according to both the location and type of the proposed facility. This section will focus on procedures for siting nuclear and fossil-fuel power plants that exist at the federal level, in Texas, and in selected other states.

Siting Nuclear Power Plants in Texas

The siting of a nuclear power plant in Texas requires permits from both federal and state agencies. Although lines of responsibility are defined by statute and administrative regulations, the process is complex and needs to be clarified.

Texas Procedures. An electric-utility company planning to construct a nuclear power plant in Texas proceeds through the following steps (these steps correspond to the explanatory numbers in Figures V-1 and V-2):

(1) After conferring informally with the Texas Water Development Board on the availability of water and the potential environmental impact of the plant on a proposed site, the utility submits permit applications to the Texas Water Rights Commission (for legal rights to state water needed for operation of the plant) and to the Texas Water Quality Board (for permission to discharge plant effluents into state bodies of water). The utility also submits permit applications to the regional offices of the Army Corps of Engineers (COE) for authorization to dispose of dredge-and-fill materials, and to the Environmental Protection Agency (EPA) for authorization to dispose of plant effluents subject to EPA jurisdiction.

[Note: The Federal Water Pollution Control Act Amendments of 1972 retracted from state agencies and returned to the EPA the power to authorize permits for waste discharge into bodies of water anywhere in the United States. By state statute, the Texas Water Quality Board retains its water quality responsibilities in spite of these 1972 Amendments, thus causing duplicative review. To eliminate duplication while insuring effective regulation, the EPA expects to issue joint permits with the Texas Water Quality Board in the future and, eventually allow the board to issue permits on its own.]

(2) The utility generally consults several other state agencies to inquire whether additional permits might be required; these agencies are:

Texas Highway Department—to ascertain if rights-of-way are involved, and, if necessary, to obtain a permit to use state highways for transporting oversized fuel loads;

Texas Railroad Commission—to make arrangements for obtaining proper certificates of convenience and necessity in the transport of radioactive wastes for storage;

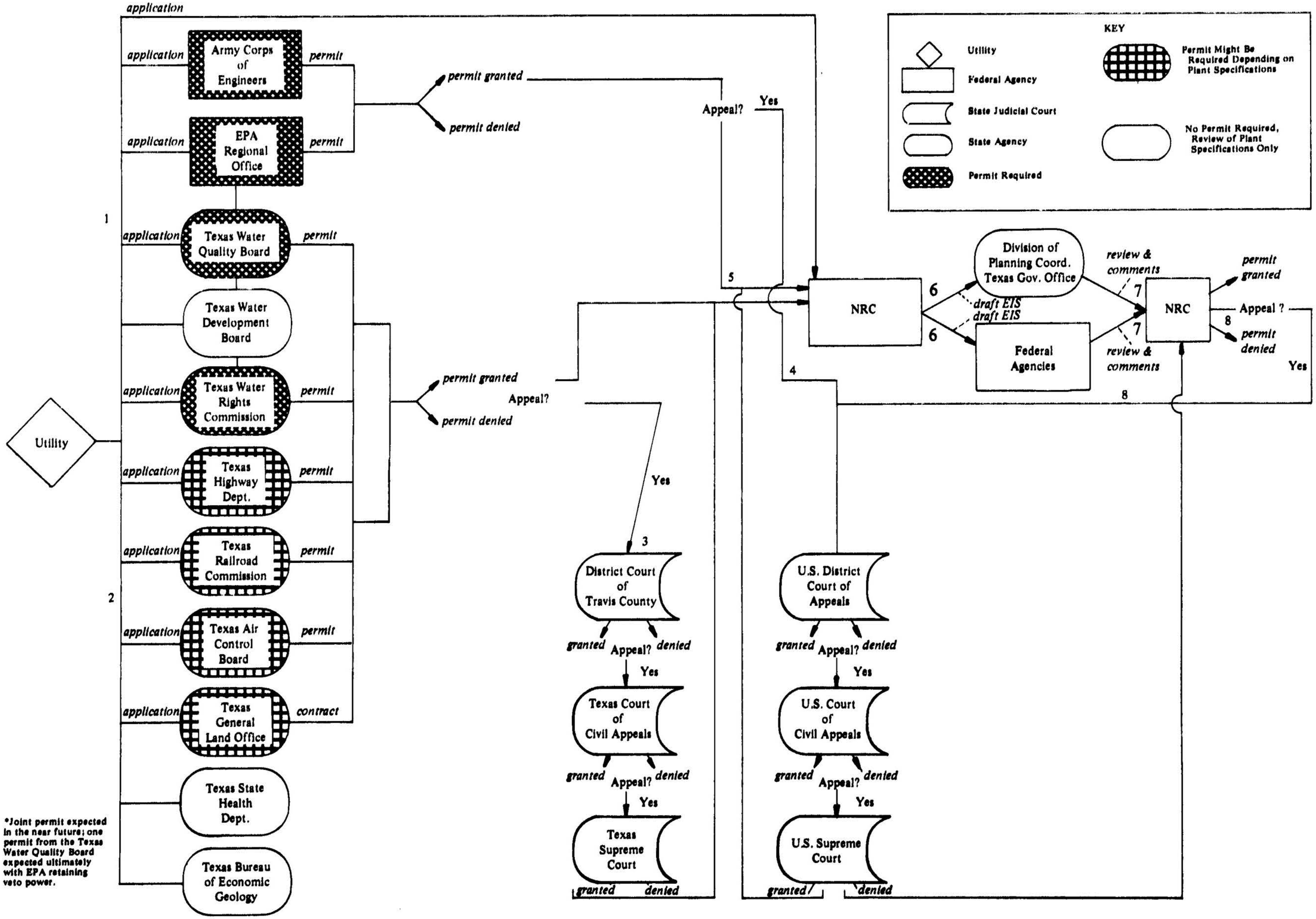
Texas Air Control Board—to insure that atmospheric emissions from the power plant require no permit;

Texas General Land Office—to insure no public lands are involved;

Radiation Control section, Texas State Health Department—to insure that proposed radioactive discharges meet federal and state standards and to provide for the cooperative monitoring of such discharges;

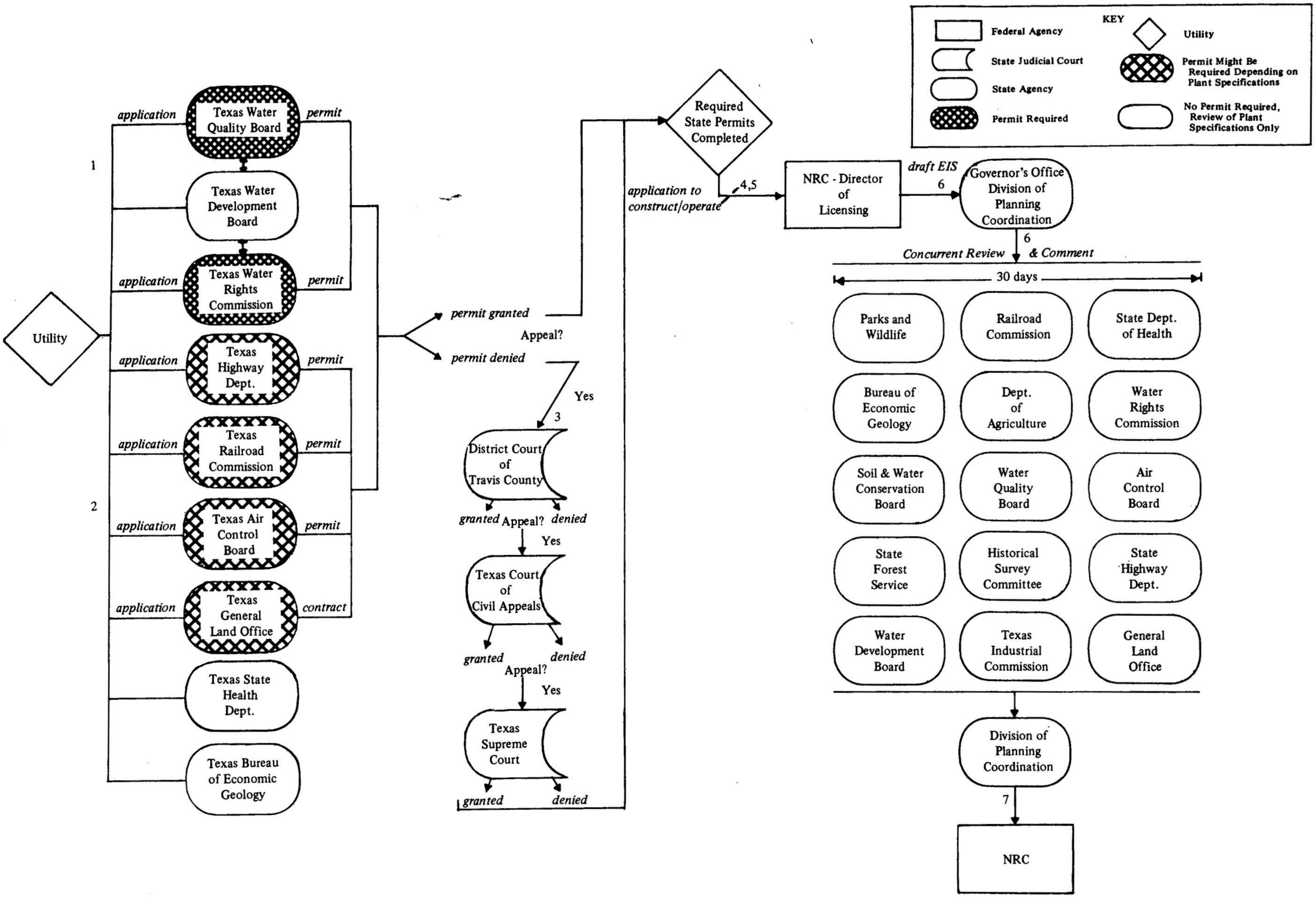
FIGURE V-1

AN OVERVIEW: LICENSING PROCEDURES FOR THE CONSTRUCTION OF NUCLEAR POWER PLANTS



*Joint permit expected in the near future; one permit from the Texas Water Quality Board expected ultimately with EPA retaining veto power.

FIGURE V-2


KEY
Federal Agency
State Judicial Court
State Agency
Permit Required
Utility
Permit Might Be Required Depending on Plant Specifications
No Permit Required, Review of Plant Specifications Only
Utility
1
2
application
Texas Water Quality Board
permit
Texas Water Development Board
application
Texas Water Rights Commission
permit
application
Texas Highway Dept.
permit
application
Texas Railroad Commission
permit
application
Texas Air Control Board
permit
application
Texas General Land Office
contract
Texas State Health Dept.
Texas Bureau of Economic Geology
permit granted
Appeal?
permit denied
Yes
3
District Court of Travis County
granted
Appeal?
denied
Yes
Texas Court of Civil Appeals
granted
denied
Appeal?
Yes
Texas Supreme Court
granted
denied
Required State Permits Completed
application to construct/operate
4,5
NRC - Director of Licensing
draft EIS
6
Governor's Office Division of Planning Coordination
6
Concurrent Review & Comment
30 days
Parks and Wildlife
Railroad Commission
State Dept. of Health
Bureau of Economic Geology
Dept. of Agriculture
Water Rights Commission
Soil & Water Conservation Board
Water Quality Board
Air Control Board
State Forest Service
Historical Survey Committee
State Highway Dept.
Water Development Board
Texas Industrial Commission
General Land Office
Division of Planning Coordination
7
NRC

Texas Bureau of Economic Geology—to avoid siting a nuclear power plant near a geologic fault (Nuclear Regulatory Commission requirement) and to evaluate the support-capability of the proposed site.

(3) After a state agency either denies or grants a permit, the utility or an intervenor in the hearings process can appeal the agency decision to the District Court of Travis County, the Texas Court of Civil Appeals, and finally, the Texas Supreme Court.

(4) In a similar manner, an appeal of a federal agency (i.e., COE or EPA) decision can be made, in turn, to the U.S. District Court of Appeals, the U.S. Court of Civil Appeals, and the U.S. Supreme Court.

(5) After the electric utility has received (or is in the process of receiving) all necessary state permits and the permits from the COE and EPA, it submits its application for a construction permit to the Nuclear Regulatory Commission for review. (This NRC review process is discussed in more detail in the section on federal procedures.)

(6) In its formal review, the NRC prepares a draft Environmental Impact Statement on the proposed plant and distributes the document to various federal agencies in accordance with guidelines established by the Council on Environmental Quality. Copies of the draft EIS are also sent to the governor of the state involved; in the Texas Governor's Office, the Division of Planning Coordination (DPC) receives the draft EIS. The DPC, in turn, distributes the draft EIS to 15 state agencies (see Figure V-2) which are expected to forward necessary and appropriate comments back to the DPC within 30 days.

(7) In Texas, the Division of Planning Coordination, Office of the Governor, summarizes the state agency comments and formulates the state response to the NRC. The Directorate of Licensing, NRC, then utilizes the state response and the federal agency comments in the development of the final EIS.

(8) After the NRC has made its decision either to deny or grant the construction permit, the utility or an intervenor in the hearings process can appeal the ruling to the U.S. District Court of Appeals, the U.S. Court of Civil Appeals, and, finally, the U.S. Supreme Court.

*Federal Procedures.** Although the electric utility must, for example, receive authorization from the COE to dispose of dredge-and-fill materials and from the EPA to dispose of plant effluents subject to EPA jurisdiction, primary utility contacts at the federal level during the nuclear plant-siting process are with the NRC.

The Nuclear Regulatory Commission's procedures for constructing and licensing a nuclear power plant are in two stages. The initial stage is the submission of an application by the utility for a construction permit. Then, after the power plant has been constructed, the utility submits another application to the NRC for an operating license. The applications for both the construction permit and the operating license include a detailed description of the proposed design and operating procedures, an accounting of the financial situation of the utility, an environmental report, and a preliminary safety-analysis report (PSAR).

A preliminary review of the application is made to determine if the application is complete. This mini-review includes a study by the NRC of both the safety and environmental reports filed by the utility as well as an antitrust review by the U.S. Attorney General's Office. The antitrust review includes an assessment of antitrust problems resulting from the licensing of a nuclear plant. When a favorable review is given by the Department of Justice, the NRC holds a hearing to ascertain whether the applicant's proposed activities are in conflict with present antitrust laws or policies.

Construction Permit. The process for obtaining an NRC construction permit for a nuclear power plant involves these steps (corresponding to the explanatory numbers in Figure V-3):

(1) The utility submits its application for a construction permit to the Director of Regulation, NRC, who in turn distributes the application to the NRC's Directorate of Licensing and the public. The public is notified via news releases, the *Federal Register*, and the Public Documents Room. Local and state officials of the state in which the proposed plant is to be located, as well as governors of neighboring states, are notified by mail that an application has been received.

(2) The Directorate of Licensing directs the technical review of the application, with most of the review conducted by national laboratories. The Directorate of Licensing meets with representatives of the utility, the nuclear supply-systems manufacturer, and others involved in the process, to discuss the plant design.

(3) The Directorate of Licensing circulates a draft Environmental Impact Statement on the proposed plan to other federal agencies (as required by NEPA) and to the governor of the state in which the plant will be built. (The governor in turn distributes it to interested state agencies for review and comment. The agencies have 30 days within which to make their comments to the governor, whose office coordinates the comments into a single, state response.) After having reviewed the draft EIS, the federal agencies and the governor direct their comments to the Directorate of Licensing for inclusion in the final EIS.

(4) When the NRC Directorate of Licensing completes its review, its comments are sent to the Office of the NRC's Director of Regulation, which in turn submits it to the NRC Commissioners.

(5) As the Directorate of Licensing completes its review,

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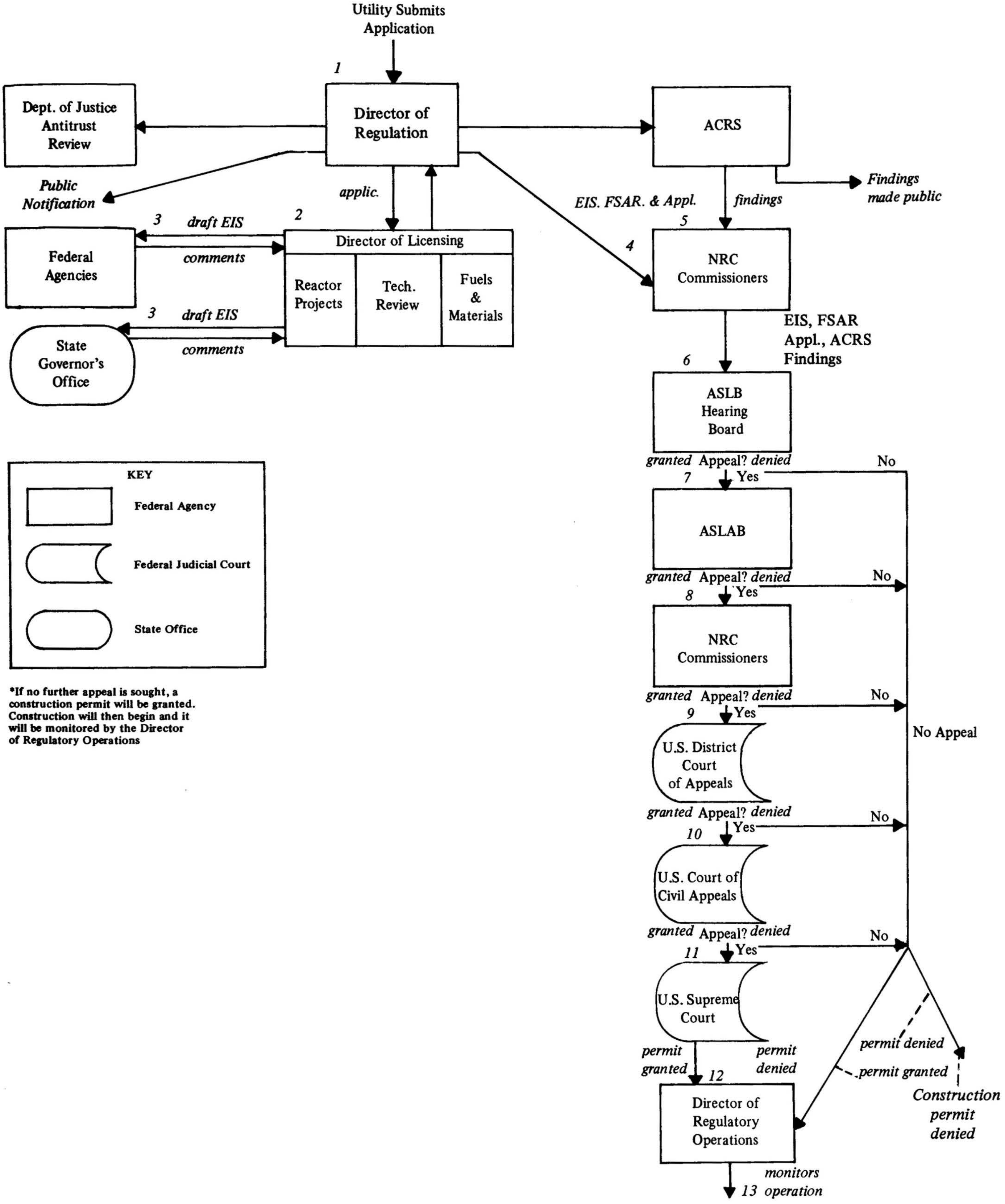
*Information based upon interviews with Mr. S.A. Schwartz, Office of Government Liaison, NRC, December, 1972.

FIGURE V-3 NRC CONSTRUCTION PERMIT PROCESS



***If no further appeal is sought, a construction permit will be granted. Construction will then begin and it will be monitored by the Director of Regulatory Operations**

the application is reviewed by the Advisory Committee on Reactor Safeguards (ACRS). The ACRS is an independent, statutory body which reviews the safety of the reactor. The ACRS furnishes its review in the form of a letter to the NRC Commissioners which becomes part of the public record. The Office of the Director of Regulation then formulates its final position with regard to the license application, taking into account recommendations from the ACRS. The findings of the ACRS and of the Directorate of Licensing are submitted to the NRC Commissioners.

(6) A public hearing is required prior to the issuance of a construction permit (42 U.S.C. § 2235 (1970)). A pre-hearing conference is first set up to identify the parties in the proceeding, the issues in dispute, and the proposed witnesses. The Atomic Safety and Licensing Board (ASLB) then conducts the official hearing. The ASLB consists of two technical persons and an attorney who chairs the hearings board. The hearing is usually held at the site of the proposed power plant. The ASLB receives testimony from state and local officials, community groups, private organizations, individual citizens, the applicant and its consultants, and NRC staff. It also reviews the permit-application file, which consists of the application and all evaluations and comments from interested parties. The ASLB issues the initial decision to either grant or deny the construction permit. If the permit is granted, it may be granted by the NRC on the basis of the decision by the ASLB.

(7) If no exceptions to the ASLB's initial decision are filed, that decision becomes the final decision of the Nuclear Regulatory Commission. If exceptions are filed, they are reviewed by the Atomic Safety and Licensing Appeals Board (ASLAB). The ASLAB, which is appointed by the commission, will either sustain or reverse the initial decision of the ASLB. If the construction permit is granted and no exceptions are filed, the initial decision becomes final.

(8) The review by the ASLAB is usually the point at which the administrative process for granting a construction permit ends. However, the NRC commissioners can review particular issues on their own initiative.

(9-11) Final opportunities for appeal are to the U.S. District Court of Appeals, the U.S. Court of Civil Appeals, and the U.S. Supreme Court. Once a construction permit is granted, the utility can begin construction.

(12-13) Throughout the period of construction the power plant is monitored by the Office of the Director of Regulatory Operations, NRC, which insures that the utility constructs the plant according to the specifications in the construction permit.

(14) There is no fixed schedule for determining how long this process will take. One estimate, however, is that the process spans approximately 10 years:

Environmental Report and PSAR completed by the utility	2-3 years
Date of permit application to start of hearings	1 ½ years
Hearings	½ year
Construction of plant	3-5 years

Operating License. The process for obtaining an NRC operating license for a nuclear power plant consists of these steps (corresponding to the explanatory numbers in Figure V-4):

(1-4) Initial procedures for obtaining an operating license are essentially the same as for obtaining a construction permit.

(5) The operating license procedure requires a more vigorous safety analysis by the ACRS.

(6-8) Procedurally, after a favorable review by the regulatory staff and the ACRS, the commission must publish a notice of intent to issue an operating license to the applicant, giving at least 30 days advance notice. This notice informs the public of the position of the NRC and the ACRS. It also states that any person whose interest may be affected by the proceeding may petition the AEC to hold a hearing. A public hearing need *not* be held. If no hearing is requested, the NRC issues an operating license to the utility. If a request is received for a hearing, and if it is granted, the hearing process is similar to the hearing process for a construction permit.

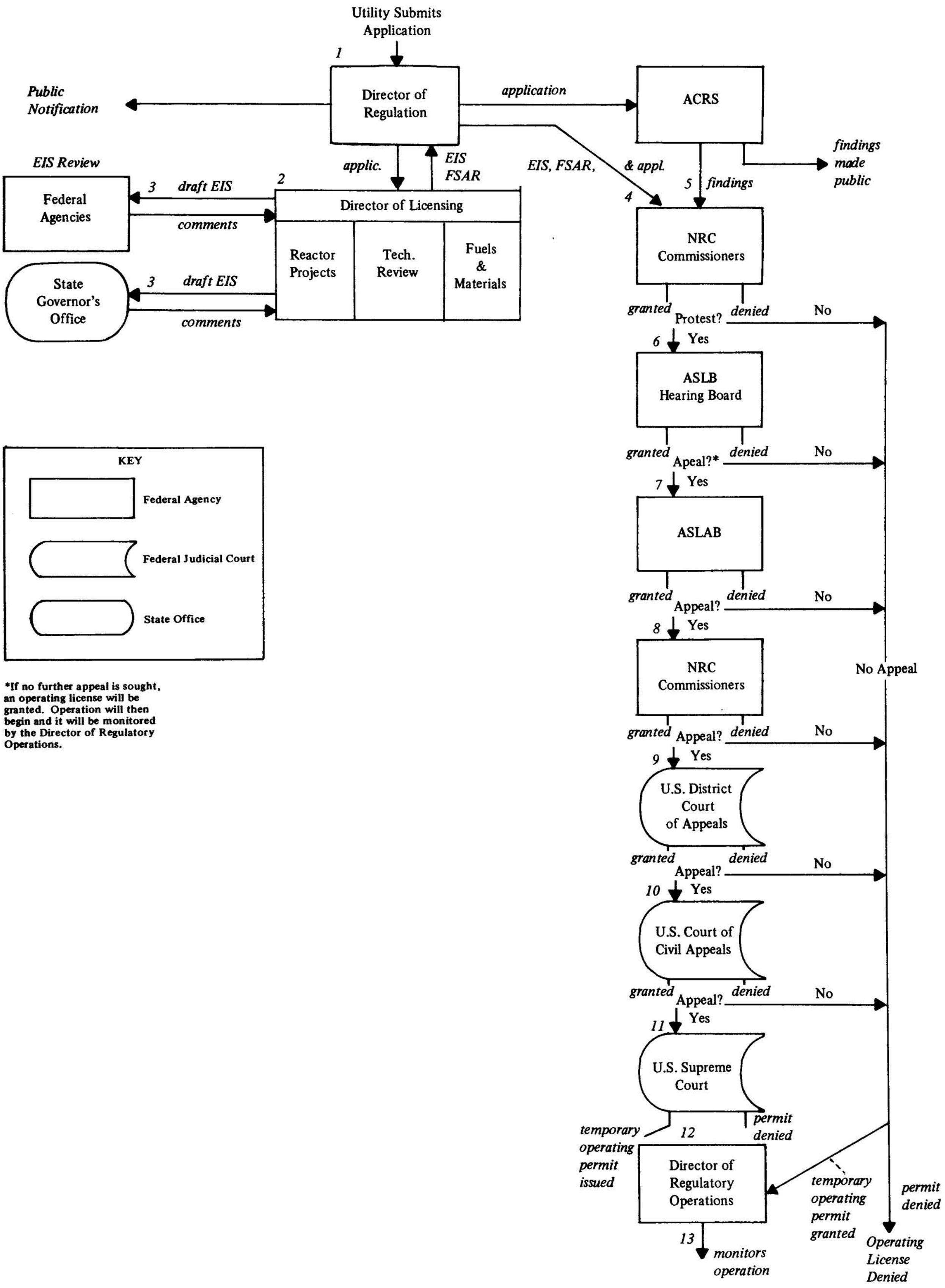
(9-11) The appeals process is similar to that for the construction permit.

(12-13) After an operating license has been issued, operation of the plant is monitored by the Director of Regulatory Operations, NRC, to insure compliance with specifications set forth in the license and other NRC regulations.

Before a permanent operating license is granted to a utility, a temporary operating license is issued. In this manner the Nuclear Regulatory Commission can better control the operation of the nuclear power facility.

(14) Again, there is no fixed schedule for this phase. However, the Director of Licensing, NRC, has estimated the process takes about 16 months (O'Leary, 1972).

FIGURE V-4 NRC OPERATING LICENSE



*If no further appeal is sought, an operating license will be granted. Operation will then begin and it will be monitored by the Director of Regulatory Operations.

Siting Fossil-Fuel Power Plants in Texas

The siting of a fossil-fuel power plant in Texas requires permits from both state and federal agencies. There is, however, no one federal agency that licenses the construction of these plants as the NRC does for nuclear power plants. In fact, prior to the 1972 federal Water Pollution Control Act Amendments (WPCAA), no federal agency required environmental impact statements for the siting of fossil-fuel plants. Although this policy is changing as a result of the WPCAA, federal agencies requiring permits continue to consider only environmental impacts of the plant and fail to adequately review other siting issues.

These are the steps an electric utility must take to construct a fossil-fuel power plant in Texas corresponding to the explanatory numbers in Figure V-5):

(1) After conferring informally with the Texas Water Development Board over state water availability and the potential environmental impact of the plant, the utility submits applications to the Texas Air Control Board and the Texas Water Quality Board (seeking air-emission and water-discharge permits, respectively), as well as to the Texas Water Rights Commission (seeking legal rights to state water needed for the operation of the plant). The utility also submits permit applications to the regional offices of the COE (for authorization to dispose of dredge-and-fill materials) and the EPA (for authorization to dispose of certain plant effluents).

(2) The utility confers with the Texas Highway Department, the Texas Railroad Commission, and the Texas General Land Office to determine whether additional permits might be required. Consultation with the Texas State Health Department to insure that state health standards would be adhered to during the construction of the plant also occurs.

(3) After a state agency denies or grants its permit to the utility, the utility or an intervenor in the hearings process can appeal the agency decision to the District Court of Travis County, the Texas Court of Civil Appeals, and the Texas Supreme Court. An appeal of the decision of a federal agency (i.e., COE or EPA) can be made to the federal courts having corresponding jurisdiction.

(4) The utility may begin construction of its fossil-fuel power plant after it obtains all required state and federal permits.

Siting Procedures in Other States

The problems of environmental destruction and decreasing electric-power reliability have led to state and federal interest in regulation of power-plant siting. State responses to problems of power-plant siting have resulted in a variety of procedures, a cross section of which will be considered in this section.

In the past, power-plant siting, if regulated at all, has been subject primarily to local zoning laws. Most states have been mainly interested in protecting the consumer by regulating rates. Although most states have state utility commissions with some authority to regulate investor-owned electric-utility systems, less than one-half have had authority to regulate publicly owned and cooperatively owned systems (FPC, *National Power Survey*, 1970). Recently the concern of the states has shifted from the relationship between the utilities and the consumer to the relationship between the utilities and the environment.

The National Association of Regulatory Utility Commissioners (NARUC), recognizing the need for state consideration of environmental factors in power-plant siting, proposed a Model State Utility Environmental Protection Act in 1970. Many states have adopted the important features of the act. The principal provisions of the NARUC Act are delineated in Appendix A.

Since a number of these features is common to all proposed federal legislation concerning power-plant siting, Table V-1 is included to illustrate the extent to which these elements have been incorporated into state siting procedures.

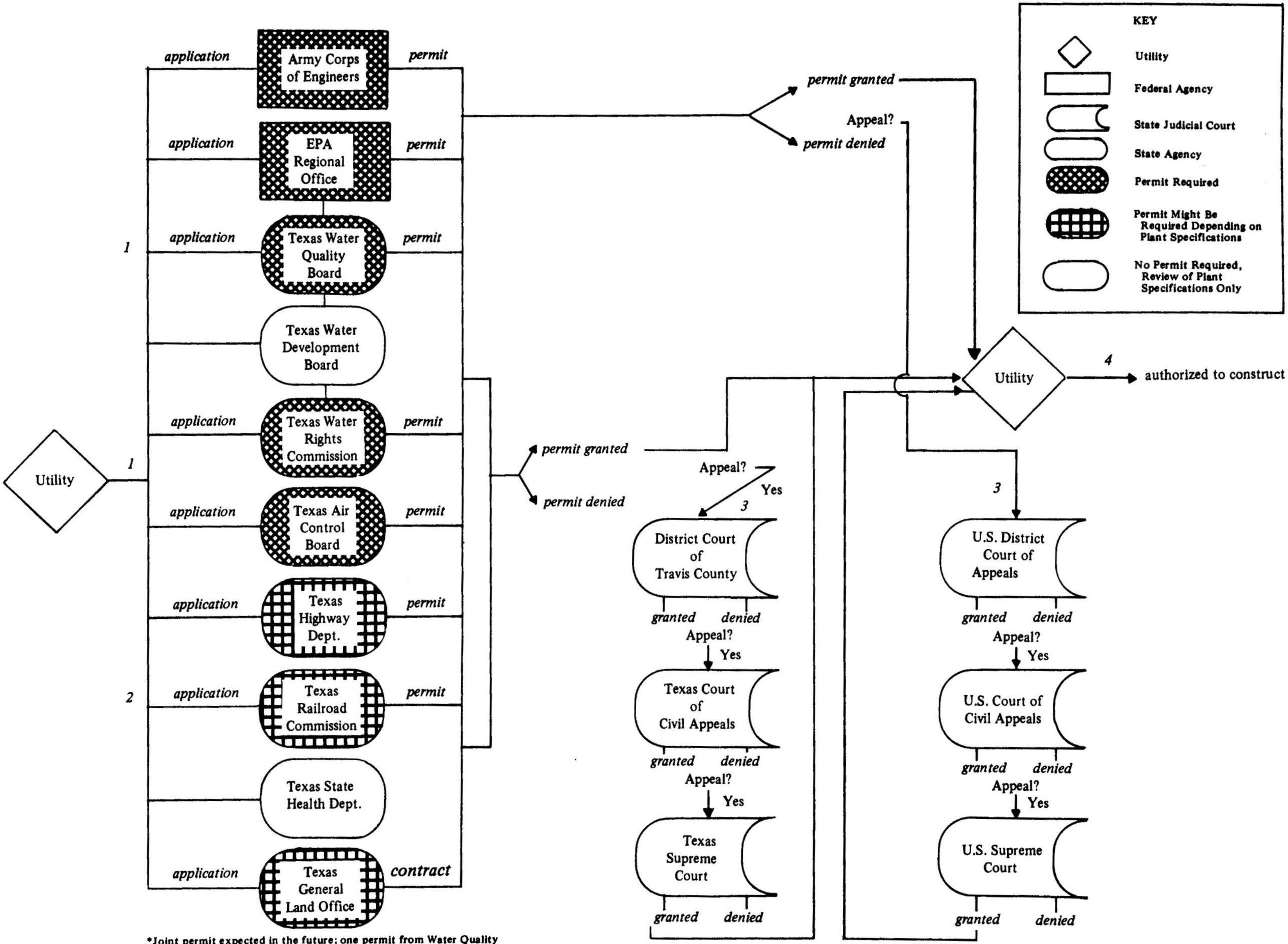
The control features summarized in Table V-1 are included in most pending federal siting legislation and are regarded as vital to the protection of the environment and to electric reliability. Power plants and transmission lines have a considerable impact on the environment, and their construction should not be permitted without first providing for (1) long-range plans by the utilities and the state government to insure the time necessary to study possible implications of the proposed sites; (2) environmental review and assessment of proposed construction by qualified state agencies; and (3) public hearings to allow citizen participation in the siting of power plants.

Environmental review is now a requirement imposed by federal pollution-control legislation. It is assumed that all states have complied with these acts; however, NA (Not Available) was used in Table V-1 if positive knowledge of compliance was not available. Environmental review and public hearings appear to be accepted in most states as legitimate controls for power-plant siting. Unfortunately, many states have not recognized the vital need for future provision of electric power in their state. These states require neither long-range planning for electric power nor certification of power plants and transmission lines. A few states have established a land-use agency in order to ensure the proper future use of land in their states.

Environmental considerations have led to involvement in the site-selection process by many groups. The delays and added costs to power-plant construction due to this volume of input has made a one-stop site-selection procedure increasingly more desirable. The coordination by one

FIGURE V-5

AN OVERVIEW: LICENSING PROCEDURES FOR THE CONSTRUCTION OF FOSSIL-FUEL POWER PLANTS



*Joint permit expected in the future; one permit from Water Quality Board expected ultimately with veto powers retained by EPA.

TABLE V-1

STATE POWER PLANT SITING CONTROLS

State	Certification required for construction of		Public hearings required	Environmental review	1-stop siting procedure	Long range plans (by state and/or utilities)	State land-use agency
	Power plants	Transmission line					
Alabama	Y	Y	Y	NA	N	NA	NA
Arizona	Y	Y	Y	Y	Y	Y	NA
Arkansas	Y	Y	Y	Y	N	NA	NA
California	Y	Y[1]	Y	Y	N	Y	Y
Colorado	Y[1]	Y[1]	Y	Y	N	N	Y
Connecticut	Y	Y	Y	Y	Y	Y	N
Delaware	N	N	N	Y	N	NA	NA
Florida	N	N	N	Y	N	NA	Y
Georgia	N	N	N	N	N	NA	NA
Idaho	Y	Y	N	NA	N	NA	NA
Illinois	Y[2]	Y[2]	Y	Y	Y	N	NA
Indiana	N	N	N	Y	N	NA	NA
Iowa	N	Y[1]	Y[1]	Y	N	NA	NA
Kansas	Y	Y	Y[1]	NA	N	NA	NA
Kentucky	Y	Y	Y	Y	N	NA	NA
Louisiana	N	N	N	Y	N	NA	NA
Maine	Y	Y	Y[1]	Y	N	N	Y
Maryland	Y	Y	Y	Y	Y	Y	N
Massachusetts	Y[1]	Y[1]	Y	Y	N	NA	NA
Michigan	N	N	N	Y	N	NA	NA
Minnesota	Y	N	Y	Y	N	NA	N
Mississippi	Y	Y	Y	Y	N	NA	NA
Missouri	Y	Y	Y	Y	N	NA	NA
Montana	N	N	N	Y	N	NA	NA
Nebraska	N	N	Y	Y	N	NA	NA
Nevada	Y	Y	Y[1]	Y	Y	NA	NA

[1] Required under certain circumstances
[2] Nuclear power plants only

Sources: Southern Interstate Nuclear Board, 1972.
Electric Power and the Environment, U.S. President, Office of Science and Technology, 1970.
Association of the Bar of the City of New York, Special Committee on Electric Power and the Environment, *Electricity and the Environment*, West Publishing Co., St. Paul, Minn., 1972.
Correspondence with state government officials from California, Maryland, New York, and Oregon.

TABLE V-1 (continued)

State	Certification required for construction of		Public hearings required	Environmental review	1-stop siting procedure	Long range plans (by state and/or utilities)	State land-use agency
	Power plants	Transmission line					
New Hampshire	Y	Y	Y	Y	Y	Y	NA
New Jersey	N	Y	Y	Y	N	NA	NA
New Mexico	Y	Y	Y	Y	Y	N	NA
New York	Y	Y	Y	Y	Y	Y	Y
North Carolina	Y	N	Y[1]	Y	N	NA	NA
North Dakota	N	Y	Y	Y	N	NA	NA
Ohio	N	N	N	Y	N	NA	NA
Oklahoma	N	N	N	NA	N	NA	NA
Oregon	Y	N	Y	Y	Y	Y	N
Pennsylvania	Y[1]	Y	Y	Y	N	NA	NA
Rhode Island	Y	Y	Y	Y	N	NA	NA
South Carolina	Y	N	Y	Y	N	NA	NA
South Dakota	N	N	Y	NA	Y	NA	NA
Tennessee	Y	Y	Y[1]	NA	N	Y	NA
Utah	Y	Y	Y	Y	N	NA	NA
Vermont	Y	Y	Y	Y	Y	N	Y
Virginia	Y	Y	Y	Y	N	NA	NA
Washington	Y	Y	Y	Y	Y	N	Y
West Virginia	Y	N	Y	Y	Y	NA	NA
Wisconsin	Y[1]	Y[1]	Y	Y	Y	NA	NA
Wyoming	Y	Y	Y	Y	Y	Y	NA

agency of all reviews should increase the efficient processing of a construction permit for a power plant or transmission line. Table V-1, however, shows that only one-third of the states have established such an agency.

In order to better understand the features of other states' procedures that might be utilized in Texas, the activities of six representative states will be more closely examined.

Arizona. The Arizona Power Plant and Transmission Line Siting Committee was established by law in 1971. The committee is composed of the directors of state agencies with a particular interest in power plants and transmission lines sites–i.e., the pollution controls boards and the Land Commission–and seven members, appointed by the Corporation Commission, who represent cities, counties, and the general public. The attorney general is the chairman.

A utility must file with the Corporation Commission an application for a certificate of environmental compatibility before construction of a power plant or transmission line. The commission refers the application to the committee, which holds hearings and then approves, denies, or modifies the application. A certificate must be affirmed and approved by an order of the commission. Any party to a certification procedure may request a review by the commission, whose decision is final.

This siting procedure incorporates many desirable features, including obligatory annual submission of 10-year plans by the utilities. However, other state or local conditions imposed on power-plant sites are permitted, except where the committee deems them "unduly restrictive" or "not feasible in view of technology available". The only other NARUC considerations not included are proposed additions to plant facilities and a definition of "construction" which would include site preparation.

California. Thirty months of public resistance to a nuclear power-plant site proposed in 1961 by the Pacific Gas and Electric Company prompted consideration of a policy for siting power plants in California. In 1964, the Administrator of the Resources Agency appointed an *ad hoc* Power Plant Siting Committee. In 1965, the State of California Policy on Thermal Power Plants was developed. This was revised in 1969.

The routine followed by the Power Plant Siting Committee, which is composed of representatives from eight agencies within the Resources Agency and a representative from the Department of Public Health, included a meeting with the utility, resulting in a signed agreement. The utility generally agreed to take certain actions to protect the environment and the Resources Agency agreed not to oppose the utility application for a certificate. However, because one of these agreements was ruled void and unenforceable in 1972, no further agreements have been signed.

The State Policy on Thermal Power Plants set forth two specific policies pertaining to thermal power plants: (1) the policy to ensure the protection of the environment and the public, and (2) the policy "to encourage the use of nuclear energy". Specific considerations implementing these policies were enunciated in the statement, providing operating guidelines from the siting committee. However, three developments prompted the secretary of resources to withdraw this policy on January 12, 1973: a) in 1970, new environmental laws formalized the agency consultation process; b) the creation of seven coastal commissions empowered to suggest environmental controls on coastal development, which constitutes a partial duplication of the activities of the siting committee; and c) the expectation of new power-plant siting legislation.

At present, the Public Utility Commission issues Certificates of Public Convenience and Necessity for the construction of generating facilities and transmission lines, backed up by an environmental evaluation by the Resources Agency. Although California was one of the first states to address power-plant siting nad environmental concerns together, the legislature has not yet formalized a one-stop siting procedure.

Maryland. The Maryland Power Plant Siting Act, enacted in July, 1971, emphasizes long-range planning by the Maryland Public Utility Commission and the utilities. Implementing this program involves action in three areas: general research, monitoring, and site evaluation. The most unusual feature of the act, however, is the authorization for site acquisition.

The Public Service Commission is directed to evaluate the annual, 10-year plans submitted by the utilities, and forward a 10-year "plan of possible and proposed sites" to the secretary of the Department of Natural Resources.

The Department of Natural Resources is directed to determine the environmental impact of each proposed site, with a detailed investigation of the acceptable sites. Also, the secretary of the department is empowered to acquire for the state desirable sites sufficient to satisfy future requirements and to hold these sites until needed by a utility. The number of sites retained is to remain between four and eight. Revenue for the implementation of the act is obtained by a surcharge per KWH on electricity, to be deposited in an environmental trust fund.

The certification procedure is a one-stop process. The Public Service Commission (PSC) may grant, deny, or modify an application from a utility for a Certificate of Public Convenience and Necessity after a public hearing and after receiving recommendations from certain state agencies, including the Departments of Natural Resources, State Planning, and Health. However,

"the highly visible utility planning and environmental

> **research called for by the legislation is not necessarily tied to the actual site-certification process. . . . The exclusive use of sites upon which the Department of Natural Resources has published a detailed environmental statement would successfully coordinate the functions of the Fund and the PSC siting procedure. . ."** (The Association of the Bar of the City of New York, 1972).

Although it seems evident that the legislature intended that only sites approved by the Department of Natural Resources be used by the utilities, this requirement is not written into the statute. This lack of statutory coordination should be corrected to prevent undesirable consequences. Another principal deficiency of the act, the lack of requirement for public input until the application for a certificate, might be eliminated by providing for public hearings on sites which the secretary finds acceptable.

New Hampshire. A number of state power-plant siting acts, as well as the NARUC Model State Act, neglected to provide for public participation before the certification process. New Hampshire is one of few which has provided for early public participation.

This state's approach to power-plant siting, although involving two separate agencies, is essentially a one-step process. The Public Utilities Commission (PUC) grants the Certificate of Site and Facilities, with input from the Site Evaluation Committee. The committee was established in 1971 and is composed of about 13 members representing interested state agencies. The committee performs two major functions: First, it reviews and comments on the utilities' long-range plans and conducts hearings on plant sites identified five years in advance of construction. Second, the committee holds joint hearings with the PUC within six months of the receipt of an application for a certificate. Before granting a certificate, the PUC must consider two criteria in addition to accepting the site committee's findings: (1) the facility must be required for present and future reliability, and must not adversely affect system stability and reliability, and (2) economic factors. A counsel for the public, appointed by the Attorney General, represents the public interest in questions of environmental quality and electric-power reliability.

The hearings on sites identified five years in advance of construction provide early public participation in the siting process. Open discussion on proposed sites this far ahead of construction serves to deal with most objections to the facility and thus minimize costly construction delays. When public hearings are postponed until an application is made for a construction permit, public protest is generally more vocal and more determined, possibly because the area's citizenry suspects the utility of secrecy in an attempt to force the acceptance of the site.

New York. A noteworthy aspect of New York's siting procedure is the provision for coordination between the Public Service Commission (PSC) and other state, local, and federal agencies. Chapter 385 of the State Statutes excludes steam electric-generating facilities "over which any agency or department of the federal government has exclusive jurisdiction, or has concurrent jurisdiction with that of the state and has exercised such jurisdiction". The statute also permits the chairman of the PSC to enter into an agreement for a joint hearing with an agency of the federal government which has concurrent jurisdiction over the facility. These two provisions thus prevent needless duplication in the siting process.

The certification process in New York is similar to other states, except that certification of transmission is done through the PSC, whereas the certification of a generating site is done by the Siting Board. The Siting Board, established by Chapter 385, is composed of the Commissioners of the PSC, Environmental Conservation, Commerce, and Health, and an *ad hoc* member from the judicial district where the proposed site is located. Public participation is insured throughout the siting process by the requirements for public hearings. A public hearing must be held for each application for a certificate for environmental compatibility and public need; in addition, each utility must submit 10-year plans to the Department of Public Service at a public hearing.

Intrastate duplication is avoided by two provisions. The Siting Board may refuse to apply any local law which the board determines is "unreasonably restrictive in view of the existing technology or the needs of or costs to consumers". In addition, no other state agency or municipality may require approval or permits of a utility, excepting the application of state laws for employee protection.

Two additional state agencies provide for comprehensive, statewide planning for adequate energy. Chapter 386 created the Legislative Commission on Energy Policy for the State of New York to formulate "recommendations regarding a comprehensive, rational energy policy". The state's Atomic and Space Development Authority is authorized to select, acquire, and furnish, through sale or lease to utilities, sites for nuclear power plants. Public participation is again permitted prior to a decision on a site.

New York's statutory provisions for power-plant siting and land use are perhaps the most extensive in the nation. All the major features of the NARUC bill have been included, as well as some additional desirable features. The one major criticism of the process might be directed at the separate certification procedures for generation and transmission of electricity.

Oregon. The Nuclear and Thermal Energy Council, composed of the public utility commissioner, the state engineer, the state health officer, the director of environmental quality, and five members appointed by the governor, was established on June 30, 1971. The council receives notices of intent (which utilities must file at least 12 months prior to submitting an application for a site certificate); receives applications for site certificates; sends copies of the notices of intent and of the application to interested state agencies for comment and recommendation; holds public hearings on the applications for site certificates; coordinates and cooperates with other state, local, and federal government agencies; monitors plants, installations, and intrastate transportation of radioactive material; reduces or curtails operation if it determines there is danger to the public health and safety; and sends its recommendation on granting certificates to the governor, who is the final authority over site applications. However, the governor's authority is limited to the power to approve or reject a site certificate submitted by the council; he cannot execute an application rejected by the council.

The noteworthy features of Oregon's statute include the annual fee required of the utilities, the designation of the governor as the final authority, and provisions for the council to take immediate action if it determines that danger to the public health and safety is imminent. Also, a statewide siting-survey task force has surveyed the state and classified potential sites into those that are suitable, less suitable, and unsuitable for siting thermal or nuclear power plants.

Activities of Other States. A number of other states have passed legislation that closely parallels many provisions already discussed. Vermont was one of the first states to enact regulations for siting power plants. In its 1969 bill, certification with environmental limitations was required for generation and transmission facilities. Maine, in 1971, prohibited construction of electric-utility facilities without a certificate of public convenience and necessity from the Public Service Commission. Nevada also passed legislation in 1971 requiring a permit from the Public Service Commission, but a hearing is required only if a protest is filed against the permit by an interested party. New Mexico's 1971 law requires construction and location permits by the Public Utility Commission. The environmental limitations are the existing air and water pollution-control standards, and the commission's finding that the "location will [not] unduly impair important environmental values". In Pennsylvania, a certificate of convenience is required only when a site is not zoned for such a use by the local zoning board. In Virginia the State Corporation Commission is required, since 1972, to give consideration to the environment and assure minimization of environmental impact when approving construction of an electric-utility facility. Wyoming requires certificates of public convenience and necessity from its Public Service Commission and public hearings for sites of plants and transmission lines. However, environmental considerations are under the purview of other departments. The Illinois Environmental Protection Act of 1970 established an elaborate and comprehensive structure but does not address power-plant siting specifically, dealing with them instead in the context of potential sources of pollution.

Interest in the problems of power-plant siting has also resulted in other types of activity. In Tennessee and Massachusetts, for example, special commissions are investigating power-plant siting.

Policy Implications and Alternatives. Investigations of various states' activities and the NARUC bill suggest specific administrative and procedural issues that should be considered by states (such as Texas) that may be contemplating changes in their power-plant siting procedures. These features include:

(1) Administrative Composition of One-Stop Siting Agencies

Most states having a one-stop siting procedure prefer to delegate siting responsibility to a commission composed of heads and/or representatives of relevant state departments (examples include Connecticut and Oregon). Remaining states with one-stop siting agencies have delegated siting responsibility to their public utility commission.

(2) Long-range Planning

Long-range planning, basic to any siting procedure, varies among the states. The most common provision requires annual, long-range plans, usually encompassing a ten-year period, by utilities (examples include Arizona and Oregon). A few states have implemented statewide planning for power-plant siting (examples include California, Oregon, and New York). New York and Maryland have provided for state acquisition of possible power-plant sites, with sites made available to utilities as needed.

(3) Notice of Intent; Early Public Participation

Oregon requires that an electric utility file a notice of intent to construct a facility at least one year prior to the submission of a site application. This requirement helps to generate early public awareness of the project. Furthermore, input by the public before the filing of a site application provides for early settlement of possible disagreements between utilities and the public.

(4) Approval by Governor

Washington and Oregon require gubernatorial approval of power-plant applications before the siting agency can issue a certificate.

(5) Emergency Action by the Siting Agency

Oregon's siting procedures include a provision for immediate action by its regulatory council when "there is a violation of a safety standard or danger from the continued operation of a plant or installation". The council is authorized to reduce or curtail operations if it is deemed necessary.

(6) Coordination with Other Government Agencies

Many states face the problem of overlapping federal, state, and local jurisdiction over power-plant siting. In order to mitigate this problem, several states have developed siting procedures which include provisions for determining where ultimate power-plant regulatory authority lies. Such provisions work to lower costs incurred through duplication of effort in the siting process.

Whether these presently optional features will be transformed into statutory requirements by future federal legislation remains to be seen. But whatever the federal government may choose to do, it will have the experience of a number of states upon which to rely.

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APPENDIX V-A

MODEL STATE-UTILITY ENVIRONMENTAL PROTECTION ACT

SUMMARY OF THE NATIONAL ASSOCIATION OF REGULATORY UTILITY COMMISSIONERS ACT:

(1) Provision for one-stop, siting procedures, with the public service commission serving as the agency involved.

(2) Requirement of certification for the construction of any major utility facility.

(3) Requirement for public hearings to be held by the public utility commission upon the receipt of an application for a certificate.

(4) Indications of the options open to the public service commission, e.g., the granting of a certificate, the denial of an application, or the conditional granting of a certificate.

(5) Provision for rehearings and for judicial review, with limitations stipulated.

(6) Prohibition of public service commission action where a federal agency has exclusive jurisdiction.

(7) Provision for the public utility commission to cooperate and coordinate actions with other state and federal agencies, particularly where concurrent powers exist.

(8) Provision for the nullification of other state, local, or regional agency's conditions which might have been applied to the construction, operation, or maintenance of a major utility facility already authorized by a certificate.

The NARUC Act includes certain requirements not found in the 1970 Model State Act: (1) long-range planning by the utilities, (2) disclosure of construction sites and plans one year ahead of proposed construction, (3) disclosure of proposed sites five years in advance of construction, and (4) required public hearings on the five-year plans.

CHAPTER SIX

PUBLIC PARTICIPATION IN THE SITING OF ELECTRIC POWER-GENERATING FACILITIES

Until recently, public participation in electric-power decisions was confined largely to individuals and groups seeking more adequate compensation for a utility's exercise of eminent domain or those who challenged proposed rate increases. The emergence of environmental concerns and increasing anxiety about nuclear power generation have greatly expanded the public's traditional role. Today, public interest groups take full advantage of the administrative process to challenge power-plant siting decisions as well as the responsiveness of regulatory agencies in protecting public health and safety.

Two arguments have become the focus of public participation as an element in policy decisions: (1) its role as a vital part of the democratic process, and (2) its hindrance to the speed and efficacy of agency operations. The democratic argument is based on the assumption that decision making must be responsive to the interests of widely representative groups and that arbitrary action in policy planning is unacceptable (42 U.S.C. 145 (1) (a), 1965). The hindrance argument, on the other hand, regards public participation as an imposition on the time, energy, and ingenuity of administrative agencies and their capacity to respond to public needs (*South West Law Journal*, 1970).

Both arguments represent extreme positions and are not addressed to the specific circumstances of power-plant siting. Power-plant siting is a process of great complexity, since it represents the merger of both public and private interests. Moreover, it not only involves the traditional economics of site acquisition (i.e., inexpensive land with an abundance of cooling water and transportation facilities) but covers such matters as the impact of site development on future land use and the environment.

There is considerable controversy, however, over the proper role of the public in site-identification and the designation of needed facilities. Power-system planning is highly technical and requires specialized knowledge. Yet members of the public will be affected by the economic, aesthetic, and environmental consequences of future system growth. It is therefore important that attention be drawn to those issues that affect the siting and development of electric power-generating facilities. This chapter provides a focus for discussing public participation in power-system expansion

- by examining the question of public representation;
- by describing barriers to participation;
- by analyzing public standing in the courts;
- by investigating delays caused by citizen litigation; and
- by commenting on the electric-utility view of public involvement.

WHO IS "THE PUBLIC"?

The battle over the public's right to intervene has been extensively reviewed by the courts. The questions that now arise are: How far does this right extend? Who may represent "the public"? Jerre Williams has attempted to define "the public" by delineating four generic groups or attitudes that are represented in decisions regarding the location of major public facilities (Williams, 1972). The first group is composed of persons immediately affected by a proposed project (e.g., those living in the vicinity of the project). A second group is made up of ecologists who have no self-interest but who are genuinely concerned with environmental protection. A third group consists of commercial developers and businessmen. The fourth group is the general public, which enjoys a high standard of living and does not wish to sacrifice it.

Other configurations of "the public" also exist, including the poorer inner-city inhabitants who are interested in cheap electric power and academics who are perhaps more concerned with preserving a democratic selection procedure than with the generating site itself. The crucial point, however, is that power-plant siting issues may induce a variety of public groups to seek an active role in their resolution, each with a different purpose. As a matter of practice, decisions regarding what group will be represented in administrative and judicial forums has been left almost entirely to precedents established by federal and administrative law judges.

BARRIERS TO PUBLIC INTERVENTION

Citizen participation can inform agencies and aid them in making wiser decisions. The traditional forum has been the public hearing, held by specific federal and state agencies before permits can be granted for the construction and operation of power plants. At the federal level, these agencies include the Nuclear Regulatory Commission, the Environmental Protection Agency, and the Army Corps of Engineers, and at the state level, the Texas Water Quality Board, the Texas Water Rights Commission, and the Texas Air Control Board. Hearings must also be held by the Texas Highway Department and the Texas Railroad Commission if permits from these agencies are required.

Although opportunities exist for public participation through the hearing process, a number of factors deter effective public input. These factors include insufficient expertise, the cost of participation, the lack of effective notice of hearings, and time. But the basic problem intervenors face is inadequate resources. For example,

> the cost of intervention against a power-plant application can exceed $100,000. While intervenors must raise the funds necessary for litigation from contributions or foundation monies, the utility can recoup its litigation expenses through rates. In addition, the applicant is frequently aided by the regulatory staff, which, by the time the case comes to hearing, has often decided to support the application (The Association of the Bar of the City of New York, 1972).

Five financial barriers to intervenor participation in the hearing process can be identified:

- Multiple-copy requirements of all documents submitted by parties are required by some agencies.
- Transcripts are prepared by private reporting companies under contract with federal agencies. Copies are on file with the agency, but can only be used by attorneys in Washington, D.C., during business hours. The transcripts are usually made available by the agency a week or more after testimony is presented and cannot be copied, thereby reducing their usefulness. Daily transcripts are helpful to attorneys for cross-examination and cost approximately $1.38 per page in Nuclear Regulatory Commission proceedings (The Association of the Bar of the City of New York, 1972). Agencies receive free copies of the hearings.
- Information made available to the public is often disorganized. Intervenors waste effort gathering information.
- Expertise is costly and usually not available to intervenors with limited resources. Many experts are employed by the government and are unable to assist or testify on behalf of the intervenors. As a result, public testimony usually falls short of expert testimony.
- Legal fees are the most costly aspects of public intervention. Counsel is required to be present at all stages of litigation. This increases costs when intervenors are only contesting a few issues.

Lack of effective notice also hampers public participation. Present notice requirements (e.g., *Federal Register*, newspapers with a general circulation in the area) may not adequately alert interested persons. Moreover,

> Time problems further magnify the inequalities of resources and information. The applicant has years to prepare its application and muster its case. Federal commissions have almost that long. But, intervenors usually have only three weeks, or at most three months, in which to decide to intervene, raise the necessary funds, and marshall a case—often with inadequate, volunteer technical resources (The Association of the Bar of the City of New York, 1972).

PUBLIC STANDING

Defined as the right of a citizen to challenge the actions of the federal government in the courts, standing embodies certain qualifications. The view has been widely held for the past half-century that the courts could not withstand an open invitation to citizens to participate in judicial proceedings contesting past or proposed federal action. Yet, the past decade has witnessed an increased concern for environmental matters that has led to greater demands for public participation in all aspects of federal decision making, including standing to review federal administrative action.

Prior to the mid-1960s, standing was granted only to those who could claim the existence of these conditions:

- an adversary condition capable of judicial review and remedy as defined in Article III of the Constitution;
- the claimant had suffered economic injury and could identify the cause of such injury as resulting from federal action;
- provision under a relevant federal statute.

Basically these conditions remain in effect today. However, since 1965, with only one exception (*Sierra Club* v. *Morton*, 1972), they have been consistently broadened through liberal interpretation by the courts to allow more interested persons standing to participate in the review of government decisions.

Article III of the Constitution restricts the judicial power of review to "cases" and "controversies". The question of standing relates to whether the dispute would be presented in an adversary context capable of judicial resolution. The fundamental test for "case" or "controversy" is whether the claimant alleges direct injury.

Initially, direct injury meant direct economic injury, but with the proliferation of electric-power facilities and environmental concerns, the courts in 1965 expanded the concept of standing to include those who seek to protect the public interest in aesthetic, conservational, and recreational aspects of power development (*Scenic Hudson Preservation Conference* v. *FPC*). Thus, economic injury was given broader significance in terms of the environment and the individual. In 1966 the concept of standing and the public interest was further broadened in *Office of Communication of United Church of Christ* v. *FCC*, which held that standing should be given to persons intending to protect the public interest as well as their own private interests. Liberal interpretations toward granting increased public participation in judicial review proceedings of government actions did not cease here. In 1967, towns, local civic organizations, and conservation groups were given standing (*Bedford* v. *Boyd*), and in several cases in 1970 standing was afforded associations to represent their members in judicial proceedings, contesting federal administrative action (*Data Processing* v. *Camp, Hudson Valley* v. *Volpe, Environmental Defense Fund* v. *Harden, Sierra Club* v. *Hickel*). It was then stated that an organization whose members are injured may represent those members in a proceeding for judicial review. The statement was emphatic that mere organizational interest was not sufficient. In 1972, with the Mineral King Case (*Sierra Club* v. *Morton*), the progressive liberal interpretation of standing hit a snag. The courts ruled that the Sierra Club had failed to allege that it or its members would be directly affected by proposed government action, and thus denied it standing. This decision has the effect of reinforcing direct injury as the basis of standing to protect the public interest.

The final standing qualification is that the review must be authorized under a relevant federal statute which generally describes petitioners as "aggrieved" or "adversely affected" by government action. For example, one of the two most widely applied statutes, the Federal Power Act (FPA), states that

> any party to a proceeding under this chapter *aggrieved* by an order issued by the commission in such proceeding may obtain a review of such order in the United States Court of Appeals for any circuit wherein the license or public utility to which the order relates is located.

The Administrative Procedure Act (APA), even more widely used than the FPA, is intended to assure comprehensive review of a broad spectrum of administrative actions, including those made reviewable by specific statutes without adequate review provisions as well as those for which no review is available under any other statute (5 USCA § 706). The APA is not applicable to the extent that (1) statutes preclude judicial review, or (2) agency action is committed to agency discretion by law (5 USC § 701 (Supp. IV)).

Currently, standing is granted to those who can claim the existence of at least one of four conditions:

- an adversary condition capable of judicial review and remedy as defined in Article III of the Constitution,
- the claimant must assert injury in fact to the interest he wishes to protect and must identify the cause of such injury as resulting from federal action,
- review must be authorized under a relevant federal statute,
- a demonstrated capacity to represent the interest must be proved.

While the last word on standing to challenge federal action has not been spoken, it is clear that the public interest has gained a point of access to the administrative decision-making process. It is equally clear that the same point of access has not been acquired in the area of private conduct affecting the public interest—a problem that will surely draw increasing attention.

A final concern is expressed and an alternative to standing offered by Christopher D. Stone, who asserts that a guardianship approach may be preferred to standing (Stone, 1972). He writes that

> one ought to handle the legal problems of natural objects as one does the problems of legal incompetents. . .Someone is designated by the courts with the authority to manage the incompetent's affairs. . . On a parity of reasoning, we should have a system in which, when a friend of a natural object perceives it to be endangered, he can apply to a court for the creation of a guardianship.

Mr. Stone is not the only one to assert legal rights for natural objects, but activation of the concept of guardianship or the elimination of the concept of standing seems a long way into the future—if, indeed, it ever comes.

DELAYS

Litigation has resulted in increasing delays in the licensing process of electric-power facilities. This can have a significant impact upon the availability of electric power in the area of the proposed site. Although intervenors do have a legitimate role in the process, the participation should not be given any more emphasis than that given to the private sector.

> Thus, a process which gives intervenors the discretion to delay the licensing of a needed plant is no more satisfactory than a process which keeps them from making their arguments effectively and submitting them for decision to a body charged with protecting the public interest (The Association of the Bar of the City of New York, 1972).

All parties have their own view about the causes of delay. Utilities see intervenors as the source of delay. To the intervenor, the administrative process is the bottleneck. However, analysis shows that the infirmities of the decision-making process are the real cause of delay. For example, since the NRC staff is overworked and rarely receives complete utility permit applications, intervenors find it difficult to get information before hearings.

Delay has a considerable impact upon utility decision making. Many utilities have dropped plans to construct power plants where they expect environmental intervention. These power plants will therefore be built at sites where environmental opposition is less likely, but the environmental impact may be no less. It is also possible that older, less-efficient power plants will be kept in service in order to avoid building new ones.

The FPC and the utility industry predict an increased number of delays because of environmental concerns. Most delays occur at the federal level, even though more state and local permits are required to build an electric power plant. These delays will result in an elongation of the licensing process. Licensing delays inject a new element of uncertainty into the process, and may significantly alter the availability of electric power in the area of the proposed site.

PUBLIC INVOLVEMENT AS VIEWED BY THE ELECTRIC-UTILITY INDUSTRY

Public participation is often confused with other processes associated with decision making. John K. Boyton delineates four processes: (1) Information—telling people what is to happen, (2) Persuasion—explaining to people why they should like what is to happen, (3) Consultation—asking people for reactions before a decision is taken, or sometimes after a decision is taken, and (4) Participation—some form of real involvement of people in the decision that is reached (Boyton, 1972). This section discusses the role of the electric-utility industry in educating the public and seeks to describe the industry's view of public intervention in power-plant siting decisions.

Public Participation or Public Education?

The utility industry believes it is not its role to accept the notion of public participation, and draws a distinction between public participation and public education. The supply of electricity to its customers is the major responsibility of utilities. A portion of that responsibility is informing or educating the public in the optimal uses of electricity and the location, safety, and environmental aspects of proposed power plants.

Public input into the decision-making process is characterized as honestly motivated, but misinformed. The public is thought to generally lack the necessary expertise to grasp the complex issues surrounding power-systems planning, and utilities lack the time and capability to educate the public on the complex issues involved. Theodore J. Nagel, vice president for system planning, American Electric Power Service Corporation, has addressed this problem with unusual candor:

> Because of its highly technical nature, [power] system planning cannot be undertaken in an "open forum" without the risk of total confusion and interminable delay. While the interests of the public in specific siting proposals must be considered, the important question is at what stage of the planning process the public's views can be focused and intelligently brought to bear on the choice of power-plant sites. In my judgment, such public involvement can be most meaningful only *after* the utility has selected its sites and prepared in full its technical, economic, and environmental evidence for public review. Earlier involvement would result in useless rhetoric and an evasion of responsibility by the utility, with a resultant failure to meet its overall public obligation.
>
> It is unrealistic to assume that responsible decisions in the public interest can be made, and opposition to power-plant siting reduced significantly, by public and regulatory involvement in the earliest stages of utility planning before full study is made of alternative sites, of their suitability for power generation purposes, and of their possible environmental impact (National Academy of Engineering, 1972).

Two questions the utilities raise are:

- Who represents the public?
- What is the purpose of intervention?

An executive of a privately owned electric utility in Texas divided the public into four interest parties: environmentalists groups, the chambers of commerce, land owners, and academics. His company is in contact with three of the four interests from the beginning of the site-selection process. (Academics usually get involved at a later stage of the process). Other Texas utilities are also in contact with these four interest parties at various stages when planning a power plant.

The Utility Viewpoint: The Role of the Public in Power-Plant Decisions

Utilities first interact informally with state agencies (e.g., Texas Water Quality Board, Texas Water Rights Commission, Texas Air Control Board). Typically, these agencies are asked to render an opinion on a number of possible sites. After soliciting informal approval from a few state agencies, the utility begins to inquire about the price of the site. Public notification of the proposed site is withheld until the largest parcel of land is purchased, in order to avoid speculation. At this point, local environmental (and other) interest groups are notified about the details of the plant. The utilities believe it is a good business practice, as well as its ethical responsibility, to supply this information.

Utilities are unsure about the purposes of intervention. They believe that delay does not make plant siting procedures more effective and power-plant operations safer; it merely increases costs. The utilities maintain that the public has ample opportunity for participation in the public hearings that are held by federal, state, and municipal bodies.

The utility industry does not see the costs of intervention as a burden that deters public participation. An executive of a privately owned Texas utility cited these examples to support his claim: (1) meetings between the NRC and the utility are filed in the Public Documents Room, Washington, D.C., and can be seen without cost, (2) the Environmental Report and the Preliminary Safety Analysis Report (PSAR) are placed in the Public Documents Room, Washington, D.C., and can be seen without cost, and (3) major environmental agencies and private foundations are giving funds to public groups to enable these groups to enter into litigation.

The utilities generally believe that government agencies are the representatives of the public. Therefore, if the local interests are dissatisfied with the site chosen for an electric power plant, their recourse logically is to the state and federal agencies that certify the plant. If the public is not pleased with the decisions agencies render, they should register their dissatisfactions with congressional oversight committees. The utility industry makes available information about the proposed power plants, but feels no need to accommodate all local opinions.

SUMMARY

The public interest is not a monolith. It is composed of a variety of interests which may not be represented when power-plant siting decisions are made. A presentation of these views may be seen as a potential aid to the decision-making process because it: (1) provides agencies with another dimension useful in assuring responsive and responsible decisions, (2) serves as a safety valve allowing interested persons and groups to express their views before policies are announced and implemented, (3) eases enforcement of administrative programs relying upon public cooperation, and (4) satisfies judicial demands that agencies observe the highest procedural standards (Boyton, 1972).

Nonetheless, we have observed that public participation can have adverse consequences. It presents us with the problem of identifying the "public" and establishing who should be allowed to represent its interests. Too little participation results in a loss of checks on and inputs into the administrative process, while too much creates duplication in presentation before administrative bodies and a consequent loss of time and money—both so valuable in this period when the demand for energy is greater than the supply.

We do not offer a resolution to the controversy, but we do pose the problem conditionally:

(1) If the realization of an adequate energy supply is to be weighed more heavily than environmental concerns and the representational benefits of public participation, then the present efforts of utilities to meet their customers' demands should be regarded with less contempt. The administrative process might be restructured to exclude duplication of testimony and to facilitate the timely issuance of construction and operation permits.

(2) On the other hand, if public input is viewed as an integral part of power system planning then:

a) Both state and federal agencies should respond promptly to citizen inquiries.
b) Each agency should maintain a register of persons who have communicated an interest in agency matters.
c) An agency should inform all registered persons of upcoming proceedings in the areas of their interest.
d) Any interested person or party should have the right to intervene in agency proceedings.
e) Intervening parties should be loaned or provided with copies of documents, hearings, and testimony free of charge.
f) Where circumstances warrant, intervening parties might be provided with legal assistance or counsel by the administrative agency.
g) Written submissions by interested parties should be accepted for filing regardless of defects in form, substance, or omission. If such defect cannot be remedied or supplied by the agency, the interested party should be notified by mail of the defect and given reasonable time in which to remedy the defect (Kaufman, 1972).

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