US Army Corps
of Engineers

National Hydroelectric Power Resources Study

Volume II
May 1983

National Report

IWR 82-H-2

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
Volume II

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
National Hydroelectric Power Resource Study
National Report

5. TYPE OF REPORT & PERIOD COVERED
Final

6. PERFORMING ORG. REPORT NUMBER
IWR-82-H-2

7. AUTHOR(s)
U.S. Army Engineer Water Resources Support Center,
Institute for Water Resources
Casey Building, Ft. Belvoir, Virginia 22060

8. CONTRACT OR GRANT NUMBER(s)
N/A

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Same as No. 7 above

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
Same as No. 7 above

12. REPORT DATE
May 1983

13. NUMBER OF PAGES
175

14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)
Same as No. 7 above

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
Approved for Public Release, Distribution Unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
National Hydroelectric Power Potential
Future Development Prospects

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
This volume presents the background of the National Hydroelectric Power Resources Study (NHS) and a brief history of hydroelectric power in the United States. It includes an overview of the policy and technical issues which affect future hydroelectric power development and operation as well as projections of future electric power supply and demand. The report outlines a plan for the future evaluation of possible future development of hydroelectric power facilities and presents the conclusions of the NHS.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

National Hydroelectric Power Resources Study

National Report

U.S. Army Corps of Engineers
Institute for Water Resources
Casey Building
Ft. Belvoir, Virginia 22060

May 1983

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

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CHAPTER 1

THE STUDY AND REPORT

The rapid increase in the price of energy and U.S. dependence on oil imports have spurred a renewal of interest in hydroelectric power. A major source of energy in this country before inexpensive fossil fuels became available, hydroelectric power was viewed as a potential alternative for producing additional electricity. However, a comprehensive study was needed to assess the range of factors affecting additional hydroelectric power development as a basis for determining the Federal role and responsibilities.

PURPOSE AND AUTHORITY

Congress authorized the Corps of Engineers to conduct the National Hydroelectric Power Resources Study (NHS) in the Water Resources Development Act of 1976 (PL 94-587), to evaluate the potential for additional hydroelectric power and to prepare a plan for future development of sites under the jurisdiction of the Secretary of the Army. This report is a synthesis of the results of the study. The full citation authorizing the study is shown in Table 1-1.

The task was assigned to the Secretary of the Army, to be accomplished by the Chief of Engineers. Management of the study was assigned to the U.S. Army Engineer Institute for Water Resources, now part of the Corps' Water Resources Support Center. All U.S. Army Engineer division and district offices participated in the data compilation and evaluation.

TABLE 1-1

PL 94-587, SECTION 167 AUTHORIZATION FOR NHS

(a) The Secretary of the Army, acting through the Chief of Engineers, is authorized and directed to conduct a study of the most efficient methods of utilizing the hydroelectric power resources at water resource development projects under the jurisdiction of the Secretary of the Army and to prepare a plan based upon the findings of such study. Such study shall include, but not be limited to, an analysis of:

(1) the physical potential for hydroelectric development, giving consideration to the economic, social, environmental and institutional factors which will affect the realization of physical potential;

(2) the magnitude and regional distribution of needs of hydroelectric power;

(3) the integration of hydroelectric power generation with generation from other types of generating facilities;

(4) measures necessary to assure that generation from hydroelectric projects will efficently contribute to meeting the national electric energy demands;

(5) the timing of hydroelectric development to properly coincide with changes in the demand for electric energy;

(6) conventional hydroelectric potential, both high head and low head projects utilizing run-of-rivers and possible advances in mechanical technology, and pumped storage hydroelectric potential at sites which evidence such potential;

(7) the feasibility of adding or reallocating storage and modifying operation rules to increase power production at Corps projects with existing hydroelectric installations;

(8) measures deemed necessary or desirable to insure that the potential contribution of hydroelectric resources to the overall electric energy supply are realized to the maximum extent possible; and

(9) any other pertinent factors necessary to evaluate the development and the operation of hydroelectric projects of the Corps of Engineers.

(b) Within three years after the date of the first appropriation of funds for the purpose of carrying out this section, the Secretary of the Army, acting through the Chief of Engineers, shall transmit the plan prepared pursuant to subsection (a) with supporting studies and documentation, together with the recommendations of the Secretary and the Chief of Engineers on such plan, to the Committee on Public Works of the Senate and the Committee on Public Works and Transportation of the House of Representatives.

(c) There is authorized to be appropriated to carry out subsections (a) and (b) of this section not to exceed $7,000,000.

OBJECTIVES

The following specific objectives were established for the study:

1. To analyze and define the nation's need for hydroelectric power.
2. To assess the physical potential for increasing hydroelectric power capacity and generation.
3. To analyze the current institutional and policy setting for hydroelectric power planning, development, marketing and utilization.
4. To determine the feasibility of increasing hydroelectric generation capacity by developing new sites, by adding generation facilities to existing water resources projects, and by increasing the efficiency and reliability of existing hydroelectric power plants and systems.
5. To assess the general environmental and socio-economic impacts of additional hydroelectric power development.
6. To recommend to Congress a national hydroelectric power development plan and any institutional and policy modifications which would increase the effectiveness of existing and future hydroelectric power development.

SCOPE

Time Frame

Actual electric demand figures were compiled for 1978. Forecasts of future electric demands were made for the years 1985, 1990, 1995, and 2000. The recommended plan for future hydroelectric development is for 1982-2000.

Geographic Area

The NHS is national in scope and includes all 50 states and Puerto Rico. The data collection and site inventory portions of the study, however, were subdivided into electric reliability council regions as defined by the National Electric Reliability Council. The map inserted in the back pocket of this report shows the regions.

Areas of Investigation

The NHS examined conventional hydroelectric power potential. Run-of-river, storage, and diversion projects were included in the inventory. All sites, both Federal and non-Federal, were assessed. Potential sites include those at existing dams and at undeveloped dam sites which had been studied by the Corps of Engineers or other Federal and state agencies. An assessment of regional pumped storage potential was undertaken as a separate study.

Several projections of future demand for electricity were used to prepare a range of possible rates of growth. Also, projection of possible supplies of energy were compiled. These demand and supply estimates were used to determine the need for additional hydroelectric power.

Several studies were initiated to investigate the legal/institutional, economic, and environmental factors that will affect the future of hydroelectric power. These studies were used to help select a plan for development and to uncover policy issues that would affect the future development of hydroelectric power facilities.

Finally, the NHS selected a set of best candidate potential sites for future hydroelectric power development. The NHS plan calls for more detailed feasibility studies of these sites to determine if development is warranted.

PLAN OF STUDY

The Institute for Water Resources, in cooperation with Corps divisions, prepared a detailed study execution plan which divided the work into two major elements. The first element contained the hydroelectric power systems identification, or the assessment of potential hydroelectric power sites. Electric power supply and demand were also investigated here. The second element focused on the important policy issues which affect the development and use of hydroelectric power resources. Information and data from these two elements were used to select best candidate potential sites for further feasibility study and to identify the issues that would affect the development

of the nation's hydroelectric power resources. The relationships between the two elements and their contribution to the final products of the NHS are shown schematically in Figure 1-1. A synopsis of the study execution plan is included as Appendix 1 of this report.

PUBLIC INVOLVEMENT

Public involvement was an integral part of the NHS. Public meetings were held in each electric reliablity council region to provide a forum for full discussion of proposed sites. Three national public meetings were held to seek comment on the preliminary results of all parts of the NHS, including the policy studies. Appendix 3 describes the public involvement process in the NHS.

FINAL REPORT VOLUMES

The NHS report consists of 23 volumes. Volumes I and II are the Executive Summary and the National Report, respectively. These volumes are a synthesis of the results of the entire NHS. This document is the National Report.

Existing and future electric demand are covered in Volumes III and IV. Specifically, Volume III is a base line (1978) study of the electric power supply system for each of the electric reliability council regions of the United States. Volume IV describes projections of electric power load growth in each region through the year 2000, in five-year increments.

Five policy studies were conducted. Volume V covers the legal and institutional aspects of hydroelectric power development and operation. Volume VI is a review of economic evaluation criteria for Federal hydroelectric power projects. Volume VII covers aspects of the marketing and transmission of Federal hydroelectric power. Volume VIII is a generic environmental assessment of hydroelectric power. Volume XI is a technology assessment of national hydroelectric power development.

Two technical overview studies dealt with the efficiency of existing hydroelectric power facilities and pumped storage. Volume IX explores the potential for increasing the output of existing hydroelectric plants. Volume X is an assessment of hydroelectric pumped storage.

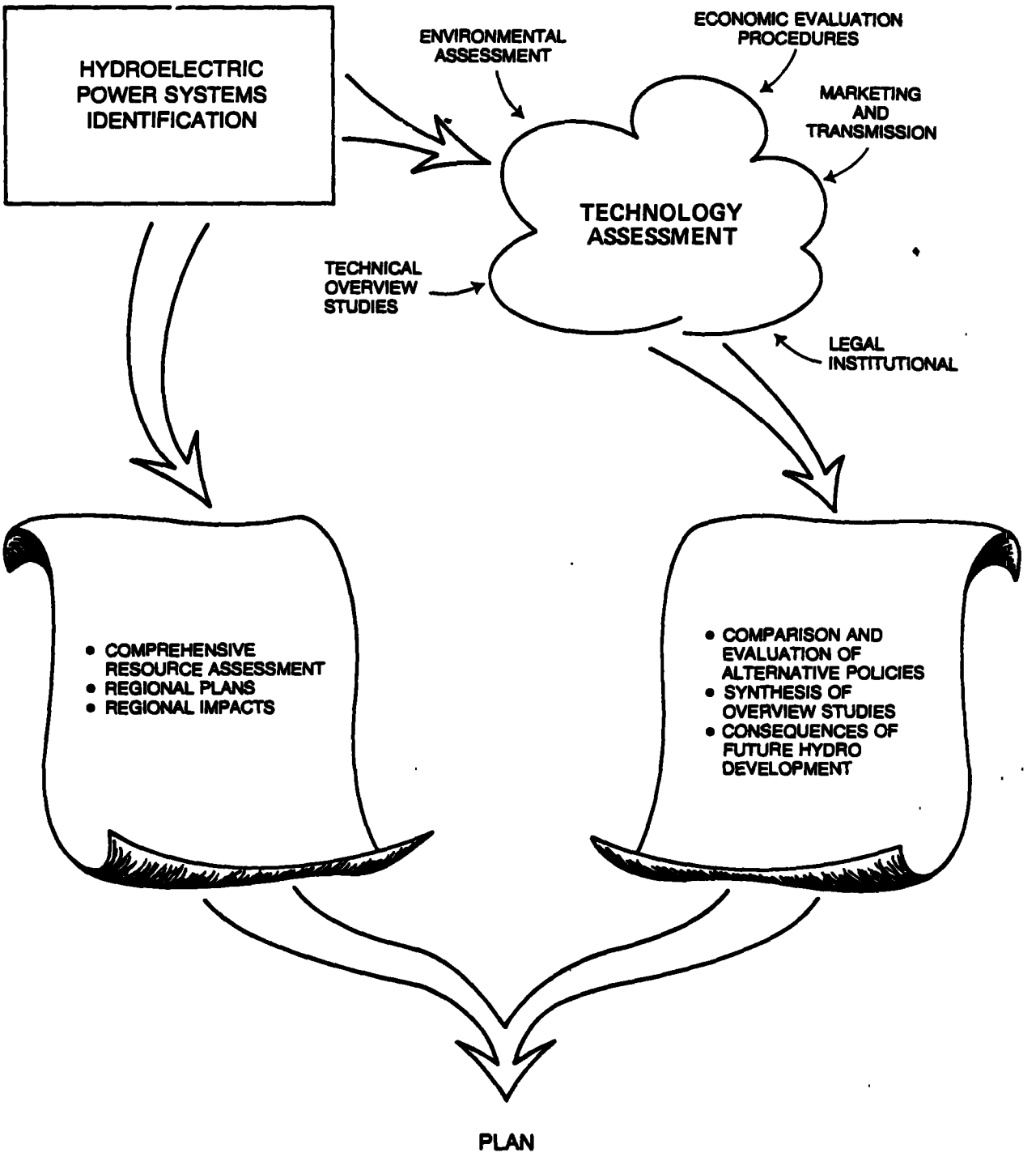


Figure 1-1 : RELATIONSHIP OF STUDY ELEMENTS, NATIONAL HYDROELECTRIC POWER RESOURCES STUDY

The next two volumes deal with the development and results contained in the computerized inventory of potential hydroelectric power sites. Volume XII addresses the sequential process used to develop the site-specific inventory, including the methods used to collect and analyze raw data, the major problems encountered in screening candidate sites, and how these problems were resolved. The resulting inventory of hydroelectric power sites is listed in Volume XII. Volume XIII includes descriptions and results of the support studies that were necessary to develop the inventory data base.

Volumes XIV through XXIII contain regional assessments of hydroelectric power potential. Each volume covers one of the nine electric reliability council regions. Volume XXIII covers the states of Alaska and Hawaii. Puerto Rico is included in Volume XVI, Southeastern Electric Reliability Council. A more detailed discussion of all NHS volumes is contained in Appendix 2.

NATIONAL REPORT ORGANIZATION

This volume, the national report, contains the study history, organization, objectives, and findings, with references to the appropriate support studies. Chapter 1 presents an introduction which discusses the authority, scope, and objectives of the NHS. Chapter 2 contains several perspectives on hydroelectric power, including a primer on hydroelectric power, a brief history of its development, and the nature and characteristics of hydroelectric power as an energy source. Chapter 3 presents the summary findings of the demand/supply studies for both existing and future conditions, as well as a brief assessment of pumped storage. Chapter 4 summarizes the results of the site-by-site assessment, including the results of each stage of the screening analysis. A summary of the total feasible resource potential is also presented. Chapter 5 describes the best candidate potential hydroelectric power sites by various categories. Chapter 6 identifies the major issues arising from hydroelectric development and operation; these issues will have to be addressed in planning for future hydroelectric power projects. Chapter 7 presents the conclusions of the NHS.

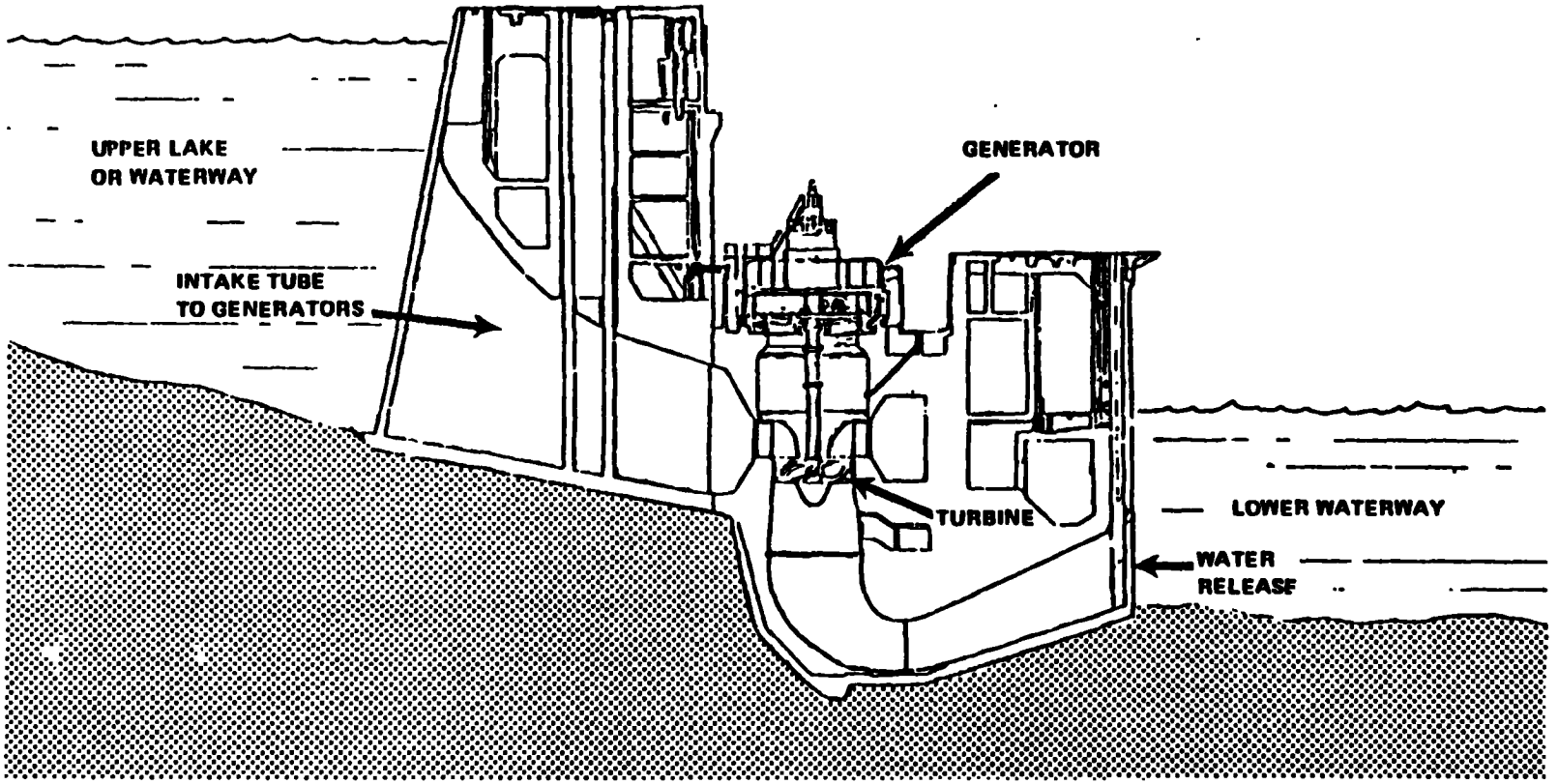
CHAPTER 2

PERSPECTIVES ON HYDROELECTRIC POWER

Hydroelectric power is a renewable energy resource. The source of energy for hydroelectric power is the sun, which drives the hydrologic cycle. Natural rivers concentrate rainfall at man-made dams and allow extraction of the energy in running water, a derivative of concentrated solar energy. Hydroelectric power has a long history of service in the United States, first as a supplier of mechanical power and then of electricity. Finally, hydroelectric power has a distinct set of characteristics as a source of electricity that set it apart from other energy sources. Some characteristics are advantageous; others detract from the utility of hydroelectric power. This chapter provides an insight into the nature of hydroelectric power from different perspectives: its physical characteristics, history of utilization, and characteristics as an energy source.

HYDROELECTRIC POWER PRIMER

Hydroelectric power plants generate electricity through the extraction of energy from running water. Water flowing from higher to lower elevations contains hydraulic energy, which can be captured and converted into electrical energy via electro-mechanical devices. Figure 2-1 shows the typical components required for producing electricity from flowing water. Generally, a water storage area or forebay is required. A penstock is required to channel the flow of water from the forebay to a turbine. The turbine is a machine with a series of curved vanes, propellers, or buckets especially designed to react efficiently in a spinning motion to the force of the water as it passes through. The turbine is connected to a generator which produces an electrical current when activated by the spinning turbine. The generator is usually connected to an electricity grid system for distribution of electric power. The total amount of



Source: 'Hydropower - An Energy Source Whose Time Has Come Again' U. S. General Accounting Office Report Number EMD-80-30 January 11, 1980

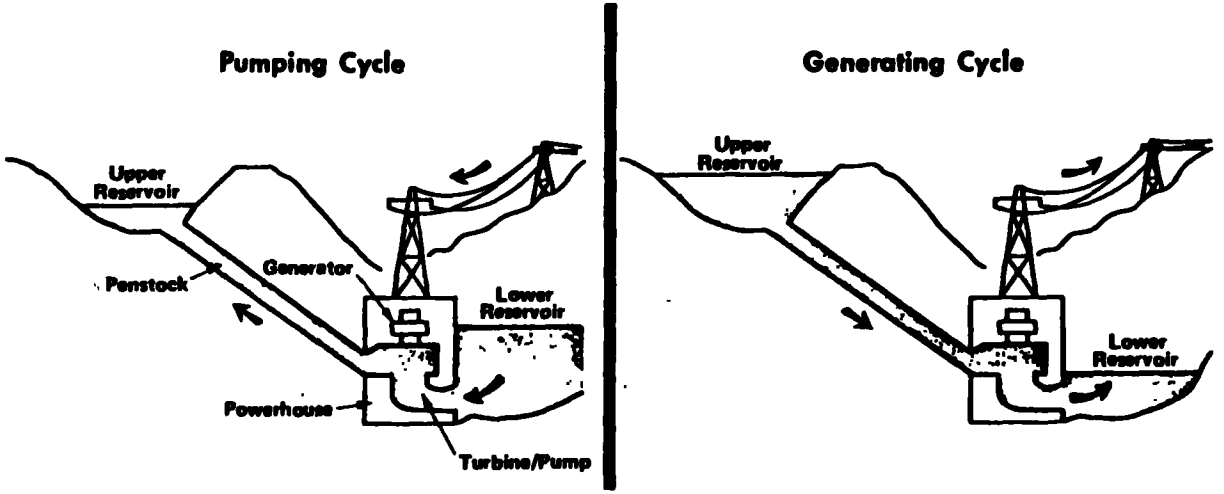
Figure 2-1 CONVENTIONAL HYDROELECTRIC SYSTEM

energy available at any given hydroelectric power site is directly proportional to the hydraulic head (the difference in elevation between the headwater and tailwater) and the quantity of water available for release during any given time.

There are two basic types of hydroelectric power plants. The first, conventional, receives the greatest emphasis in the NHS. Conventional hydroelectric power plants include run-of-river plants that use water flow as it arrives at the site and storage plants that can store water flows for later release during periods of high demand for electricity. Conventional hydroelectric power is a net producer of energy, requiring only the hydrologic cycle to replenish the water necessary to generate electricity.

The second type of hydroelectric power plant is pumped storage. A pumped storage plant consists of an upper and lower reservoir, a penstock connecting the reservoirs, and a turbine-pump and generator-motor near the lower reservoir (Figure 2-2). Electricity is generated by releasing water through the penstock and turbine to the lower reservoir. Water is pumped back to the upper reservoir during low electricity demand periods. Most pumped storage plants rely only on water pumped to the upper reservoir to produce energy. A few pumped storage plants use both pumped water and runoff.

In either case, the water that is pumped into a storage reservoir requires more energy for pumping than can be recaptured during release. The ratio of energy consumed to energy generated is about 3:2; consequently, pumped storage plants are net consumers of energy. The advantage of pumped storage plants is the use of excess steam-generated power to pump water to the upper reservoir during lower electricity demand periods. During these periods of lowered demand, it is not practical to shut down thermal (coal or nuclear) base load plants because of the high cost and long time required to start them up again. Instead, this excess base power is used to operate the pump in a pumped storage plant. The stored energy (water) can then be released during periods of peak power demands when base load plants are already under full load. Currently, pumped storage is the only method available for storing and releasing large amounts of electric energy over short periods of time. Thus, when pumped



DURING LIGHT POWER LOAD

DURING PEAK POWER LOAD

Figure 2-2 OPERATION OF A PUMPED STORAGE PLANT

storage is available, it makes efficient use of excess base load power as well as providing a means of meeting peak demands without consuming additional valuable, non-renewable energy resources. To a lesser extent, conventional hydroelectric power plants with storage can help meet peak loads by storing flows for release during peak demand periods.

Hydroelectric power (kW) plants are described by capacity and energy output. Capacity is measured in kilowatts (kW) or megawatts (MW) and is the ability to sustain a level of power output. The energy output (electricity) is measured in kilowatt-hours (kWh) and is the level of output multiplied by the amount of time the output is sustained.

Two distinctions are important in understanding the generation and use of hydroelectric power. The first is the difference between peak, intermediate, and base load. The second is the difference between firm and secondary power.

At any given moment, electric power suppliers must match exactly the electricity being supplied with that being demanded. The demand for electricity by consumers is called the load. Load is separated into base, intermediate, and peak load. Base load is the constant load on a system during a period of time, typically one day. Intermediate load is that portion of demand that is relatively steady but occurs only during part of the day in addition to base load. Peak load occurs when demand is at a maximum during highest use of electricity. Peak load occurs only for short periods during the day (Figure 2-3). The amount of electrical energy supplied during a day is the level of demand multiplied by the amount of time the level is sustained.

Hydroelectric power plants supply electricity to utility systems to help meet each type of load. However, the greatest value of hydroelectric power plants is their ability to supply electricity during peak load. Hydroelectric power plants can vary output efficiently and quickly to meet peak loads. Coal and nuclear plants are designed for near constant outputs and are better suited to base load.

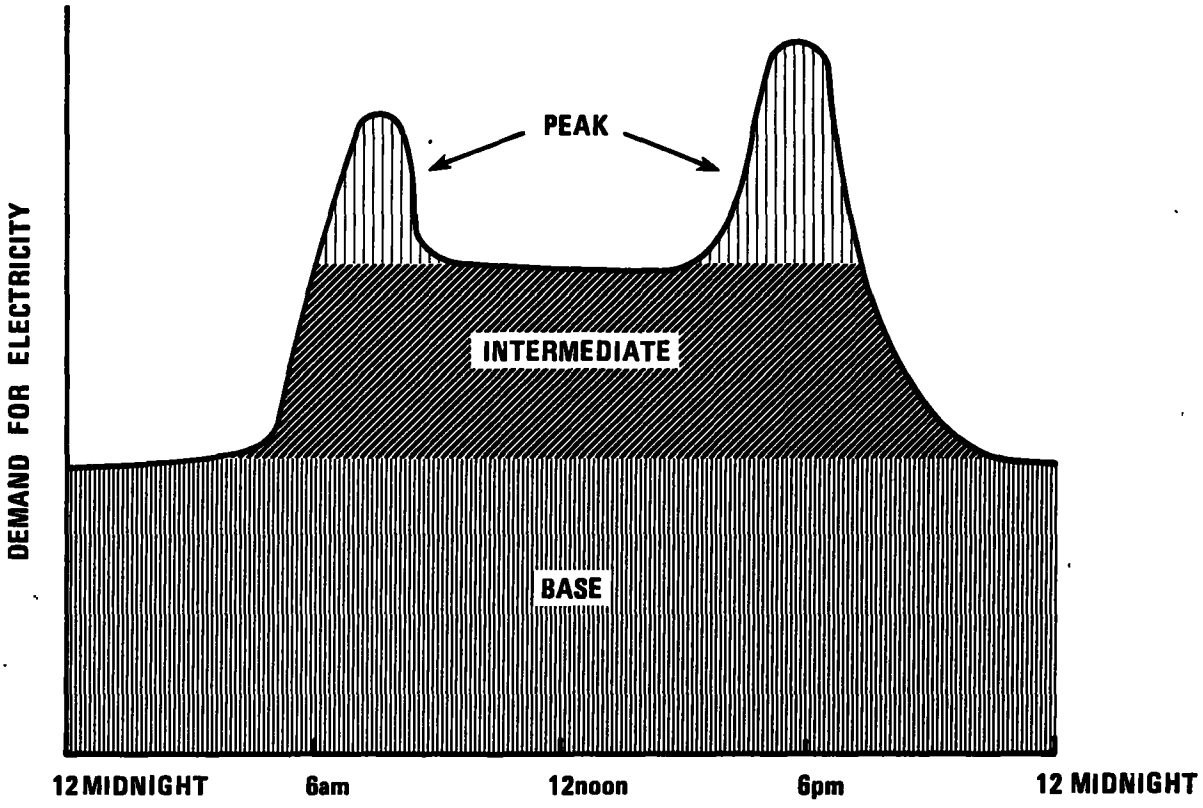


Figure 2-3 ILLUSTRATION OF PEAK, INTERMEDIATE AND BASE LOAD

The distinction between firm and secondary hydroelectric power depends on the variation of the hydrologic cycle. Firm power levels must be assured even under critical stream flow, the lowest flow based on historical conditions. Since water flows can vary substantially, the firm power at a site could be low. All energy generated at levels of capacity greater than firm power is considered secondary power. The use of reservoirs to control water flow can help to increase firm power output. Firm power is more valuable than secondary power. Hydroelectric power facilities are usually designed to maximize firm power output and to maximize the flexibility of the plant to meet peak load.

HISTORY OF HYDROELECTRIC POWER IN THE UNITED STATES

Both conventional hydroelectric power and pumped storage plants provide useful and needed energy while displacing or conserving other non-renewable energy resources. Today, hydroelectric power helps to conserve diminishing fossil fuels. In its earlier years, hydroelectric power displaced human labor and animal power.

Early settlers of New England were the first to exploit the abundant waterpower resources of the United States. New England has numerous small streams which have sufficient streamflow and hydraulic head to supply power. Numerous water wheels which were mechanically connected to grindstones, saws, and other industrial equipment were built throughout the region. Thus, by the early 1800s, the present day patterns of New England small dam development were established. To a large extent, the industrial development and settlement patterns in New England were influenced by waterpower availability.

The first substantial waterpower development in the United States began operation in 1822 near Lowell, Massachusetts, on the Merrimack River. Other industrial and commercial developments followed until by 1880 almost 1,225,000 horsepower of waterpower was serving New England industry (Klotz, 1979, p. 33).

Significant technological breakthroughs during the late 19th century led to the development of generators for the production of electricity. A companion development, the incandescent lamp, completed the ingredients necessary for a change in waterpower use from mechanical to electrical power.

The first hydroelectric power station in the United States was built at Niagara Falls in 1879 and powered arc lamps for lighting in a nearby community. It was soon followed by the construction of a hydroelectric plant for producing commercial power for incandescent lamps on the Fox River at Appleton, Wisconsin in 1882 (Klotz, 1979, p. 34-37). From that point on, many new sites were developed, and older, mechanical plants were converted to produce electric power. By 1920 about 5000 megawatts (6,700,000 horsepower) of hydroelectric capacity had been developed in the United States, and by 1940 hydroelectric power supplied nearly 40 percent of the nation's total electrical energy requirements (U.S. Department of Energy, 1979, p. 1-1). Before 1930 most hydroelectric power sites were privately built; but the Federal government also began development of hydroelectric power through the Corps of Engineers, the Bureau of Reclamation, and the Tennessee Valley Authority (Figure 2-4). In addition to its role as project developer, the Federal government was spurred into regulatory action to protect the public interest in private development of waterways. The Federal Power Act created the Federal Power Commission, now the Federal Energy Regulatory Commission (FERC), to oversee non-Federal development of hydroelectric power plants. Many large-scale Federal water resource projects which included hydroelectric facilities were built during the years 1950-1970. The Federal share now amounts to about half the nation's total conventional hydroelectric power capacity. Federal projects were typically large and were built for multiple-purpose use including navigation, flood control, irrigation, and/or water supply.

In the 1950s and 1960s, the relative amount of hydroelectric power in the United States energy mix began to decline as a result of competition from relatively inexpensive fossil fuels. By 1970, hydroelectric power contributed less than 15 percent of total U.S. electric generation capability.

During this period of relative decline in hydropower generation, the per kilowatt-hour cost of electrical power generated by coal, oil, and gas fell precipitously. New large-scale, steam powered plants were able to take advantage of increasing economies of scale. As the marginal cost of new power

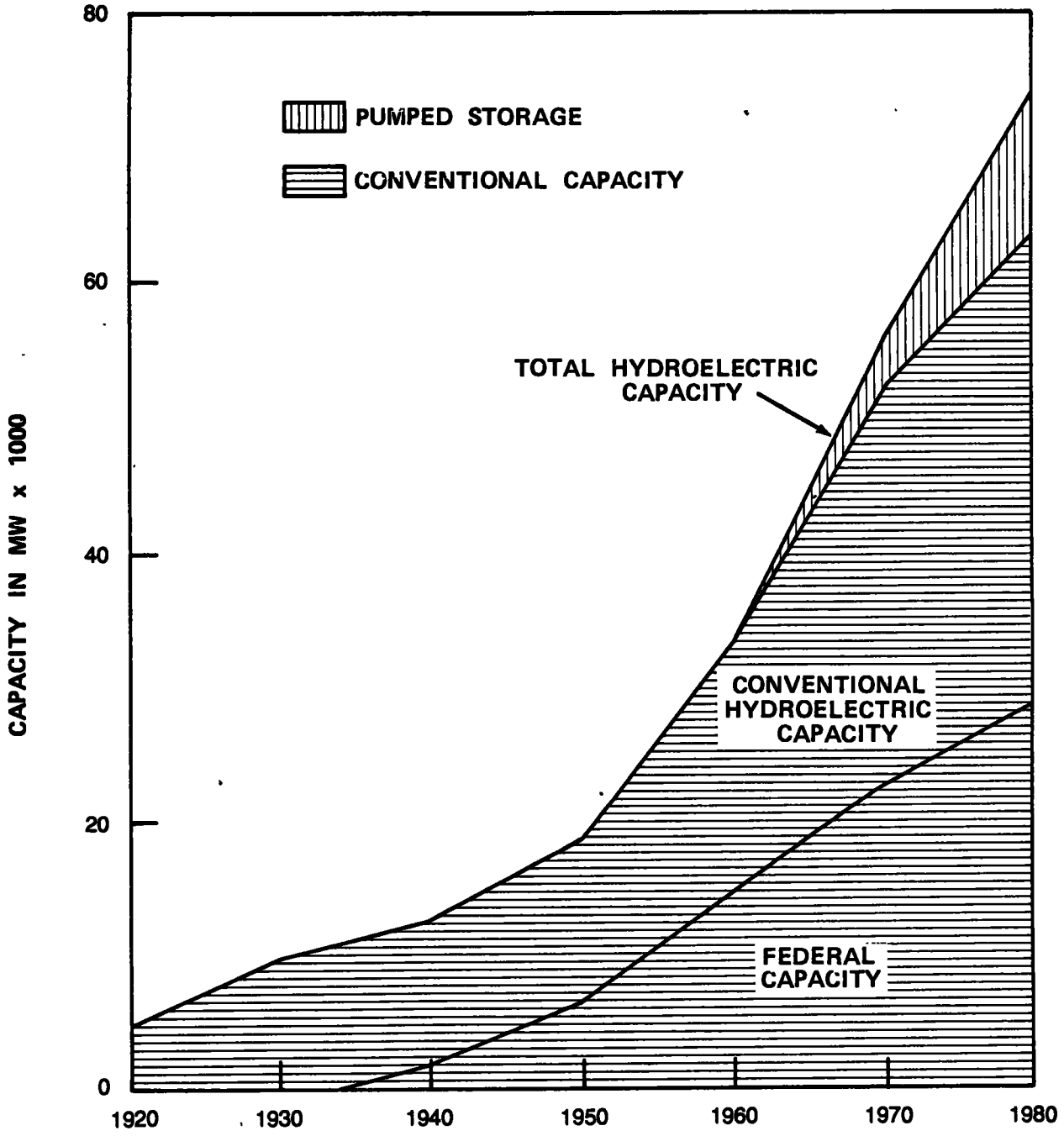


Figure 2-4: GROWTH OF HYDROELECTRIC POWER CAPACITY

plants decreased, it made good economic sense to build new fossil fired power plants and to retire older, smaller hydroelectric plants, especially those in need of major repairs.

Large hydroelectric power plants could still compete economically with other electricity sources, but most of the promising, easily accessible, economic sites located near load centers had already been developed. New sites were becoming harder to find, were located far from cities, and were more expensive to develop. Consequently, new large-scale hydroelectric power development projects became scarce.

Finally, the environmental movement began to focus on large-scale reservoir development on free-flowing streams. Hydroelectric power sites were large and visible and were the focal point for a number of environmental groups that registered protests against encroachment on the environment. With the construction of new dams being fought at every step of the development process, the addition of hydroelectric power was difficult.

The 1970s saw a reversal of several of the above factors and a sudden renewal in interest in hydroelectric power. First of all, the OPEC oil embargo caused oil prices to skyrocket, dragging coal and gas prices along with them. Environmentalists turned their attention to the air, water, and noise pollution from thermal sources and, by comparison, hydroelectric power began to look better in terms of overall environmental impact. Many of the sites that had been passed over, especially sites where hydroelectric power plants had been abandoned during the era of cheap oil, were once again recognized as being economically feasible to develop and operate.

Both small-scale and large-scale hydroelectric power development are creating considerable interest. Currently in the United States there are about 1300 hydroelectric power plants which provide about 13 percent of the nation's total electric generating capability with an installed capacity of some 63,000 megawatts, excluding pumped storage. This amount of capacity produces an average energy generation of about 280 billion kWh/year or about 3 quadrillion BTU thermal equivalents (quads).

Of the 1,300 plants, about two-thirds were constructed before 1940 but provide only about 20 percent of the present installed capacity. About 75 percent of the hydroelectric power plants have less than 25 MW of installed capacity but contribute only seven percent of the total capacity. Thus, newer, larger hydroelectric plants provide most of the capacity (U.S. Army Corps of Engineers, 1979, p. 4-5).

On a regional basis, hydroelectric power accounts for over 40 percent of the total electric capacity in the WSCC, 12 percent in the SERC, 10 percent in the NPCC, and less than 10 percent in other regions. As in the case of existing capacity, most of the new feasible capacity is in the WSCC, but almost all other regions of the country contain developable sites. Figure 2-5 shows the existing hydroelectric power capacity by National Electric Reliability Council region.

CHARACTERISTICS OF HYDROELECTRIC POWER AS AN ENERGY SOURCE

As with all of the major sources of energy generation, there are certain advantages and disadvantages associated with the development and operation of conventional hydroelectric power (Table 2-1).

Hydroelectric power is a renewable energy resource powered by the hydrologic cycle. Thus, the energy source (water) for hydroelectric power turbines is not affected by the declining supply or rising price of fossil fuels.

Hydroelectric power plants can save fuel used to generate electricity by displacing the energy sources that use these fuels. As new hydroelectric projects are brought on line, existing oil-fired plants can be replaced and new ones can be deferred.

Hydroelectric power plants are flexible in meeting load. As discussed above, hydroelectric projects can adjust to changing load quickly and can supply backup capability known as spinning reserve. In addition, hydroelectric power

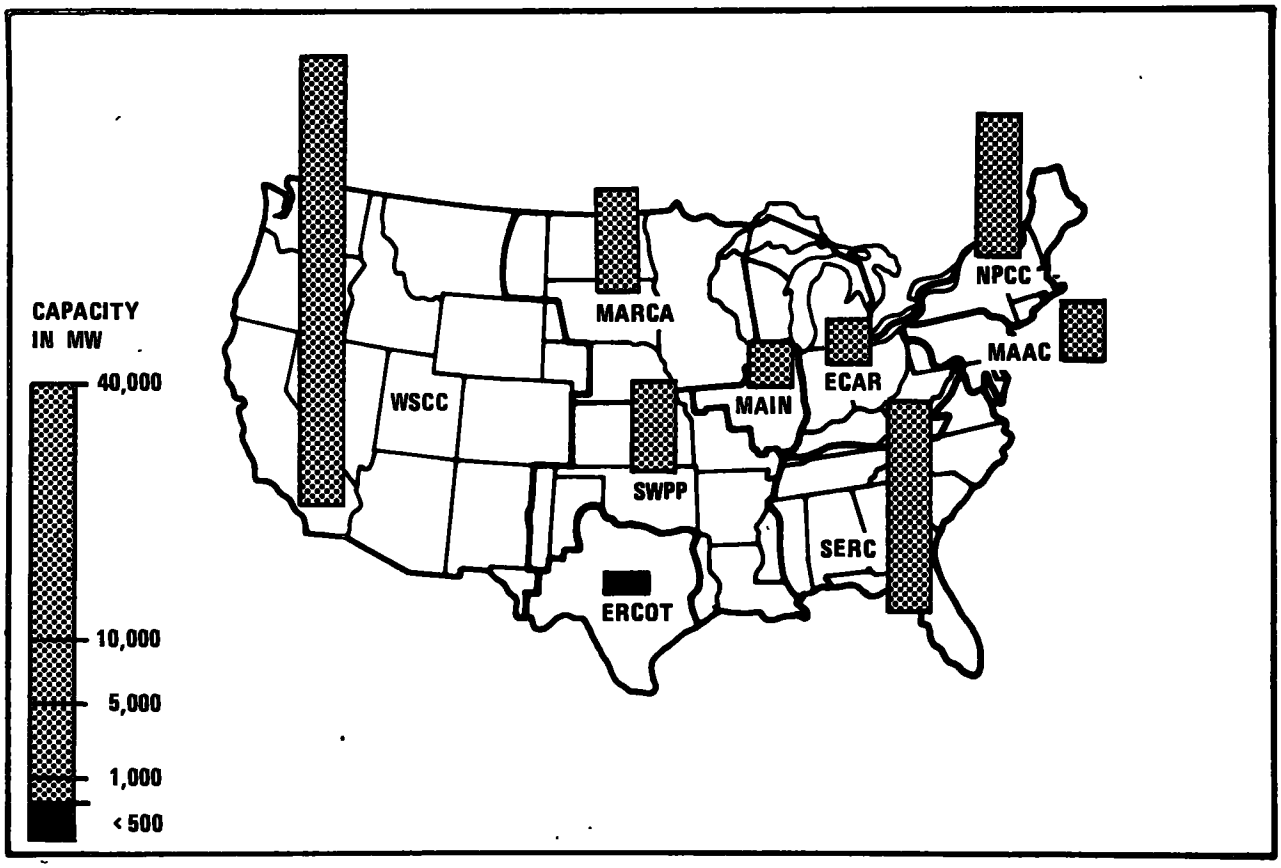


Figure 2-5 EXISTING HYDROELECTRIC POWER CAPACITY BY NERC REGION

TABLE 2-1

ADVANTAGES AND DISADVANTAGES OF HYDROELECTRIC POWER AS AN ENERGY SOURCE

ADVANTAGES	DISADVANTAGES
Renewable Resource	High Initial Cost
Fuel Saver	Variable Output
Flexible to Meet Load	Riverine Impacts
Efficient	
Reliable and Durable	
Low Operation Cost	
Mature Technology	
No Atmospheric Pollutants	

plants are the best large-scale means of storing electrical energy for later use. Hydroelectric power plants are also very efficient producers of electricity. Most operate at 85-90 percent efficiency, about twice that of coal plants.

Hydroelectric power plants are reliable and durable. The machinery involved is well designed, is durable, and has relatively few moving parts. The fact that heat is not involved means that cycling has a minimal effect on the machinery, contributing to its long life and low level of maintenance. Few breakdowns are experienced in operation, and unplanned outage rates for hydroelectric power turbines are the lowest in the electric industry. With no fuel costs, hydroelectric power plants are relatively inexpensive to operate. This characteristic best accounts for the inflation-proof label often given to hydroelectric power.

Hydroelectric power is a mature technology. The engineering involved is straightforward and well known. There exists a wealth of experience in design and operation of hydroelectric power facilities.

There are certain environmental advantages associated with hydroelectric power. Since heat is not used in the process, there is no thermal pollution. Furthermore, hydroelectric power, unlike coal and nuclear power, produces no harmful residual waste. The effects of hydroelectric power plants are well known and controllable, whereas other energy sources may entail uncertain risks.

The major disadvantages of hydroelectric power as an energy source are the high initial cost of facilities, the variable output of energy subject to water flows, and the impact of a plant on the riverine environment where it is located.

The cost of a dam, if one is not already in place, and the other facilities of a hydroelectric power plant contribute to the high capital cost. High interest rates make it difficult to obtain financing for capital intensive hydroelectric power plants and may limit the contribution of hydroelectric power in meeting electric energy demand.

Unless there is sufficient storage of water behind a dam, the output of electricity from a hydroelectric power plant can fluctuate seasonally depending on streamflow. Without an assured ability to produce a given output at any time, the value of a hydroelectric power plant to a utility system is diminished.

Finally, hydroelectric power plants can affect the quantity and quality of water flowing in a river. A hydroelectric plant alters the river system upon construction and by its mode of operation in generating electric power. These impacts are discussed in Chapter 5 and in the NHS Environmental Assessment.

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CHAPTER 3

ELECTRIC POWER SUPPLY AND DEMAND

THE EXISTING ELECTRIC ENERGY INDUSTRY

The electric utilities' consumption of energy resources for 1980 was an estimated 24.8 quads or about 32.5 percent of the nation's total energy consumption of 76.27 quads. Of the electrical energy produced, coal accounted for 48.8 percent of total output; natural gas, 15.3 percent; hydroelectric power, 12.5 percent; petroleum, 12.1 percent; nuclear power, 10.9 percent; and other sources, 0.5 percent. Figure 3-1 shows electric power sources by region.

The electrical power utilities in the United States vary greatly in size, type of ownership, and range of functions. There are six distinct ownership segments:

- Investor-owned (regulated by governmental agencies)
- State-chartered (state power authorities, public utility districts, irrigation districts)
- Municipal-owned
- Customer-owned (Rural Electrification Administration)
- Federal (including the Tennessee Valley Authority)
- Industrial

Most systems which serve large population centers perform the functions of generation, transmission, and distribution. In rural and small urban areas, there are many utilities which provide only distribution services and others that generate some power while relying on outside purchases to meet the remainder of their load requirements. These are usually smaller systems owned by municipalities and cooperatives. Available statistics on composition of the electrical utility industry (Table 3-1) indicate that, over the years, investor-owned utilities have tended to merge and interconnect to improve economy and reliability of operation.

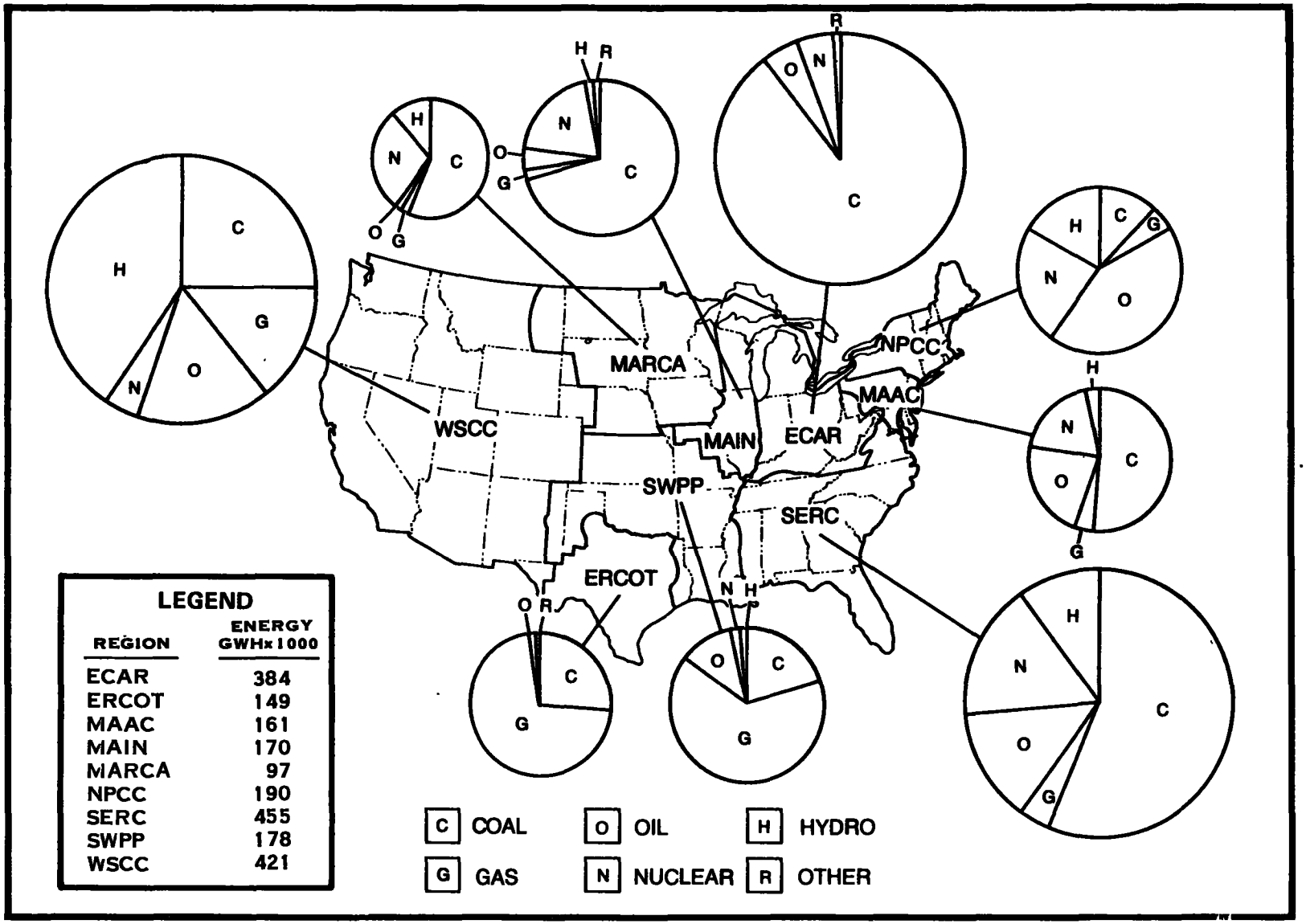


Figure 3-1 : NET ELECTRIC POWER SOURCES BY NERC REGION (1979)

TABLE 3-1

NUMBER OF ELECTRIC UTILITY COMPANIES -- CONTIGUOUS U.S.

Ownership	1927[1]	1937[1]	1947[1]	1957[1]	1968[1]	1978[2]
Investor-Owned	2,135	1,401	858	465	405	283
Public, Non-Fed	2,198	1,878	2,107	1,890	2,075	1,839
Cooperatives	---	192	887	1,026	960	933
Federal[3]	1	3	4	5	5	5
TOTAL:	4,334	3,474	3,856	3,386	3,445	3,060

1 Federal Power Commission, "The 1970 National Power Survey," December 1971.
2 McGraw-Hill, Electrical World Directory of Utilities 1978-1979, 87th Ed.
3 Marketing Agencies.

The large share of electricity provided by investor-owned utilities is shown in Table 3-2. Although comprising less than 10 percent of the total number of utility companies, the investor-owned utilities provide nearly 80 percent of the electricity generated in the United States. Public-owned utilities and Federal government agencies each supply about 10 percent of electricity generated.

ELECTRICAL ENERGY DEMAND AND SUPPLY (1978)

In 1978, an estimated U.S. population of over 219 million people consumed electric energy at an average rate of more than 10,000 kwh per capita per year, requiring 2.21 million GWh of electrical energy and exerting a peak demand for electrical power of nearly 400,000 MW. Total consumption in 1980 was in excess of 2.28 million GWh.

TABLE 3-2

CAPACITY AND ENERGY PRODUCTION BY INDUSTRY SECTOR

Industry Sector	Capacity Percent	Generation Percent
Investor-owned	77.6	79.3
Public non-Federal	10.4	8.5
Cooperatives	2.3	2.1
Federal	9.7	10.1
TOTAL:	100.0	100.0

The 1977 electric peak power requirements of the nation are summarized in Table 3-3. The peak demands shown are hourly but are not simultaneous. This table reflects regional summer peaks throughout the contiguous United States, with winter peaks in Alaska and Hawaii. Some individual subregions have winter peaks, but summer cooling is a dominant factor and a growing demand.

Figure 3-2 shows generating capabilities and energy production by type of fuel for the contiguous United States as of 1977, while Figure 3-3 shows the distribution by electric reliability council region. More recent data (DOE, March 1981) indicate that coal-fired plants now produce 50.8 percent of total electric energy (a significant increase since 1977), while the oil plus gas share dropped from 30.6 to 25.9 percent of the total. Nuclear generation accounted for 11 percent, and net hydroelectric energy accounted for 12.1 percent. Coal is the major electric generation fuel source nationally and is heavily dominant in some regions. Oil and gas dominate in regions where they are produced, where coal is relatively more expensive, or where strict air quality controls are needed.

TABLE 3-3

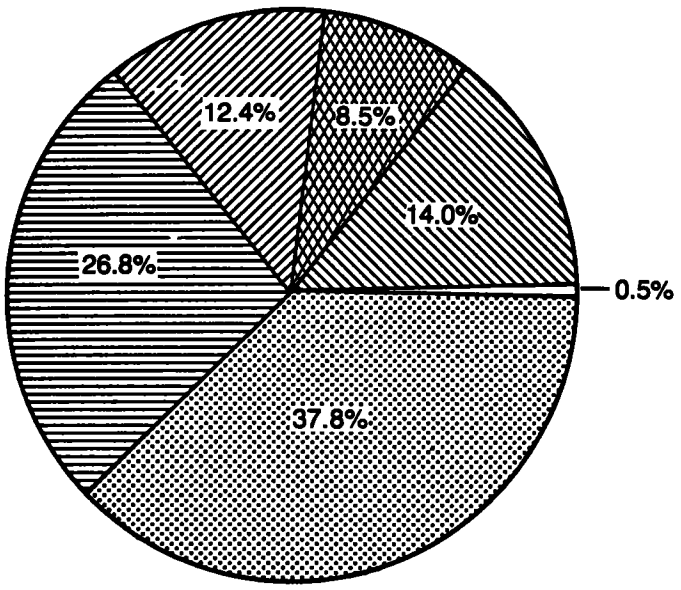
ELECTRIC POWER REQUIREMENTS IN THE UNITED STATES -- 1977

	Actual Reported Peak Demand (MW)	
	Summer	Winter
Contiguous United States	388,604	339,724
Alaska	342	538
Hawaii	984	1,090
U.S. total[1]	389,930	341,352

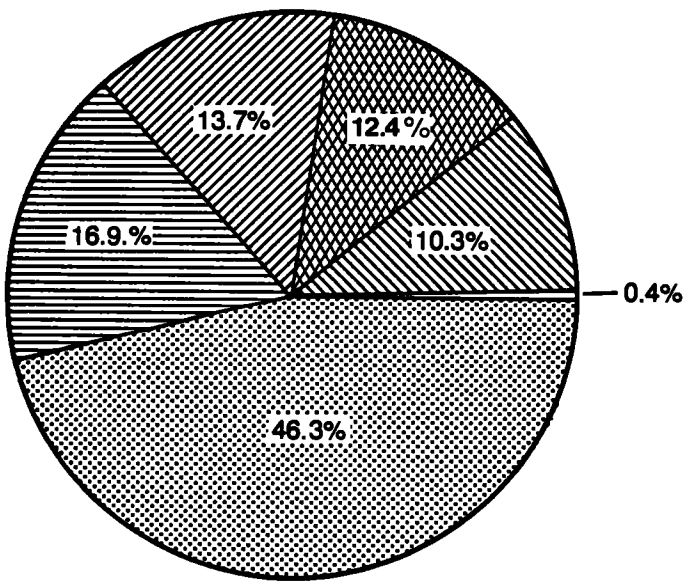
[1] "U.S. total" is not the actual simultaneous total peak demand, which cannot be readily ascertained; rather, it indicates the order of magnitude of the U.S. demand.

With a total national generating capability exceeding 613,000 MW as of 31 December 1980 (Electrical World, April 1981), the indicated generating reserve margins for both summer and winter peaks are substantial. However, local and regional energy and/or capacity shortages can result from unscheduled outages. Furthermore, transmission outages can cause generating capability to be unavailable to specific areas.

Before the 1973-74 oil embargo, utilities initiated construction of new electrical generating plants in anticipation of a load which was growing rapidly prior to that time. Load growth has since slowed -- as has plant construction, because of construction postponements and delays. Until recently, the rate of plant construction had been leading load growth, creating unusually large reserves. Nationally, reserve percentages, as projected by the reliability councils, are expected to decline in the near future as new plants are delayed and load growth absorbs existing under-utilized capacity.



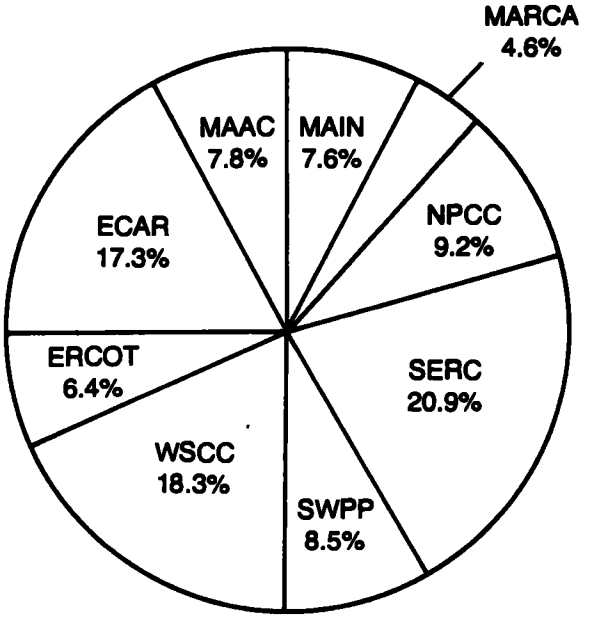
EXISTING CAPABILITY



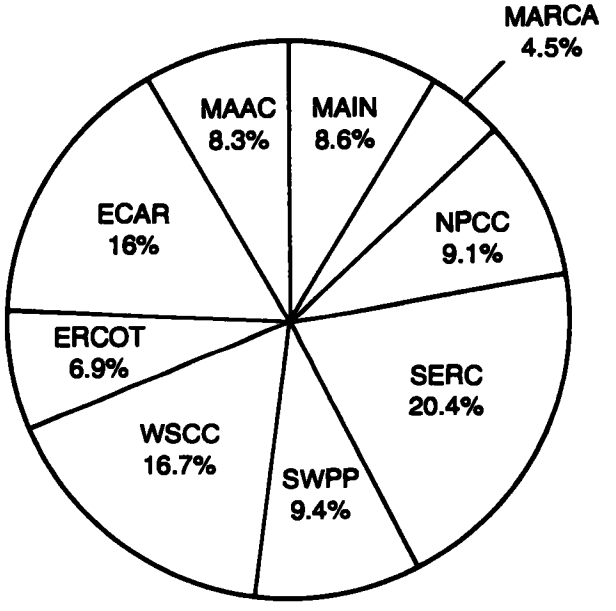
NET ENERGY GENERATION

NUCLEAR
COAL
OIL
GAS
HYDRO
OTHER

Figure 3-2: GENERATING CAPABILITY AND ENERGY PRODUCTION BY ENERGY SOURCE, CONTIGUOUS UNITED STATES–1977



ANNUAL NET ENERGY
APPROXIMATELY 2,115,000 GWH



PEAK DEMAND
APPROXIMATELY 388,600 MW

Figure 3-3 : ELECTRIC POWER AND ENERGY REQUIREMENTS, CONTIGUOUS UNITED STATES—1977

Current Role of Conventional Hydroelectric Power

Hydroelectric power ownership in the United States as of 1977, both conventional and pumped storage, is presented in Figure 3-4. The figure represents generating performance capability. More than one-half of the nation's hydroelectric power is installed in the western states. The northeast and southeastern parts of the United States also have large amounts of installed hydroelectric power. Elsewhere in the country, the percentage of installed hydroelectric power is relatively small.

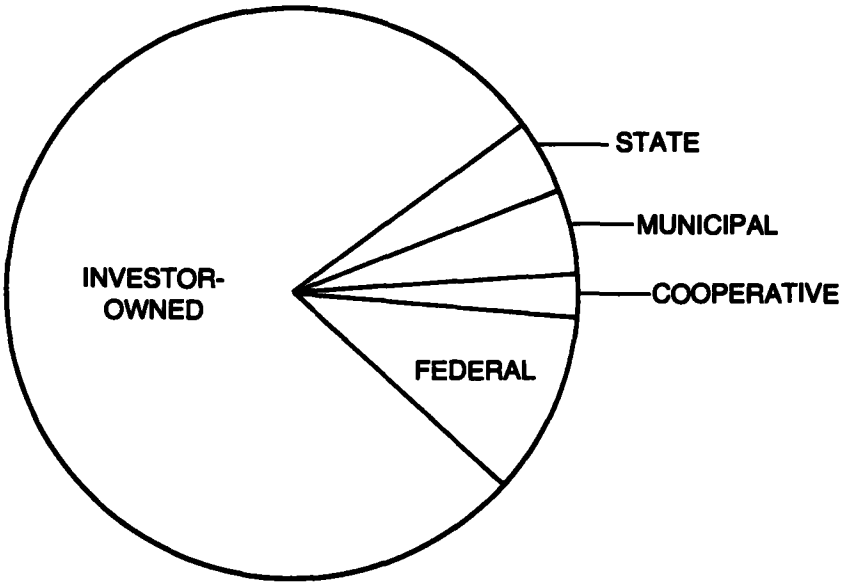
The Corps of Engineers has become the nation's largest among all categories of hydroelectric power producing entities. The Corps currently operates 68 multiple-purpose hydroelectric power projects (1978) having a capacity of 18,925 MW, representing about 26 percent of the nation's installed hydroelectric power capacity. This capacity at Corps projects generates about four percent of the nation's electrical energy.

As power demand increases within a system and more thermal generation capability is installed, the ideal would be to utilize hydroelectric power generation during peak-load hours. This would reduce the total requirement for thermal capacity and improve thermal efficiency, allowing thermal plants to operate at more uniform output for base and intermediate loads.

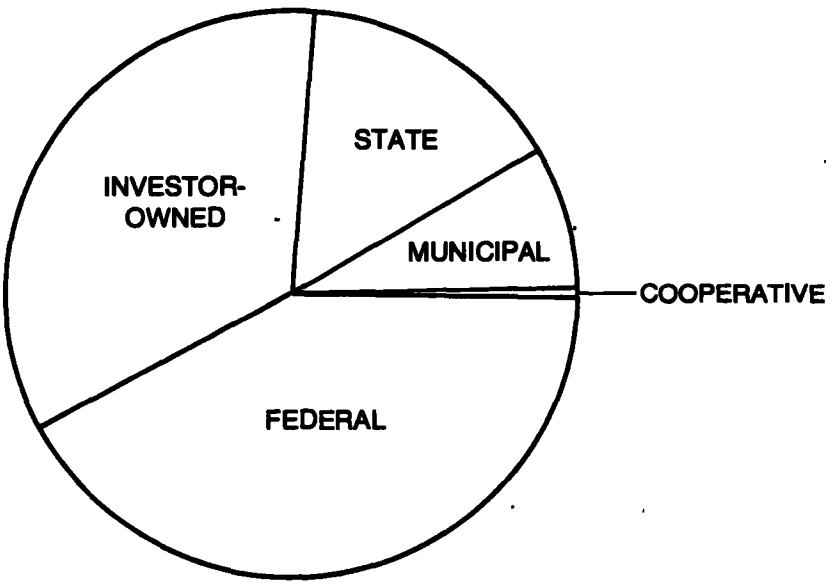
Low head run-of-river hydroelectric power plants built on streams where flow regulation is not possible will have value as thermal fuel displacement. However, run-of-river hydroelectric power plants would be even more valuable if even small amounts of pondage (daily or weekly storage) is available to allow some peaking operation and credit for dependable (firm) capacity.

The larger multiple-purpose storage projects are more suited for peaking operations. The reservoir fluctuations at these projects are usually more noticeable seasonally than daily or weekly.

The projected demands for electrical power along with potential shortages and price increases in petroleum fuels indicated that conventional hydroelectric power will become an increasingly valuable resource for oil and gas displacement



ALL GENERATION SOURCES



HYDROELECTRIC SOURCES

Figure 3-4: OWNERSHIP OF ELECTRIC POWER CAPABILITY – 1977

and that peaking capability (including pumped-storage hydroelectric plants) will continue to be the most economically attractive application of hydroelectric power in contributing to the electrical system.

This preference in using hydroelectric power for peaking operations is demonstrated by actual power use during 1977. In that year, the average annual plant factor (ratio of actual energy generated to maximum energy that could be generated with plant at full capacity during the entire year) for all electric power plants was 47 percent. However, the average for hydroelectric plants was 35 percent.

PROJECTIONS OF FUTURE ELECTRIC POWER DEMAND AND SUPPLY

National Figures

Projections of future electric energy consumption are difficult. Future levels of demand depend on economic, social, environmental, and political factors, both domestic and international, which can have profound effects but which cannot be readily foreseen.

There are many available forecasts of energy and electrical demands. Rather than preparing a separate Corps of Engineers forecast, the NHS analyzed a range of recent (1976-1979) forecasts to derive three projections of future electrical power and energy demands.

Utility Projections (Projection 1)

"Utility projections" are forecasts made by the electric utility industry. The electrical demands and energy needs for the contiguous United States are projected by the regional electric reliability councils and reported to the Department of Energy. The reliability council projections of peak demand prepared in 1979 were extended from 1997 to 2000 using the 1995-97 forecasted growth rate. Then the annual energy requirements between 1988 and 2000 were computed based on 62.6 percent load factor, which is the national annual load factor estimated for 1987 in the reliability council projections.

IEA "Low" Projections (Projection 2)

This forecast was developed in September 1976 by the Institute for Energy Analysis (IEA) at the Oak Ridge Associated Universities. The IEA study projects economic growth and energy demand for the United States to the year 2010. According to that study, both economic growth and total energy demand are likely to grow more slowly than had been assumed in most previous analyses of energy demand. The study also noted that electric energy demand is expected to grow more rapidly than total energy demand. Two scenarios, designated "high growth" and "low growth," were developed in the IEA study. In both scenarios the electricity demand projections are lower than the utility projections. The "low" projections were used as representative of other recently derived low growth projections.

Consensus Projections (Projection 3)

Projection 3 is a consensus forecast of U.S. electricity demand which represents an average of 15 energy demand forecasts of Federal and private sector economists between September 1973 and April 1975. Here, as in projection 2 above, an average annual per capita energy consumption growth rate is developed first, then total energy demand is determined from population projections. Peak demand is determined from total energy demand by using a projected load factor.

Median Projections

Within the eleven regions for which projections were made, the utility projections (Projection 1) were highest in four regions, lowest in three other regions, and between the IEA and consensus forecasts for four regions and for the national totals. The consensus projections (Projection 3) were between projections 1 and 2 in four regions and were highest in seven regions and the national total. The IEA "low" projections (Projection 2) were lowest in eight regions and resulted in the lowest national forecast.

In order to establish a projection for use in the NHS regional reports (Volumes XIV through XXIII), median projections were formulated. For each of the selected years in Projections 1, 2, and 3, the median projection for seven regions is simply the intermediate forecast among the three different projections discussed previously. However, an actual median projection was developed for four regions.

The details of each of the forecasts discussed above are documented in Volumes III and IV of the NHS report. The results show a range of overall expected growth rate in electrical energy demand from 3.5 percent to 4.7 percent per year for the 22-year period 1978 - 2000. Corresponding growth rates in peak power demands vary from 3.6 percent to 4.8 percent per year. Actual growth in generation capability in 1980 and 1981 was 2.6 and 4.3 percent, respectively. These projections indicate a range in the growth rate of overall per capita electricity consumption from 2.6 percent to 3.8 percent per year.

This set of growth rate projections indicates that the national electricity demand of 2,200,000 GWh in 1978 will grow to a value between 4,700,000 and 6,100,000 GWh per year by the year 2000 and that the peak demand of 397,700 MW in 1978 will grow to somewhere between 869,000 and 1,127,000 MW. Even under the lower growth rate projections, both energy and peak capacity demands are expected to more than double by the end of this century.

Several more recent projections have become available since preparation of the analysis reported in Volumes II and III. The 1980 NERC forecast (modified Projection 1) now shows an expected peak demand of 893,271 MW in 1999. Further, subsequent research to assess the need for development of hydroelectric pumped storage within the United States (NHS Volume X) used another projection (modified Projection 2). This projection estimates that the annual average compound growth rate for peak power demands between 1979 and 1999 is expected to be only 2.6 percent (721,600 MW by 2000).

The various projections of future peak demand are shown for comparison in the following tabulation:

Projection	Year	Indicated Peak Demand (MW)	Annual Growth Rate (Percent)
Projection 3 (Consensus)	2000	1,127,000	4.8
Projection 1 (Utility)	2000	1,066,500	4.6
Projection 1	1990	711,000	4.9
Modified 1	1990	643,600	4.4
Median Projection	2000	1,029,400	4.4
Projection 2 (IEA "Low")	2000	869,600	3.6
Modified Projection 2 (Pumped Storage Study)	2000	721,600	2.6

Even the lowest growth rate would result in about a 150,000 MW increase in peak demand by the year 2000.

Projected Generation Mix

To reflect the uncertainties and the numerous factors which affect future generation mixes to meet the projected demand, a range of future installed capacities for each major generation type was estimated in early 1980 and reported in NHS Volume IV. For future hydroelectric power capacity, the range reflects the difference between the "committed" hydroelectric power already in the construction pipeline and the total potential that could be developed based upon preliminary NHS inventory estimates. Figures in Appendix 3 give an indication of the range in which each fuel type may be utilized in fulfilling these future demands within each region by the year 2000.

These "range" projections indicate from 25,000 to 35,000 MW of conventional hydroelectric power to serve base load, 17,000 to 36,000 MW to serve intermediate loads, and 20,000 to 41,000 MW of conventional capacity to serve peaking loads. In addition, the projected load mix includes from 21,000 to 54,000 MW of pumped-storage peaking capability.

The results of the "range" projections for all generation sources are shown in Figure 3-5.

The extent to which demand for additional electric power sources will affect future construction of conventional and pumped-storage hydroelectric plants is uncertain. However, many potential small hydroelectric power projects are insensitive to the growth of demand for power. The output from these plants can be absorbed with little consequence to a utility grid. If such hydroelectric power plants are cost effective as fuel savers, they will probably be built to replace existing oil-fired generating plants.

Hydroelectric power potentials for fulfilling a portion of future energy needs vary among regions according to the distribution and cost of alternative thermal fuel supplies, expected growth of regional economies, and potential future changes in regional distribution of the nation's population. In all regions the amount of new electric generating capacity needed to meet demand exceeds the amount of hydroelectric power potential that can feasibly be developed.

Impact of Conservation and Load Management

Figures 3-6 and 3-7 illustrate the national consumption of energy by type and by end use sector from 1973 through 1980. The total energy consumption dropped from almost 79 quads in 1979 to 76.27 quads in 1980, the lowest level since 1976. However, the consumption of energy by electrical utilities has shown a continual increase in each year since 1973. The bulk of the reduction in total energy consumption for 1980 occurred in industry (1.25 quads) and in transportation (1.33 quads).

Conservation is intended to reduce both total capacity and energy requirements. Recently the Federal government has emphasized energy conservation and development of alternative energy sources to offset diminishing domestic petroleum and natural gas supplies and to decrease the nation's dependence on foreign supplies of these resources. Research, development, and demonstration programs are underway and include small scale hydroelectric plants, synthetic fuels, geothermal energy, solar energy (including wind), and others.

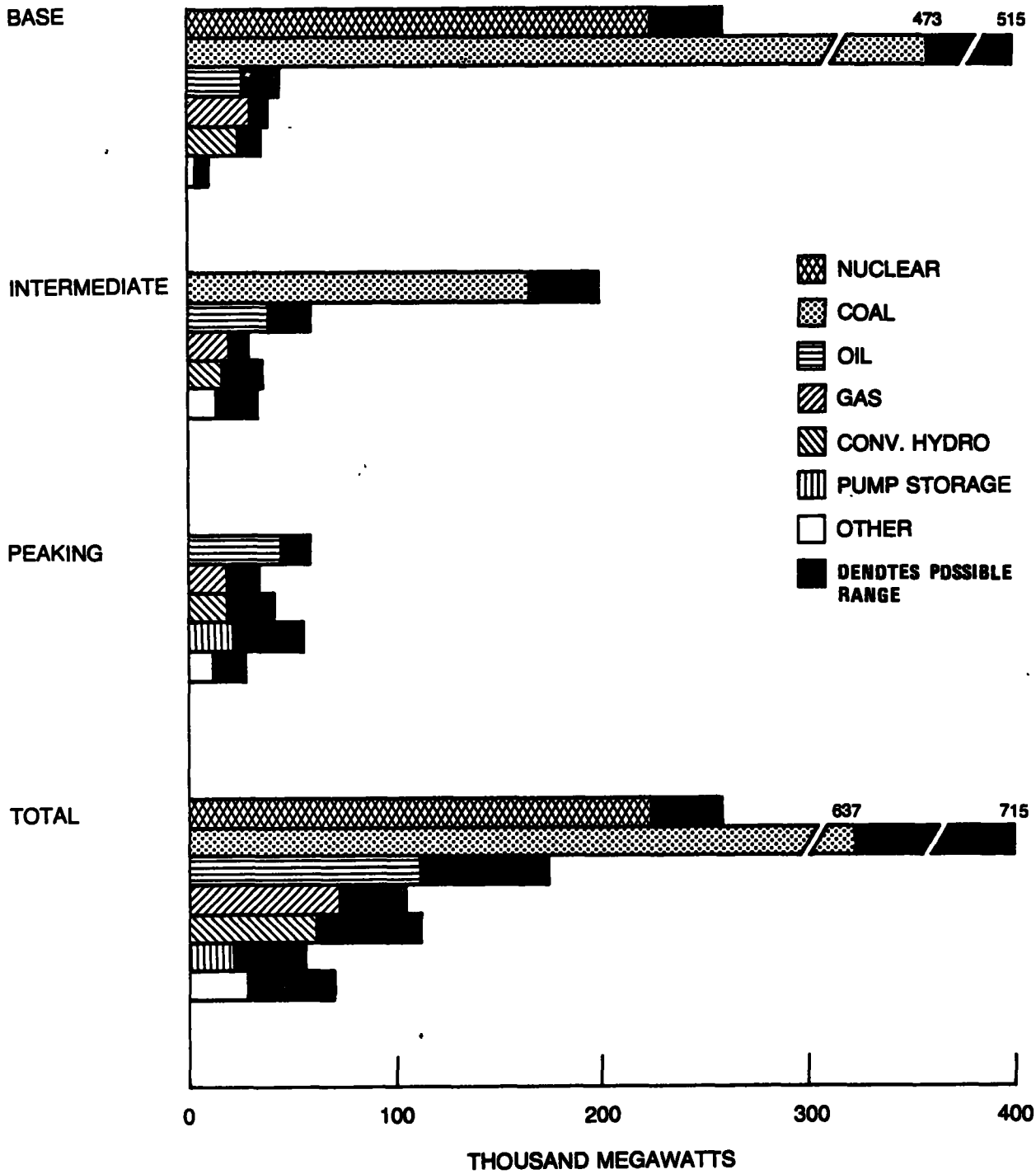
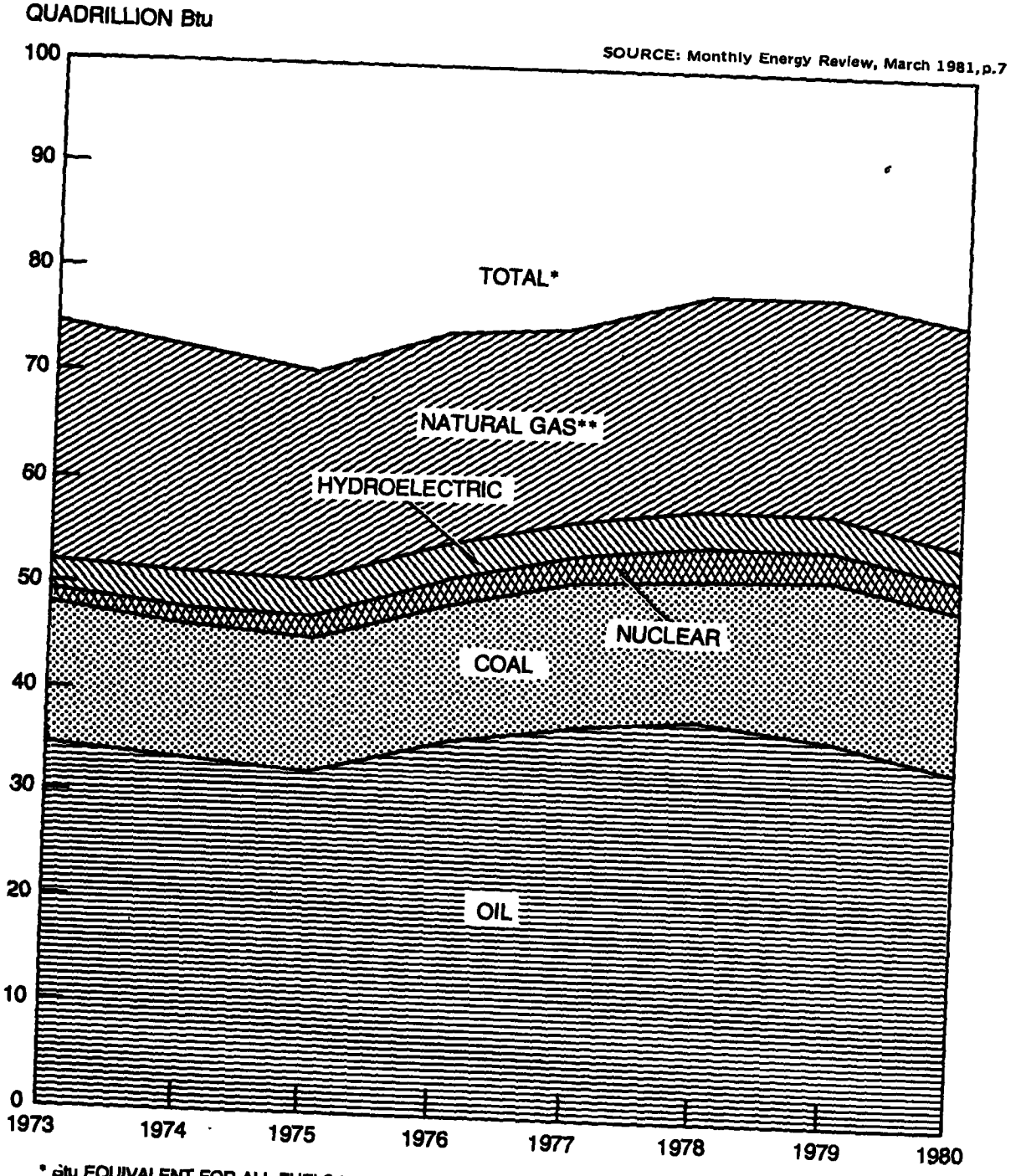


Figure 3-5: RANGE OF FUTURE GENERATING CAPABILITIES FOR MEETING LOAD PROJECTIONS, CONTIGUOUS UNITED STATES (2000)



* Btu EQUIVALENT FOR ALL FUELS WERE CUMULATED TO CREATE TOTAL.
** INCLUDES NET IMPORTS OF COAL COKE AND OTHER.

Figure 3-6 : CONSUMPTION OF ENERGY BY TYPE

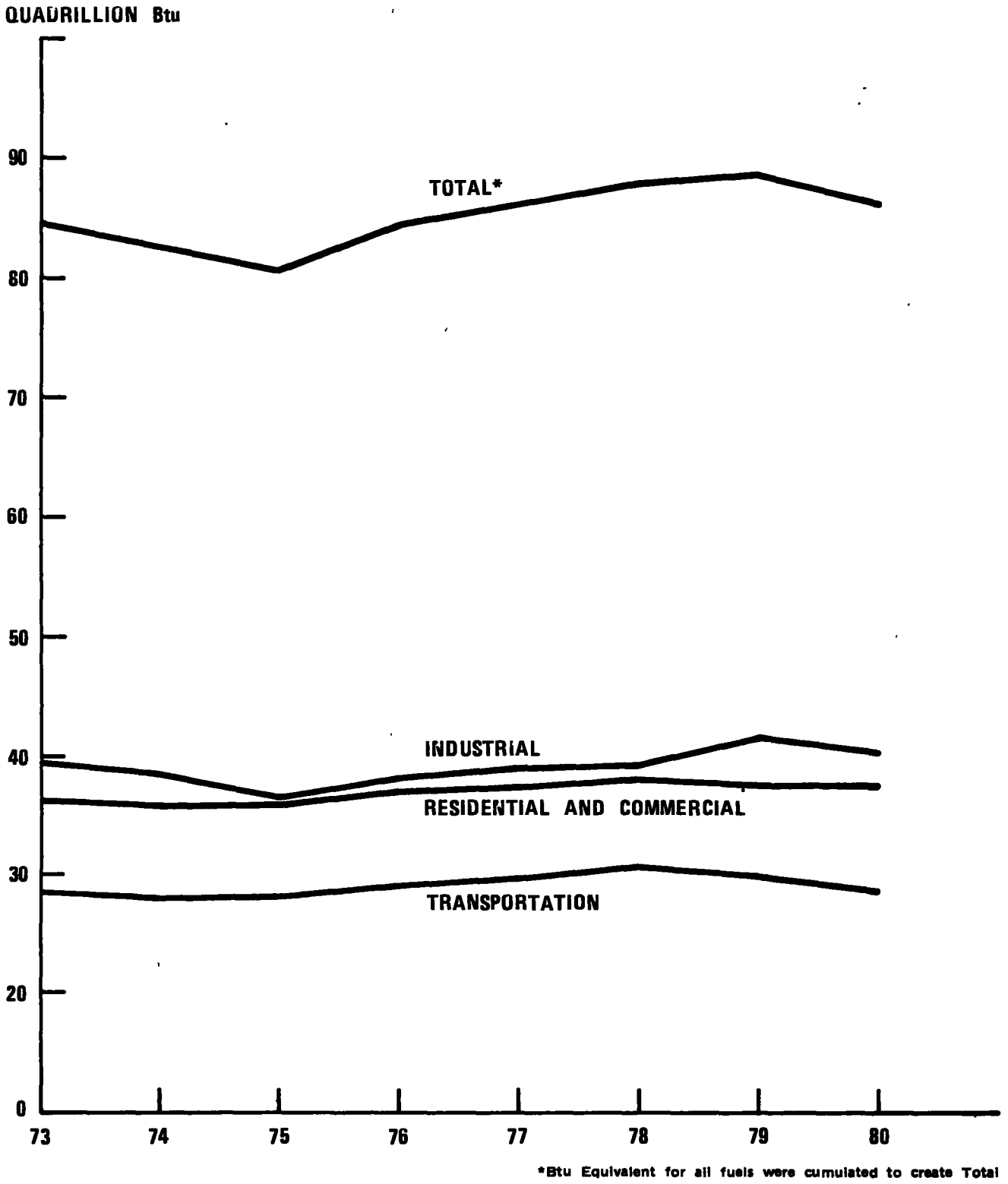


Figure 3-7 CONSUMPTION OF ENERGY BY END USE SECTOR

Load management techniques are intended to help reduce the need for installation of expensive peak load capacity. The desired effect of load management is to reduce peak demand rather than reduce total electric energy consumption. The magnitude and consequences of load management efforts which may be expected through the year 2000 are detailed in two NHS reports: the electricity demand studies documented in NHS Volumes III and IV and the pumped-storage study documented in NHS Volume X. As mentioned earlier, the growth rate for electrical power demand remains positive even under the lowest projections considered. However, sensitivity analyses on the effects of load management and control indicate that the magnitude of reduction of the amount of additional peaking power required under the lowest growth rate projection may be as high as 70 percent.

Table 3-4 gives statistics on potential effects of load management under various assumptions of future peak load growth. As shown in the tabulation, the assumptions regarding the overall economic climate are critical to determining the magnitude of additional peaking power needs. However, the net reduction resulting from load management is approximately the same under either assumption. Under the Modified Projection 2 (resulting from the pumped storage assessment for new peaking needs), load management is shown to reduce the need for new peaking capacity from 188,000 MW to 107,000 MW, or a net reduction of 81,000 MW given the assumption of most favorable economic climate for construction. The corresponding net reduction under least favorable economic climate for construction is 76,000 MW.

TABLE 3-4

EFFECTS OF LOAD MANAGEMENT ON NEED FOR ADDITIONAL PEAKING CAPACITY BY 2000
(Megawatts)

		Projection 1 Industry Projection	Projection 2 IEA "Low" Projection	Modified Projection 2 (Pumped Storage Study)
Assuming Most Favorable Economic Climate	Need w/o Load Management	255,000	302,000	188,000
	Need w/Load Management	146,000	178,000	107,000
	Net Effect	(109,000)*	(124,000)	(81,000)
Assuming Least Favorable Economic Climate	Need w/o Load Management	195,000	242,000	117,000
	Need w/Load Management	82,000	122,000	41,000
	Net Effect	(113,000)	(120,000)	(76,000)

* Data from pumped storage assessment -- NHS Volume X. Numbers in parentheses indicate reduction in need. All numbers have been rounded to nearest thousand megawatts.

HYDROELECTRIC PUMPED STORAGE AND ALTERNATIVE PEAKING SOURCES

A pumped-storage project is a hydroelectric development that generates electric energy by using water that previously has been pumped from a lower reservoir to an upper reservoir. There are two principal categories of pumped-storage projects:

- Pure developments produce power only from water that has been previously pumped to an upper reservoir.

- Combined developments utilize both pumped water and natural streamflow to produce power.

In a pure storage development the upper reservoir is located offstream, while in a combined development the upper reservoir is located on a stream. In the latter case some electricity may be generated without the pumping requirement as in a conventional hydroelectric facility. In either type of development the lower reservoir may be located either onstream or offstream.

Within the last 12 years the concept of underground pumped storage has received serious consideration. In an underground pumped-storage arrangement the lower reservoir and powerhouse would be located up to 4000 feet below ground. Use of both man-made and natural cavities for the lower storage reservoir has been studied. Although underground pumped storage facilities have been shown in theory to be economically feasible, no such facilities have been constructed in the United States nor are any under serious consideration for FERC licensing.

The first hydroelectric pumped-storage project in the United States was constructed in 1929. Large-scale development of pumped storage began in the 1960s when low-cost off-peak power for pump-back became available from the new, large-capacity conventional and nuclear steam-electric generating plants. In 1980, the total capacity of the 31 existing pumpedstorage projects was about 13,406 MW, as shown in the following tabulation:

Status in 1980	Number of Projects	Installed Capacity MW
Pumped-storage projects in operation	31	13,406
Pumped-storage projects licensed and/or under construction	11	9,346
Pumped-storage projects for which license applications have been filed	7	10,150

Although the objectives of pumped-storage facilities have changed over the last 50 years, the common purpose of almost all such plants is to store energy for use during peak demand periods. However, with the recent increase in

interest in and development of non-firm, renewable electrical energy resources (primarily wind and small-scale, run-of-river hydroelectric power), there is also an increasing interest in pumped storage as a means of shaping the energy output from large numbers of these projects on a daily and weekly basis to fit local and regional loads.

Other objectives which have been documented during the planning of pumped-storage projects in the United States include

- Provision of emergency power
- Increase in system reliability
- Voltage regulation capability
- Increase in system efficiency
- Fuel selection capability
- Multiple use of storage reservoirs including recreation, water supply, low-flow augmentation, flood control, and irrigation
- Seasonal storage of hydroelectric energy.

Figure 3-8 is a diagram of a typical weekly electric load curve and illustrates the portions of the demand which are satisfied by various generating facilities of a utility. Pumped storage plants are best utilized to meet the peak demands which occur daily, since their quick response and easily regulated output capability cannot be matched by larger fossil-fueled or nuclear plants. Note that the pumping energy for the pumped-storage plant is obtained during off-peak hours which also allows for the base load fossil-fueled and nuclear plants to operate at a more level output and therefore more efficiently. As a result, even though pumped-storage plants operate at an overall cycle efficiency between 66 percent and 78 percent, they are economical to construct and operate because of the increased efficiency of the entire, integrated electric generating system of a utility. In addition, they may allow postponing construction of new, costly base load plants.

Pumped storage is a well-known technology. There is virtually no risk that the project will be unable to operate substantially as designed. However, one economic disadvantage is the high cost and long construction time of large

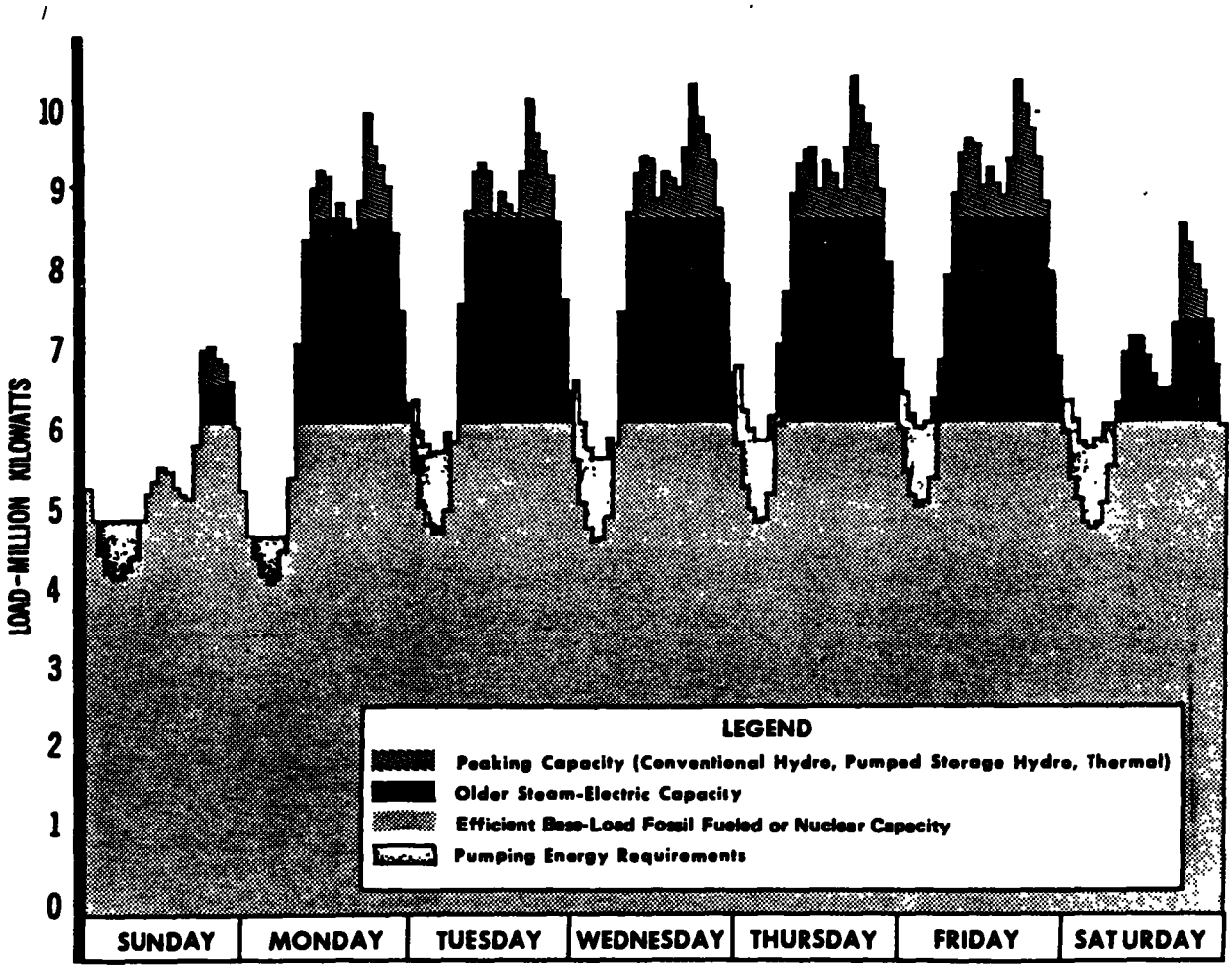


Figure 3-8 TYPICAL WEEKLY LOAD CURVE

pumped-storage facilities in comparison to some of their alternatives. In addition, extremely tight financial markets and diminishing electric growth rates at present make it difficult for utilities to undertake major pumped-storage projects.

Since pumped storage uses relatively large land areas in comparison to thermal alternatives, its effects on the environment (land use, terrestrial ecology, aesthetics) are potentially greater, although the use of existing reservoirs or lakes as part of the pumped-storage system is likely to lessen these effects to some degree. Water quality and aquatic ecology effects are also potentially significant, but, again, existing conditions will dictate their magnitude. However, pumped-storage systems do not have air quality impacts that are common with thermal systems.

Alternatives to Pumped Storage

Active research is underway on new technologies (ranging from advanced batteries to load leveling techniques) which may compete with pumped storage. These new technologies can be divided into supply alternatives and demand alternatives. Supply alternatives are storage and power generating technologies that a utility can use to meet peak loads. Demand alternatives refer to rate restructuring, load management, conservation, and end-use technologies.

Overall, combustion turbines and hydroelectric power will continue to be the major supply alternative options for new peak-load power generation over the next two decades. If further reductions in capital cost can be achieved, fuel cells have the potential to become a viable alternative to diesels and combustion turbines in the 1990s. Photovoltaic energy conversion is likely to be limited to a minor supplemental role between now and the year 2000.

Existing oil- and coal-fired units will continue to be used for intermediate-load power generation. Conventional hydroelectric power plants will continue to be a major option for new intermediate-load as well as peak-load capacity. Combined-cycle fossil units are ideally suited to intermediate-load operation, but new orders may be constrained by limitations imposed by the Fuel Use Act.

The demand alternatives fall into three categories: thermal storage, load management, and conservation. The storage of heat by residential or commercial customers in either water or solid matter is technically simple and is limited only by economic considerations.

Load management falls under two general approaches. In the first, the utility provides the customer with an economic incentive to manage his own peak loads. In the second, the utility manages the customer's load through load control and communication devices. Generally, the utility controlled-load customer receives a lower rate for electricity. However, projections by the Edison Electric Institute (EEI) indicate generating cost savings of only about one percent.

Future Role of Pumped Storage

The future development of pumped-storage systems will be affected by the need to add new generating capacity and by the overall competitiveness of alternatives to pumped storage. Major economic, physical, and environmental factors will affect the future development of pumped-storage facilities. However, pumped storage has a clear advantage over other peaking alternatives in terms of turnaround and starting times, operation, and useful life.

To forecast the future development of pumped-storage capacity and alternative peak capacity technologies for this report, various scenarios were used. Briefly, the potential for pumped storage capacity development was assessed under three load growth forecasts. Existing peak capacity plants were retired under two separate schedules: utility-announced retirements, as reported by the National Electric Reliability Council (NERC), and generic retirements based strictly on the age of a generating unit. Various dispatch schedules for pumped storage were used and the effects assessed. In addition, the effects of load management on future peak load capacity development were examined. The same scenarios were used to assess the future development of alternative peaking technologies.

The combination of the most likely conditions (economic criteria only) results in an estimate of potential for pumped-storage capacity development for the continental United States of 59,875 MW by the year 1999. Regional components of this national total are given in Table 3-5. This estimate does not consider the environmental, physical, and geographical limitations affecting pumped-storage capacity development. Unsited base capacity development needed in conjunction with this amount of pumped storage capacity development is estimated at 8,478 MW in 1999. Estimates were developed for seven composite regions of the United States, and under all of the scenarios developed, the ECAR-MAIN-MARCA region was estimated to have the greatest need for pumped-storage capacity development, followed by the Southern-TVA-VACAR (subregions of SERC).

The RMPA-NWPP (subregions of WSCC) was estimated to have no potential demand for pumped-storage development for the purpose of meeting increases in peak capacity demand requirements. The mechanics of the load forecasting model rely very heavily on the probability of shifting existing conventional hydropower projects, located primarily in NWPP, from their current operational mode to a higher peaking operation mode. This shift may not be an acceptable operational change for many projects because of the increasing public awareness and opposition to peak power operation of conventional hydroelectric power plants. Results of studies by the Western Area Power Administration, Department of Energy, indicate a potential need for 4000 MW of additional peaking capacity by 2000 within their Colorado River Storage Project marketing area which includes Utah, Colorado, Wyoming, New Mexico, Arizona, and portions of Nevada and California.

Resolution of minimum instream flow requirements for fish in the large Columbia/Snake Rivers system in the Pacific northwest will probably result in flows producing hydroelectric power which exceeds regional electrical energy demand during portions of each year. Development of pumped storage in the region could mitigate potential energy losses by generating pumping energy with minimum flow release during off-peak hours and releasing water (energy) from pumped storage during peak hours. Releases from conventional storage reservoirs would be reduced during peak hours to allow for the utilization of pumped storage generation.

TABLE 3-5

MAXIMUM PUMPED STORAGE DEVELOPMENT BY REGION

	Maximum Pumped Storage Capacity
Continental United States	59,875 MW[1]
New England, New York, Mid-Atlantic (NEPOOL-NYPP-MAAC)	3,353
Florida	5,254
Southern, Tennessee Valley, Virginia-Carolinas (Southern-TVA-VACAR)	13,399
East Central, Mid-America, Mid-Continent (ECAR-MAIN-MARCA)	35,981
Southwest, Electric Reliability Council of Texas (SPP-ERCOT)	1,314
Rocky Mountains, Northwest (RMPA-NWPP)	0[2]
Arizona-New Mexico, Southern California-Nevada Northern California-Nevada (AZNM-SCNV-NCNV)	574

(1) Based on low load growth projections, utility-announced retirement schedule, dispatch of pumped storage after all other fuel types, and load management techniques not presently in effect.

(2) Excludes consideration of potential environmental impact of changes to peaking operation of conventional hydroelectric plants.

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CHAPTER 4

HYDROELECTRIC POWER RESOURCE ASSESSMENT

In order to obtain an accurate estimate of the magnitude of the nation's potential hydroelectric power resources, site specific information was accumulated on existing dams, on other water resource structures, and on undeveloped sites that had been previously studied for potential development. This chapter explains the methodology used to identify and evaluate the potential for developing hydroelectric power facilities at existing dams and previously identified, undeveloped sites; describes special studies completed to facilitate the identification and evaluation of projects; and, to the extent possible, summarizes the characteristics of projects evaluated during each stage of the study. Existing Corps dams, existing dams owned by others, and previously studied undeveloped sites are included in the analyses.

PLAN OF STUDY

Hydroelectric power potential and economic feasibility were evaluated in an initial inventory and four stages. The purpose of the initial inventory was to amass a complete list of potential projects for further study. The first three stages of evaluation included four levels of screening to eliminate from further study projects which did not meet desired criteria. The criteria became more stringent as the stages advanced; hence, only the most desirable projects survived until the fourth stage. The four stages and four screenings are summarized in Table 4-1. A flow diagram of the four stages and the overall screening process is shown in Figure 4-1.

SPECIAL STUDIES

Special studies were made to develop (a) data-collection procedures; (b) generalized regional power values; (c) generalized cost-estimating procedures; and (d) computer programs to analyze site hydrology, optimum project size,

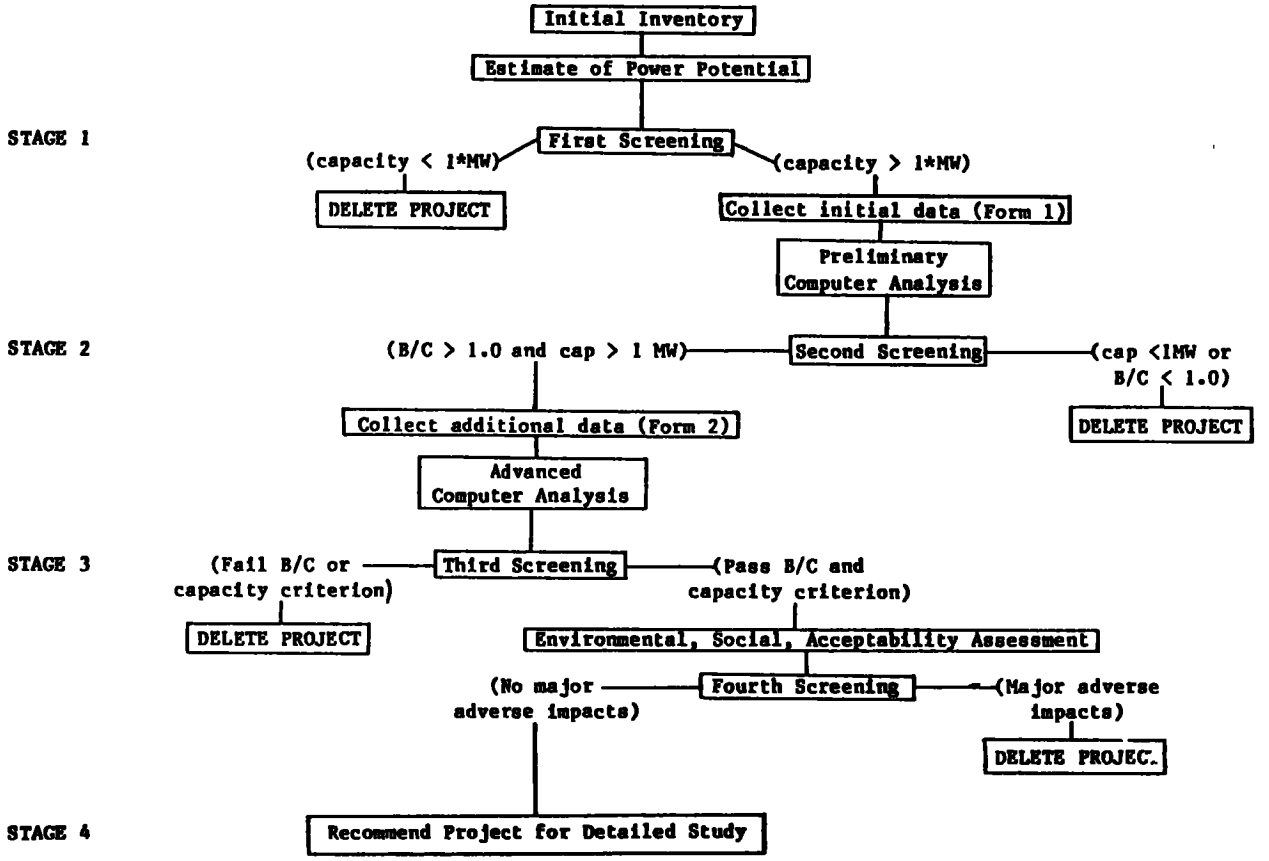
TABLE 4-1

GENERAL SITE EVALUATION PROCESS

Stage	Objective	Basic Evaluation Potential Sites Investigated	Screening Criteria	Data Required
First	Determine physical hydroelectric power potential	All existing dams and previously identified potential sites	Minimum Installed capacity potential	1. Inventory of dams 2. Previous studies/ inventories of hydro-electric power potential
Second	Determine economic feasibility (rough cut)	Projects passing stage 1 physically able to support development	Powerhouse cost vs. power benefits	1. Head, streamflow 2. Computer/routines-power potential/ powerhouse costs/power benefits
Third	Identify economically feasible, environmentally acceptable projects	Projects passing stage 2 with possible economic feasibility	1. Total project costs vs. power benefits 2. Acceptability a. Environmental b. Social	1. Economic feasibility a. Detailed site data b. Total project data c. Regionalized power values d. Computer routines for costs/benefits, hydrology 2. Environmental, social and project acceptability data a. Public comments
Fourth	Identify projects suitable for further study	Projects passing stage 3 that are economically feasible and environmentally acceptable	1. Match developable potential with demand with demand 2. Assess marketability	Data from stages 1, 2, and 3

FIGURE 4-1

FLOW CHART OF THE SCREENING PROCESS



*The Lower Limit in the NPCC Region was 50kW

costs, and benefits. In addition, computerized data-base and data-base management programs were developed. All of the data compiled on the inventoried sites which showed minimum potential for hydroelectric power development (i.e., passed Stage 1 screening criteria), together with the results of the project analyses, are stored in the data base. These data are readily retrievable in total or in user-defined format.

Generalized regional power values were developed by the FERC. These generalized power values are based on the cost of generating electricity at conventional fossil fuel or nuclear power plants and were used to compute benefits for Stage 2 and for the first screening of Stage 3. The second screening of Stage 3 consisted of an assessment of possible environmental, social, and institutional constraints to development.

Generalized cost-estimating procedures were developed so that preliminary estimates of project costs could be obtained for all projects on a comparable basis. Cost-estimating curves which include powerhouse and switchyard costs were used in making the Stage 2 calculations. For the first screening of Stage 3, cost-estimating procedures which include all project features were used. The generalized cost curves were programmed for computer analysis, and the cost estimating procedures were compiled in a manual for use in office studies. The cost-estimating manual is included in NHS Volume XIII, as are detailed descriptions of the computer programs and FERC power values.

Site hydrology, construction costs, and power value benefits were evaluated using computer programs. The computer programs enabled analysis of streamflow data using flow duration, sequential flow, or fixed capacity techniques to find a range of capacity and energy potentials; project benefits on the basis of FERC power values; project costs from generalized cost curves; and size of project which would maximize net benefits (except when the fixed capacity techniques were used). Figure 4-2 illustrates a typical economic screening analysis to determine the optimum project size at each site. For each potential project, 10 sizes of potential development were analyzed covering the complete range of streamflow rates estimated for the site. For each installation size, the capacity, average annual energy, cost, and benefits were then estimated, and a

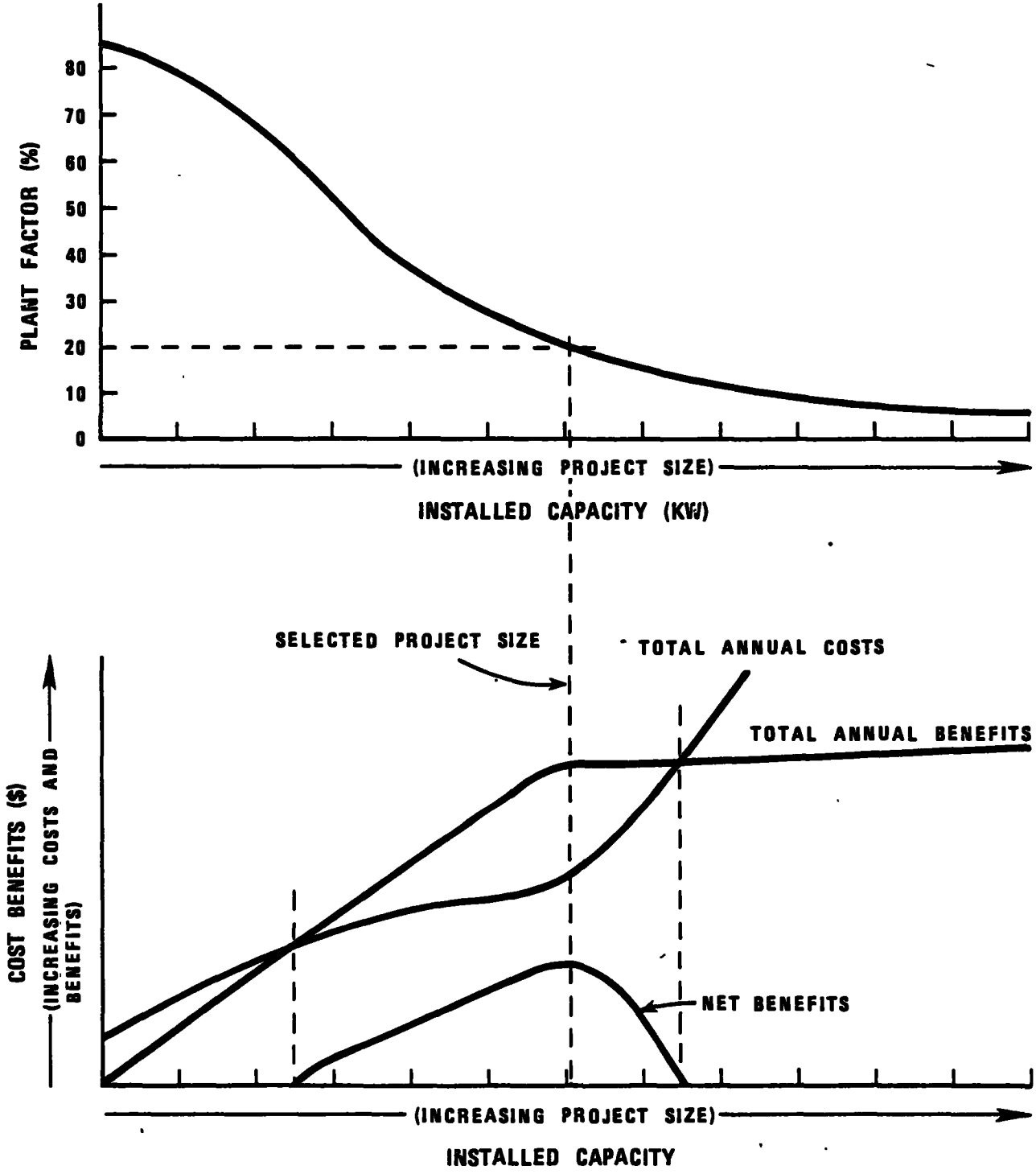


Figure 4-2 GENERALIZED ILLUSTRATION OF ECONOMIC ANALYSIS PROCESS AND SELECTION OF PROJECT SIZE

"net-benefit" vs. installation-size curve was constructed. The size of installation selected by economic screening was that size which exhibited the highest net benefits unless a field estimate of developable capacity had been predetermined and entered in the data base.

As shown in Figure 4-2, the typical project size was optimized at a plant factor of about 20 percent (The average plant factor for all projects recommended for further study is 24 percent.) This is significantly lower than plant factors for existing hydroelectric power projects, which averaged 35 percent in 1977. There are two basic reasons for the selection of plant sizes with relatively low plant factors: First, FERC power values are higher for plants with lower plant factors because they are assumed to displace alternatives which burn high-cost oil and natural gas; second, interruptible capacity (capacity associated with streamflows with an exceedence frequency of less than 85 percent) was uniformly credited with one-half of the firm capacity benefit. As a result of these two factors, plant capacities as determined by the NHS computer routines are, in most cases, higher than would be reasonable to actually install.

IDENTIFICATION OF POTENTIAL PROJECTS

Initial Inventory

To compile the initial inventory, all known dams and dam sites for which data were available were included. The principal sources of data were catalogues of dams compiled by Corps dam safety personnel, other reports by state engineers, the FERC computerized data base, previous water resource studies, and waterpower surveys conducted by the U.S. Geological Survey. Data on dams and dam sites were amassed for the entire nation. Although no precise record was kept of the number of projects considered for inclusion in the inventory, a rough estimate would place the number at about 60,000 (50,000 existing dams and 10,000 undeveloped sites). The number of projects in the initial inventory as reported in the NHS regional reports by Electric Reliability Council Region is shown in Table 4-2.

TABLE 4-2

NUMBER OF PROJECTS IN INITIAL INVENTORY AS RECORDED IN REGIONAL REPORTS 1/

ERC	Existing Projects	Undeveloped Projects	Total
ECAR	(not reported)	(not reported)	4,500
ERCOT	(not reported)	(not reported)	4,500
MAAC	(not reported)	(not reported)	(not reported)
MAIN	1,410	110	1,520
MARCA	735	80	815
NPCC	1,249	678	13,127
SERC	11,500	600	12,100
SWPP	(not reported)	(not reported)	5,040
WSCC	9,869	5,692	15,561
Alaska	61	634	695
Hawaii	22	7	29
Puerto Rico	42	25	67
TOTAL	50,000 (est.) 2/	10,000 (est. 2/	60,000 (est.) 2/

1/ Includes mutually exclusive alternative sites and sites with no new or additional energy capacity.

2/ National totals are gross estimates of all projects considered. Reliability council regional totals are not available since data collection in the early stages of the NHS was on a state and district basis. Reliability council designations were made after Stage 1 screening in many regions.

Stage 1

Stage 1 screening served to identify the projects that might have physical potential for hydroelectric power development. The principal criterion applied was the amount of capacity which could potentially be installed. The minimum size selected depended on regional conditions, including the amount of remaining undeveloped potential and marketing and transmission constraints. The minimum size selected ranged from a low of 50 kW in NPCC to a high of one MW in WSCC. With a few exceptions, potential projects with less than the minimum selected potential were not included in the NHS computerized data base. Another criterion was to eliminate pumped-storage sites from consideration.

Because of the large number of existing dams and undeveloped dam sites, the first task was to eliminate from consideration those with no practical physical potential. For existing dams, data on project name, location, maximum storage capacity, and hydraulic height were obtained from the Corps' inventory of dams. To estimate flow, it was assumed that (1) continuous streamflow would be available sufficient to fill any reservoir in 24 hours, (2) this flow would convert to power at head equal to the maximum height of the dam, and (3) this conversion would be 85 percent efficient. Each site was analyzed by means of the standard formula for hydroelectric power, $KW = HQe/11.8$, where KW = power output in kilowatts, H = head in feet, Q = streamflow in cubic feet per second, and e = plant efficiency, 85 percent in this case. For undeveloped projects, head and average annual flow estimates were obtained directly from the reference source and potential capacity was computed using the above formula, assuming a 50 percent annual plant factor. Even under these admittedly liberal criteria, roughly 72 percent of the originally considered potential sites failed to meet the minimum size criteria. These projects were eliminated from further consideration. The remaining projects, which under preliminary analysis showed potential of at least the minimum selected size, were transferred to the preliminary data base. Most of the deleted projects were very small existing dams (stock ponds) with small drainage basins and intermittent streamflows.

Approximately 17,000 sites remained for further consideration. The number of projects remaining at the end of Stage 1, by ERC region, is shown in Table 4-3. The minimum size project retained in each region is also shown.

Stage 2

Stage 2 was designed to identify projects which have physical hydroelectric power potential and which might be economically feasible. The approximately 17,000 projects in the preliminary data base were reanalyzed using additional, more detailed, physical data for each site and applying more stringent physical criteria than in Stage 1 to find potential power capacity, average annual energy, costs for project power features, and estimated power benefits. Costs (at July 1978 price levels) included only powerhouse and switchyard costs and were amortized over 50 years at 6 5/8 percent interest (the effective Federal discount rate) to obtain average annual costs. Costs associated with dams, reservoirs, lands, and other required project features were not included at this stage in order to minimize data collection requirements. This procedure assured that projects which could not generate enough power to repay power facility costs would be deleted before more detailed costs and economic analyses were performed. In addition, actual streamflow data and a lower, more realistic net power head were used in the analysis of power potential in Stage 2 in place of the assumed values used in Stage 1. General screening criteria were a minimum capacity potential and power benefits at least equal to power facility costs. This screening deleted many projects from further consideration as potentially viable. In all, nearly 8000 sites met the required criteria and were selected for further analysis in the first phase of Stage 3. The only projects retained that did not pass Stage 2 criteria were those for which local conditions indicated that they should be evaluated further. The number of projects remaining at the end of Stage 2, just over 47 percent of the projects that entered Stage 2, is shown in Table 4-4 by ERC region. More detailed information was collected and entered into the data base for projects remaining after Stage 2. The new information included social, environmental, and other acceptability data, as well as more detailed physical and economic data.

TABLE 4-3

NUMBER OF PROJECTS REMAINING AFTER STAGE 1 AS RECORDED IN REGIONAL REPORTS 1/

Region	Min Size 2/ Project (MW)	Existing Projects	Undeveloped Projects	Total
ECAR	1.0	(not reported)	(not reported)	1,200
ERCOT	1.0	(not reported)	(not reported)	1,735
MAAC	1.0	(not reported)	(not reported)	828
MAIN	1.0	745	18	763
MARCA	1.0	239	11	250
NPCC	0.05	2,931	493	3,424
SERC	1.0	755	350	1,105
SWPP	1.0	(not reported)	(not reported)	2,520
WSCC	1.0	1,720	2,875	4,595
Alaska	1.0	57	427	484
Hawaii	0.1	22	7	29
Puerto Rico	1.0	42	25	67
TOTAL		undetermined	undetermined	17,000 (est.) 3/

1/ Includes mutually exclusive alternative projects and projects with no new or additional energy potential.

2/ The minimum size shown is the general size criterion applied in each region; however, some exceptions were made.

3/ National totals are either undetermined or gross estimates because many divisions did not accumulate total by reliability council regions at this stage.

TABLE 4-4

NUMBER OF PROJECTS REMAINING AFTER STAGE 2 AS RECORDED IN REGIONAL REPORTS 1/

Region	Min Size 2/ Project (MW)	Existing Projects	Undeveloped Projects	Total
ECAR	1.0	(not reported)	(not reported)	604
ERCOT	1.0	201	159	360
MAAC	1.0	166	88	254
MAIN	1.0	203	0	203
MARCA	1.0	75	2	77
NPCC	0.05	1,100	163	1,263
SERC	1.0	305	328	633
SWPP	1.0	(not reported)	(not reported)	1,500
WSCC	1.0	782	1,747	2,529
Alaska	1.0	19	403	422
Hawaii	0.1	21	7	28
Puerto Rico	1.0	25	25	50
TOTAL		undetermined 3/	undetermined 3/	7,923

1/ Includes mutually exclusive alternative projects and projects with no new or additional energy potential.

2/ The minimun size shown is the general size criterion applied in each region; however, some exceptions were made.

3/ National totals for existing and undeveloped projects are undetermined because some regional reports did not include this information.

Stage 3 First Screening

The purpose of the Stage 3 first screening was to identify all economically feasible projects. Existing dams and undeveloped sites failing to pass Stage 2 were assumed not to have any potential for development on a commercial basis. Economic feasibility as determined at this stage is based on total project costs, i.e., for a dam, reservoir, and powerhouse, rather than for a powerhouse alone, as was done in Stage 2. Also, hydrologic studies (more detailed than in Stage 2) were made to obtain a final estimate of site power capability.

To assure that project cost estimates would be sufficiently detailed and adequate for comparison, these estimates were based on the average of major construction-cost items derived from historical experience at more than 100 Federally constructed projects nationwide and indexed to the July 1978 price level. Cost estimates were obtained by computer and compared with power benefits to determine each project's economic feasibility. Because the benefits are derived on an annual basis, the costs are converted to their annual equivalent. Annual costs reflect 6 7/8 percent interest, an economic project life of 100 years, costs for major replacements, and charges for annual operation and maintenance. Although cost estimates are adequate for comparing potential hydroelectric power developments with each other on an equivalent basis, the costs obtained for the projects are not sufficiently detailed to be relied on as estimates of actual construction costs. Analyses of project costs in this report, therefore, do not establish actual economic feasibility but only a generalized ordering of potential projects from least to most expensive. For a site to be retained after Stage 3 first screening, it had to meet the basic minimum project size and equal or exceed a minimum benefit-cost ratio or show total annual energy costs of less than the maximum set by each Corps field office. The specific economic criteria set by each field office varied according to the present incremental cost of power in each region and the opportunity for multiple-purpose development at each site. In general, the minimum criteria for multiple-purpose projects were lower (as low as about 0.35 benefit-cost ratio) than for single-purpose hydroelectric power projects (usually a minimum benefit-cost ratio of 1.0 or a maximum cost of energy of from

about 70 to 100 mills per kilowatt-hour) because benefits accruing to other purposes (flood control, irrigation, water supply, recreation, etc.) were not evaluated.

In the first screening of Stage 3, then, the most favorable projects from an economic standpoint were identified. The number of projects remaining in Stage 3 after the first screening is shown by ERC region in Table 4-5 . Less than half the projects which had passed Stage 2 screening survived the first screening of Stage 3. These projects (2794) were retained during the second phase of Stage 3 for the purpose of evaluating potential environmental and social constraints to development.

Stage 3 Second Screening

This screening was made to identify economically feasible hydroelectric power projects most suitable for further study and possible development. The screening criteria included environmental, social, and power-marketing constraints to project development. These criteria differ from those used in the earlier stages because they are judgmental rather than based on set mathematical or statistical values.

In an attempt to understand fully the effect of "non-economic" constraints which might influence the realization of the economically feasible hydroelectric power potential, adverse impacts were reviewed through an iterative process which included three distinct steps or phases. During the first phase an in-house review of each project was made by Corps environmental specialists (assisted in some instances by consultants) to identify known potential impacts and to flag all projects with known legal constraints to development, such as wild and scenic river status. During the second phase, 18 public meetings were held throughout the United States. More than 1300 people attended these meetings. At least 1000 formal presentations, several hundred informal comments, and several thousand telephone calls and letters were generated by these public meetings. In addition, formal and informal workshops, panel discussions, and site review meetings were held with Federal agency and state government representatives, Federal and state water resources development

TABLE 4-5

NUMBER OF PROJECTS REMAINING AFTER STAGE 3

FIRST SCREENING, AS RECORDED IN REGIONAL REPORTS 1/

Region	Min Size 2/ Project (MW)	Existing Projects	Undeveloped Projects	Total
ECAR	1.0	(not reported)	(not reported)	205
ECROT	1.0	19	39	58
MAAC	1.0	46	13	59
MAIN	1.0	112	0	112
MARCA	1.0	46	5	51
NPCC	0.05	553	102	655
SERC	1.0	103	110	213
SWPP	1.0	64	149	213
WSCC	1.0	358	682	1,040
Alaska	1.0	13	147	160
Hawaii	0.1	8	7	15
Puerto Rico	1.0	13	4	17
TOTAL		undetermined 3/	undetermined 3/	2,798

1/ Includes mutually exclusive alternative projects and projects with no new or additional energy potential.

2/ The minimum size shown is the general size criterion applied in each region; however, some exceptions were made.

3/ National totals for existing and undeveloped projects are undetermined because some reginal reports did not include required data.

officials, utilities, individuals, and local, regional, and national special interest groups. The final step was to provide copies of the draft regional reports incorporating the views and comments resulting from previous public input to state and Federal agencies, special interest groups, and the general public for final review and comment.

In general, projects were dropped from further consideration in this screening if they would have significant adverse environmental or social impact. A team of Corps scientists and engineers determined significant adverse environmental impact based on available data and their knowledge of the sites. However, all projects with legal constraints to development, i.e., location on a designated wild and scenic river or in a national or state park or wilderness area, were deleted. Also, projects requiring major relocations or fish and wildlife mitigation features (Relocation and mitigation costs were not included in estimates of total project costs.) were dropped, as were projects with substantial public opposition. In the case of public opposition, however, a project usually was not dropped until the state's position as expressed though its governor's office was obtained. All projects opposed by the states were deleted at this stage and were not included in regional listings of projects determined to be suitable for additional, more detailed study.

As a result of the three-step environmental/social impact review process, 748 projects located primarily in WSCC and Alaska were dropped from further consideration. More than 2000 projects survived this final screening. The number of projects remaining by ERC region is shown in Table 4-6.

Stage 4

In Stage 4 of the evaluation process, Corps division offices separated the sites passing the final screening into those with near-term (1990) and long-term (2000) potential. Mutually exclusive sites, i.e., those alternative sites proposing development of the same stretch of a river, also were excluded in this stage. The near-term and long-term project lists are contained in the NHS regional reports. Table 4-7 summarizes the sites, the capacity, and the energy resulting from the completion of Stage 4.

TABLE 4-6

NUMBER OF PROJECTS REMAINING AFTER STAGE 3

SECOND SCREENING, AS RECORDED IN REGIONAL REPORTS 1/

Region	Min Size 2/ Project (MW)	Existing Projects	Undeveloped Projects	Total
ECAR	1.0	174	20	194
ECROT	1.0	19	33	52
MAAC	1.0	46	1	47
MAIN	1.0	112	0	112
MARCA	1.0	46	2	48
NPCC	0.05	630	102	732
SERC	1.0	100	83	183
SWPP	1.0	62	40	102
WSCC	1.0	317	245	562
Alaska	1.0	10	49	59
Hawaii	0.1	7	7	14
Puerto Rico	1.0	13	4	17
TOTAL		1,536	586	2122

1/ Includes mutually exclusive alternative projects and projects with no new or additional energy potential.

2/ The minimum size shown is the general size criterion applied in each region; however, some exceptions were made.

TABLE 4-7

NUMBER OF PROJECTS REMAINING AFTER STAGE 4 EVALUATION
AS RECORDED IN REGIONAL REPORTS 1/

REGION	EXISTING			UNDEVELOPED			TOTAL		
	No.	Capacity (MW)	Energy (GWh)	No.	Capacity (MW)	Energy (GWh)	No.	Capacity (MW)	Energy (GWh)
ECAR	178	2,900	10,620	16	1,540	2,540	194	4,440	13,160
ERCOT	19	137	292	33	466	950	52	603	1,242
MAAC	46	465	1,024	1	424	521	47	889	1,545
MAIN 2/	58	1,244	3,483	0	0	0	58	1,244	3,483
MARCA	46	1,022	1,573	2	24	81	48	1,046	1,654
NPCC	553	2,432	8,367	102	2,394	8,336	655	4,826	16,703
SERC	100	1,513	2,416	83	5,234	11,103	183	6,747	13,519
SWPP	62	1,027	3,602	40	1,217	3,747	102	2,244	7,349
WSCC	315	8,730	16,416	204	11,682	33,392	519	20,412	49,808
Alaska	10	17	162	49	3,510	15,380	59	3,527	15,542
Hawaii	7	9	28	7	29	84	14	38	112
Puerto Rico	13	35	109	4	24	71	17	59	180
TOTAL	1,407	19,531	48,092	541	26,544	76,205	1,948	46,075	124,297

1/ Excludes mutually exclusive alternative projects.

2/ Data on the number of projects and capacity and energy potentials in the MAIN reliability council are estimates based on data in the current data base because these data were not included in the regional report.

These are potentially economically feasible projects without severe environmental, social, or other non-economic constraints to development and are considered to be the best candidates for possible development by the year 2000. In addition, they are projects whose output could be used to meet future increases in electrical energy requirements or to displace presently installed thermal generating plants. In all, these 1949 projects have a total of 46,075 MW of generating capacity and could provide 124,476 GWh of energy annually. The potential, however, is not distributed evenly throughout the nation. The WSCC region has the most, with 40 percent of the energy potential, followed in descending order by NPCC (13 percent), Alaska (12 percent), SERC (11 percent), ECAR (one percent), SWPP (six percent), MAIN (three percent), ERCOT (one percent), MAAC (one percent), MARCA (one percent), Hawaii (less than one percent) and Puerto Rico (less than one percent).

Most of the potential at the best candidate sites would be obtained from undeveloped sites (26,120 MW). However, almost 20,000 MW of capacity can be gained by tapping the potential at existing dams.

These sites offer the best opportunity for increasing the amount of hydroelectric power nationwide. Already, both Federal and non-Federal developrs are conducting feasibility studies on some of these sites. Based on the results of the NHS screening, all of these sites should be studied further to determine if a project should be constructed.

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CHAPTER 5

NATIONAL HYDROELECTRIC POWER DEVELOPMENT PLAN

This chapter outlines a plan for the further evaluation of possible future development of hydroelectric power facilities at the best candidate sites identified by the NHS regional reports. The plan focuses on sites under the jurisdiction of the Secretary of the Army and on undeveloped sites with multiple-purpose potential where the Corps of Engineers might have a role in the future. The chapter includes a discussion of non-Corps dams with additional hydroelectric power potential, although no Corps development role is expected at these sites.

The best candidate sites are broken into four categories defined by ownership. Each category is described in terms of capacity, energy, and geographic distribution. Potential developers are also identified within each category.

CATEGORIES OF SITES BY OWNERSHIP

Table 5-1 is a summary of the NHS best candidate sites categorized by ownership. The sites are separated into four categories: Corps of Engineers dams with existing hydroelectric power facilities, Corps of Engineers dams without existing hydroelectric power facilities, all non-Corps dams either with or without existing hydroelectric power facilities; and undeveloped sites. All sites contained in the table have the potential for additional hydroelectric power facilities. These sites are the same ones contained in Table 4-7 and described in the NHS regional reports. For more detailed information on any individual site, consult the regional reports.

The first category includes all Corps dams with existing hydroelectric power facilities where there is a potential for additional hydroelectric power. There are 30 sites in this category with a potential capacity increase of 2204 MW and

	Corps Dams with Hydroelectric Power			Corps Dams without Hydroelectric Power			All Non-Corps Dams with Additional Power Potential			Undeveloped Sites			Total		
	Number	Capacity (MW)	Energy (GWh)	Number (GWh)	Capacity (MW)	Energy (GWh)	Number (GWh)	Capacity (MW)	Energy (GWh)	Number (GWh)	Capacity (MW)	Energy (GWh)	Number	Capacity (MW)	Energy (GWh)
ECAR	2	23	76	107	1960	7538	69	917	3006	16	1540	2540	194	4440	13160
ERCOT	0	0	0	9	37	75	10	100	217	33	466	950	52	603	1242
MAAC	0	0	0	12	84	275	34	381	749	1	424	521	47	889	1545
MAIN	10	129	560	20	500	2442	28	615	481	0	0	0	58	1244	3483
MARCA	4	575	-20	6	110	328	36	337	1265	2	24	81	48	1046	1654
NPCC	0	0	0	15	15	74	538	2417	8293	102	2394	8336	655	4826	16703
SERC	2	84	187	18	223	722	80	1206	1507	83	5234	11103	183	6747	13519
SWPP	4	117	161	40	572	2278	18	338	1163	40	1217	3747	102	2244	7349
WSCC	8	1276	3063	22	795	1374	285	6659	11979	204	11682	33392	519	20412	49808
Alaska	0	0	0	0	0	0	10	17	162	49	3510	15380	59	3527	15542
Hawaii	0	0	0	0	0	0	7	9	28	7	29	84	14	38	112
Puerto Rico	0	0	0	0	0	0	13	35	109	4	24	71	17	59	180
Total	30	2204	4027	249	4296	15106	1128	13031	28959	541	26544	76205	1948	46075	124297

Table 5-1 Summary of NWS Best Candidate Sites Categorized by Ownership

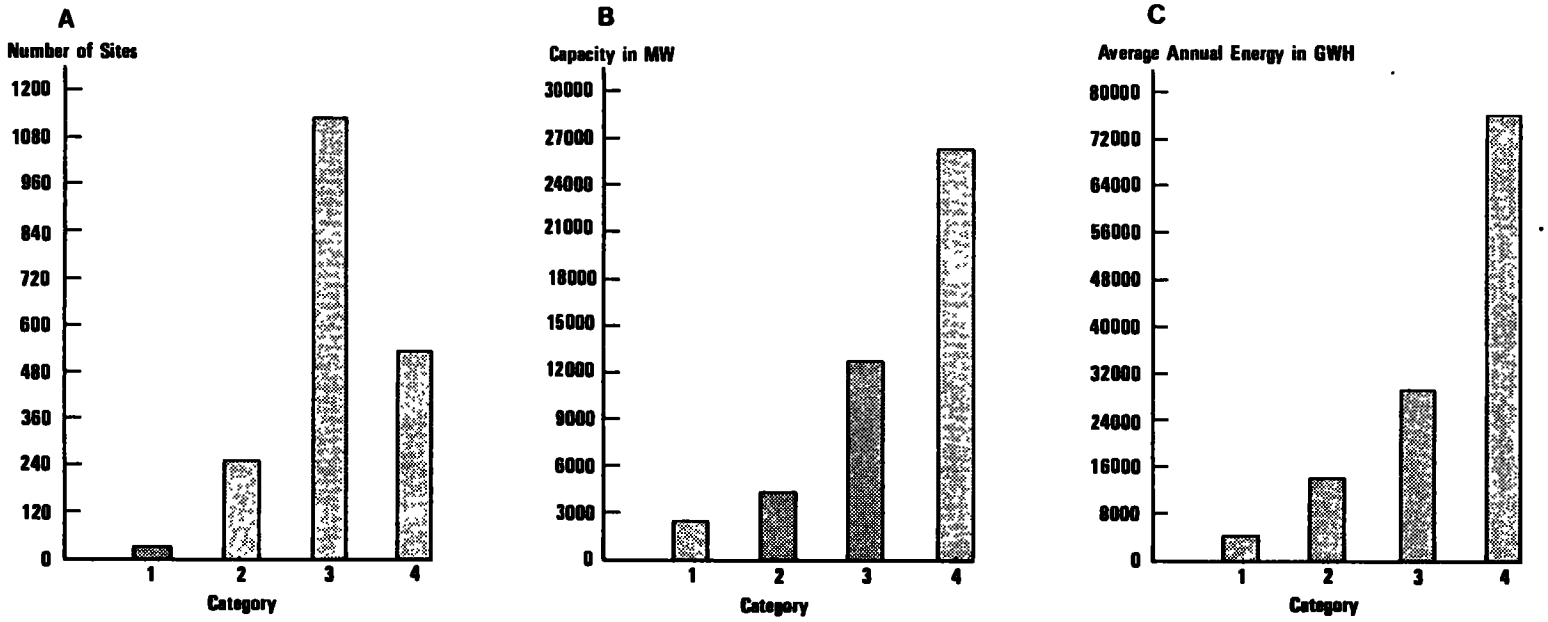
average annual energy generation of 4027 GWh. The capacity and energy figures are in addition to what is already being produced at these sites. The second category includes all Corps dams without existing hydroelectric power facilities but with feasible hydroelectric power potential. These dams were built for purposes other than hydroelectric power but were identified during the NHS as best candidates for future hydroelectric power development. There are 249 Corps dams in this category with a potential capacity of 4296 MW and averge annual energy production of 15,106 GWh. The third category contains all non-Corps dams either with or without existing hydroelectric power facilities. This category contains sites operated by other Federal agencies as well as non-Federal developers. There are 1128 non-Corps dams in this category with a potential capacity of 13,031 MW and average annual energy of 28,959 GWh. The fourth and final category includes all undeveloped sites identified in the NHS regional reports as best candidate sites. No dam or other structure exists at these sites, and a new dam would be required to capture the hydroelectric power potential. There are 541 sites in this category with a potential capacity of 26,544 MW and average annual energy generation of 76,205 GWh. In all four categories, there are a total of 1948 sites with an aggregate capacity of 46,075 MW and average annual energy potential of 124,297 GWh

As shown in Figure 5-1, the majority of potential sites are at non-Corps existing dams. However, most of the additional capacity and energy is at undeveloped sites. Corps dams, although relatively few in number, account for about one-third of the additional potential capacity and energy available at all existing dams.

DISCUSSION OF SITES BY CATEGORY

Corps Dams With Existing Hydroelectric Power Facilities

Figure 5-2 depicts the distribution of existing Corps hydroelectric power dams that have additional potential for capacity and/or energy. Only six of the NERC regions contain sites in this category, with over one-half of the sites in the WSCC, MAIN, and SWPP regions. Alaska, Hawaii, and Puerto Rico have no existing Corps hydroelectric power projects.



CATEGORY 1 = Existing Corps Hydroelectric Power Dams with Additional Capacity Available.

CATEGORY 2 = Existing Corps Dams with Hydroelectric Power Potential.

CATEGORY 3 = Existing Non-Corps Dams with New or Additional Hydroelectric Power Potential.

CATEGORY 4 = Undeveloped Sites which have Feasible Hydroelectric Power Potential.

Figure 5-1 - NHS Best Candidate Sites Categorized by Ownership

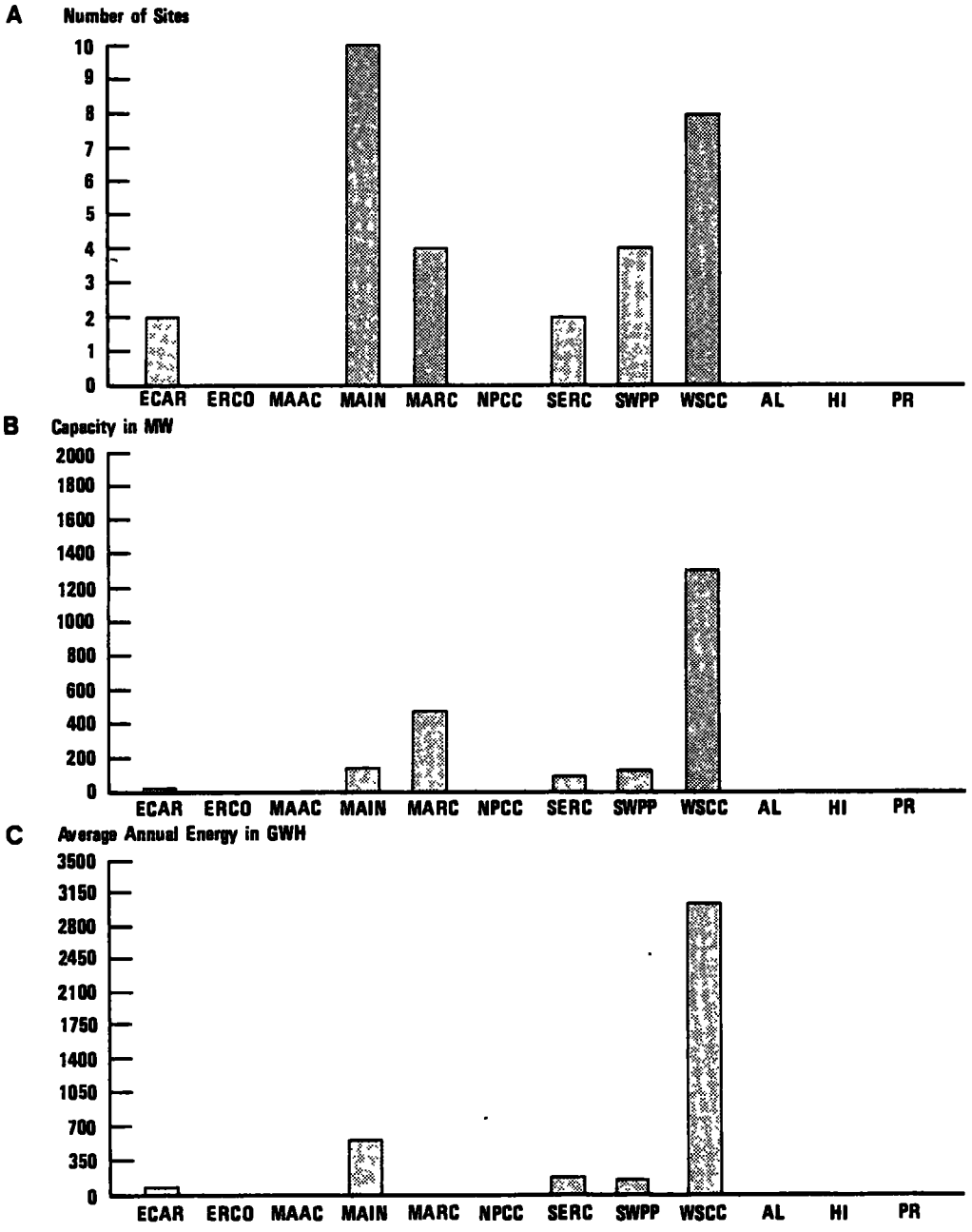


Figure 5-2: Corps Existing Hydroelectric Power Sites with Additional Potential by NERC Region:

The additions of capacity and energy available in the WSCC are quite large compared to the rest of the regions. Well over one-half of the additional capacity and energy to be gained at these sites is found in the WSCC region.

The primary means of increasing the capacity and energy output at the 30 Corps dams in this category are to add new generating units rehabilitate or replace existing units modify water handling facilities and alter existing operating policies (reallocation of existing storage and/or change of annual and seasonal operating schedules). Most of the additional capacity and energy to be gained at these sites would be gained by adding new generating units to capture excess flow or spill. Small amounts of capacity and energy would be gained by increasing the efficiency of converting fluid energy to electricity by uprating turbines and generators. Additional study of each site is needed to determine which means of increasing capacity and/or energy is warranted. Particular attention must be given to the existing purposes of a dam in addition to providing hydroelectric power. The environmental impacts of any proposed changes in operation must also be evaluated.

The addition of power at these Corps sites could be accomplished by non-Federal developers under FERC license as well as by the Corps. However, it may be more practical for the Corps to develop this potential because of the efficiency of administration and operation of the facilities under one rather than two distinct entities.

Corps Dams Without Existing Hydroelectric Power Facilities

The potential sites in this category, existing Corps dams that were built for purposes other than hydroelectric power, are highly attractive candidates for near-term development. Many of these sites had penstocks built into the dams and had other provisions that anticipated eventual hydroelectric power development. All of the dams are in good physical condition, and streamflow data are available for accurate power analyses.

The distribution of these sites is shown in Figure 5-3. Just over 40 percent are in the ECAR region. Most of these sites are lock and dam structures built for navigation on the Ohio River and its tributaries. Many of these sites, if developed, would operate as run-of-river hydroelectric power projects. The sites in the ECAR region would supply almost one-half of the total additional capacity and energy to be gained from all sites in this category.

The total capacity available from sites in this category is about 95 percent higher than the previous category (2204 MW vs 4296 MW), and the amount of energy to be gained is nearly four times as much (4027GWh vs 15106 GWh). The addition of capacity at existing hydroelectric power projects is usually attained by routing more streamflow through the turbines in a shorter time period. There are diminished returns of energy by gaining this additional increment of capacity. New facilities, especially run-of-river projects, can capture more energy because they operate continuously. For two sites of the same capacity, more energy is gained by operating for longer periods each day.

To capture the hydroelectric power potential at these Corps dams, it will be necessary to equip the dam with water conveyance facilities, turbines, and generators. As noted above, provisions for the eventual addition of hydroelectric power have been made at many of the Corps dams, making them particularly attractive for development. The addition of power facilities at Corps dams must take into account the existing project purposes. Dams constructed for such purposes as navigation and/or flood control must preserve authorized project purposes with the addition of hydroelectric power facilities. In addition, the Corps must insure the structural integrity of the dam. Feasibility studies must take these factors into account.

There is no procedure to predetermine whether these sites are developed by Federal or non-Federal developers. Congress authorizes the Corps to study a potential site, and, if Federal construction is determined to be in the public interest, a construction authority is given to the Corps by Congress. Non-Federal developers must comply with Corps guidelines and FERC rules to obtain a license to construct hydroelectric power facilities. The issue of Federal vs non-Federal development at Corps dams is discussed in the next chapter.

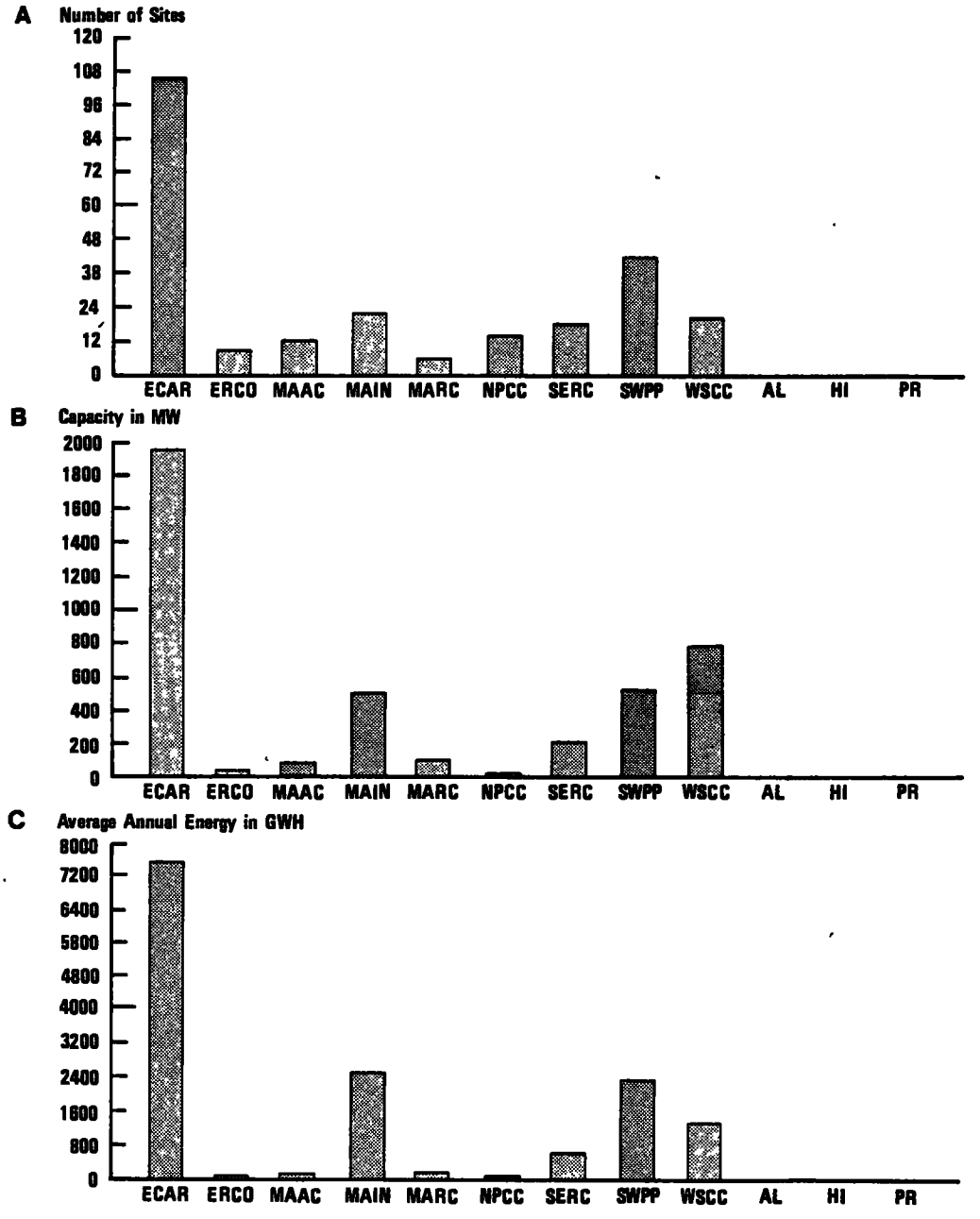


Figure 5-3: Corps Existing Dams with Hydroelectric Power Potential by NERC Region

Non-Corps Existing Dams With Hydroelectric Power Potential

This category of sites contains existing dam sites that may or may not have existing hydroelectric power facilities. This includes dams operated by the Bureau of Reclamation, Tennessee Valley Authority, and other Federal agencies, as well as states, municipalities, and individuals. All sites in this category have the potential for new or additional capacity and/or energy.

Figure 5-4 show the distribution of these sites. Most of the sites in this category are in the NPCC and WSCC regions. The NPCC region contains almost one-half of the sites. Most of the sites in the NPCC region are small dams and are generally classified as small-scale hydroelectric power sites (less than 15 MW). On the other hand, the potential sites in the WSCC region include some larger sites that have been built to store water. The capacity and energy to be gained from the sites in the WSCC region are greater than in the NPCC region for that reason. Together these two regions account for slightly above two-thirds of the total capacity in this category. All of the sites in this category will be developed by other Federal agencies and/or non-Federal developers.

Undeveloped Sites

The final category of sites contains the largest amount of additional capacity and energy although it contains less than 25 percent of the total sites. These sites are different from thoses in the previous categories in that, to capture the potential at undeveloped sites, a new dam must be built.

Figure 5-5 shows the distribution of potential undeveloped sites. By far the largest potential for new-site hydroelectric power projects is in the WSCC. This region possesses the topography and the abundant streamflows necessary for large projects. Alaska has immense physical potential for hydroelectric power, but note that only 49 sites were deemed suitable for further evaluation in the NHS. A combination of low projected electric demand and the availability of other energy sources makes many new hydroelectric power dams unnecessary in Alaska. A large number of potential sites are also within the NPCC and SERC regions.

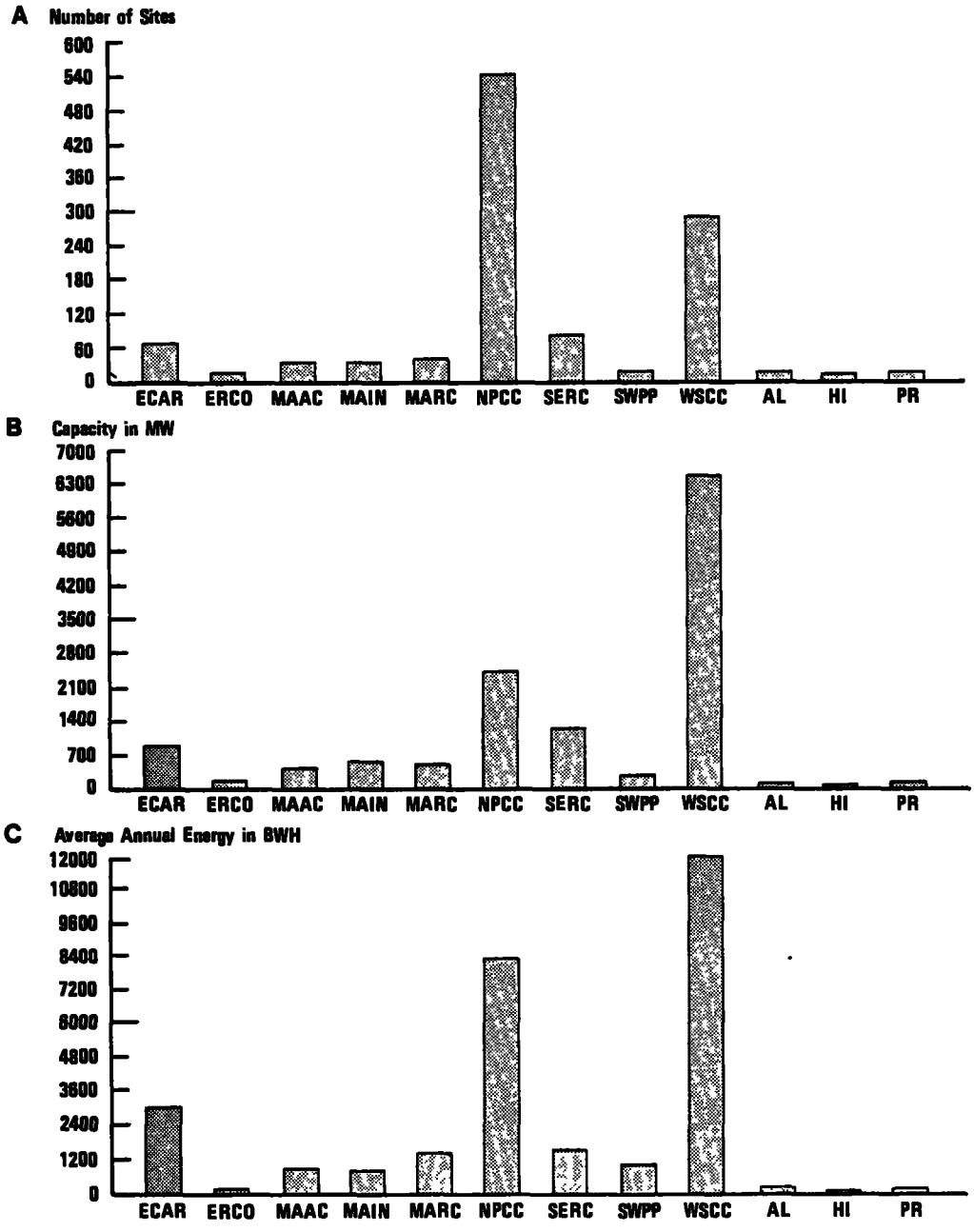


Figure 5-4: Non-Corps Dams with Additional Hydroelectric Power Potential

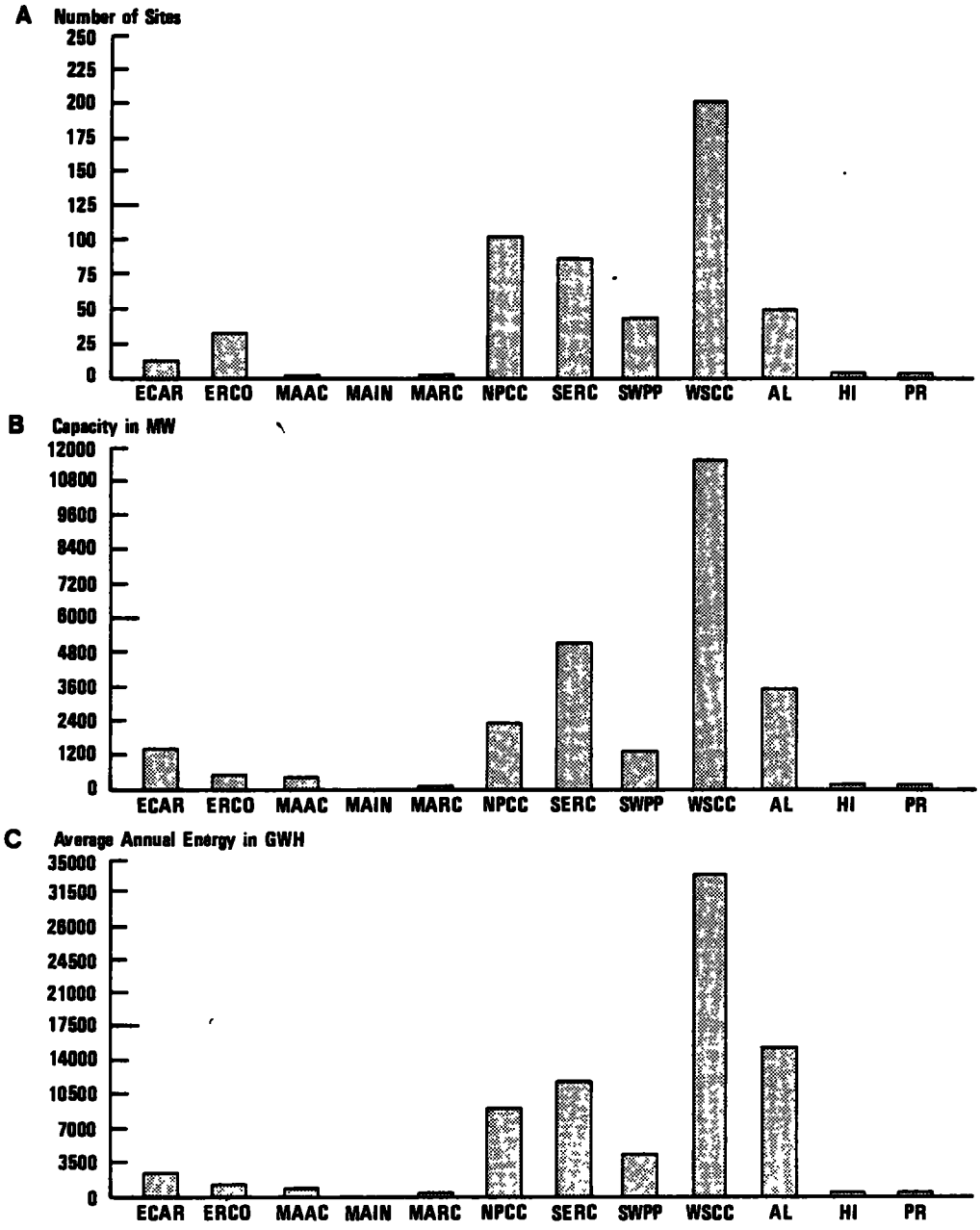


Figure 5-5: Best Candidate Undeveloped Sites with Hydroelectric Power Potential by NERC Region

These sites will most likely be developed as multiple-purpose sites that accommodate other project purposes besides hydroelectric power. Multiple-purpose development is necessary for full utilization of water resources. The primary developers of large, multiple-purpose dams have historically been the Federal government and the states. This is likely to continue, with states assuming an increased share of development cuts. New cost-sharing and financing arrangements are being pursued by the Federal Government will shift project cost from the Federal government to non-Federal project sponsors.

CHAPTER 6

ISSUES AFFECTING HYDROELECTRIC POWER DEVELOPMENT

This chapter identifies the issues raised by the prospect of additional hydroelectric power development. Some of these issues reflect the inherent uncertainty regarding aspects of future hydroelectric power development, for example, the uncertain future demand for electric power. Other issues reflect a basic conflict between competing objectives, competing priorities for the use of resources, and differences in legitimate interests and values. The competing land use issue is of this type. Often the issues are based on both unresolved questions and points of conflict (Coates, 1981, p. 7-8).

These issues have been investigated in technical overview and policy studies conducted under NHS. Table 6-1 lists the major issues by planning, legal/ institutional, economic, environmental, and resource categories. The discussion of each issue focuses on a description and analysis of the issue. The realization of the hydroelectric power potential identified in the NHS will depend, in large part, on how these issues are resolved. Resolution of some of these issues will require action by the Federal government and/or states. Others can be handled on a case-by-case basis through the site planning process.

Planning Issues

a. Electric Power Demand Uncertainty

Recent post-oil embargo forecasts of future electric power demands vary widely, reflecting a high degree of uncertainty. The revolution in oil prices, the availability of fuels, and the emerging concern about the long-term environmental effects of all types of electric generation are examples of recent changes that increase uncertainty about the future growth of electric energy production.

TABLE 6-1

ISSUES AFFECTING THE DEVELOPMENT OF HYDROELECTRIC POWER

PLANNING ISSUES

- Electric power demand uncertainty

LEGAL/INSTITUTIONAL ISSUES

- Choice of developers
- Regulatory system
- Indian rights

ECONOMIC ISSUES

- Federal evaluation procedures
- Cost of capital
- Marketing

ENVIRONMENTAL ISSUES

- Hydroelectric power impacts
- Alternative source impacts

RESOURCE ISSUES

- Competing water use
- Competing land use

The construction of individual small hydroelectric power projects--even dozens of them in a single power supply area -- will not be materially affected by any difference between forecasted and realized demands, but larger projects could be. In the latter case, a substantial portion of the economic rationale for hydroelectric power projects is often based upon the need for additional peaking capacity, and if that need does not materialize, the justification could be somewhat tainted.

Legal/Institutional Issues

Federal laws and the institutions that have evolved to enforce the laws affect decisions on hydroelectric power development. Several principles have guided the creation and evolution of the current legal and institutional framework. Foremost among these are the consideration of hydroelectric power as a public resource and the relationship of Federal and non-Federal roles in development.

The waterpower of the nation's streams and rivers has been considered a public resource since the presidency of Theodore Roosevelt. As a public resource, hydroelectric power is conserved and developed for the benefit of the people. Any development of a river must simultaneously maximize the capacity for hydroelectric power development and other uses of the waterway. The public must be able to enjoy the benefits of hydroelectric development. Thus, the rights to develop hydroelectric power are retained by the government or are leased to private developers under terms and conditions that protect the public interest.

Hydroelectric power resources are developed in two ways: (1) direct development by Federal agencies and (2) non-Federal, public or private development licensed by a Federal agency.

Federal development results from congressional authorization and funding of hydroelectric power construction -- primarily by the Corps of Engineers, Bureau of Reclamation, or Tennessee Valley Authority, usually as one part of a multiple-purpose project which can include navigation, flood control, water

supply, recreation, and/or irrigation development. Such a project is planned in compliance with Federal water resource evaluation procedures and standards. Federally produced power is marketed by the Department of Energy through its regional power marketing agencies.

Non-Federal developers include states, municipalities, public utility districts, investor-owned utilities, private entrepreneurs, special districts and organizations, and joint-action agents that may be composed of any combination of these entities. These developers are distinguished from their Federal counterparts because they are subject to regulation by the FERC rather than a series of direct congressional approvals. Electricity generated by non-Federal hydroelectric power plants is generally sold under contract to utilties or is used directly by the owner of the plant.

Evaluation of Federal hydroelectric power projects must comply with Principles and Standards, and Procedures promulgated by the Water Resources Council (WRC) under authority of the Water Resources Planning Act of 1965. The Principles and Standards provide a policy framework to guide all Federal water resource development, while the Procedures establish criteria by which the relative merits of alternative proposals are evaluated. In particular, the latter requires Federal developers to pay greater heed to conservation and nonstructural alternatives and requires a rigorous cost/benefit analysis of proposed projects. New Principles and Guidelines are now being published and will replace the Principles and Standards and Procedures, 120 days after their issuance.

Non-Federal hydroelectric power development in the United States is licensed and supervised by FERC. The agency regulates the construction and operation of hydroelectric dams under the provisions of Part I of the Federal Power Act and the sale and transmission of electricity in interstate commerce under the provisions of Part II of the Act. It also enforces Federal laws which regulate

or affect various aspects of hydroelectric power development. All actions are coordinated with Federal and state agencies (Franklin Pierce Law Center, 1981, p. II-5-II-6).

FERC's jurisdiction over non-Federal development is pervasive. FERC licenses four types of hydroelectric power projects: those located on navigable waterways, those affecting interstate commerce, those involving Federal lands, and those utilizing surplus water from Federal dams (Nero, 1981, p. II-32-II-37).

Given this basic institutional framework, there are several issues that will affect future hydroelectric power development.

a. Choice of Developers

There are many considerations in determining who among the Federal and many non-Federal developers will have the opportunity to develop a particular hydroelectric power site. There is no established policy that predetermines who develops a site. If Congress authorizes development, then a Federal agency develops a site, and the power is marketed through a Federal power marketing agency. If a non-Federal developer receives a license from FERC, then the non-Federal developer proceeds. Because there is no policy, there are current instances where a Federal agency is studying the feasibility of a hydroelectric power project at an existing Federal dam and a non-Federal developer has obtained a permit from FERC to study the same site. Also, there are many undeveloped sites with no existing dam where either Federal or non-Federal development is possible. With no formal procedure for allocation of sites between Federal and non-Federal developers, conflict can occur. The potential for conflict is greatest at existing Federal dams and at undeveloped sites.

The situation at Corps of Engineers dams provides an example. According to the NHS resource assessment, there are 271 existing Corps dams that could generate new or additional hydroelectric power with a potential capacity of 7165 MW and energy output of 19,647 GWh annually. These dams are in good physical condition and are generally attractive for hydroelectric power development.

More than two-thirds of these Corps dams have at least one application from a non-Federal developer, and often there are competing applications for these dams at FERC.

At the direction of Congress, some of these Corps dams are being studied for the possible addition of hydroelectric power facilities by the Corps. This dual action by Federal and non-Federal developers is not resolved directly. As a result of the Corps study, Congress may elect to authorize Federal hydroelectric power development, in which case the non-Federal developer is pre-empted. If no congressional action is taken, FERC can grant a license to a non-Federal developer to develop hydroelectric power at the Federal dam.

The decision about who develops hydroelectric power facilities at a Federal dam should consider the public interest. The Corps of Engineers has established general requirements that must be met by non-Federal developers applying for a FERC license at a Corps facility. The proposed project must be compatible with authorized purposes of the Federal project, such as flood control and navigation. No detrimental changes can be made to alter any existing project purpose. Plans to modify the existing Federal project that would affect the structural integrity of the Federal dam must be approved by the Corps. Also, the prospective developer must reimburse the Federal government for the use of lands and facilities and for an appropriate part of the costs of the existing Federal dam by which the head created at the Federal project makes the installation possible. FERC levies this charge as part of the license to construct the hydroelectric project.

Currently, non-Federal developers are thought to have two major advantages over Federal agencies in developing hydroelectric power facilities at existing Federal dams. Non-Federal development takes less time than Federal development, given the lengthy congressional authorization and funding processes, and non-Federal developers use private rather than public funds for capital. However, these advantages should not alter decisions about development made on a public interest basis.

Non-Federal developers can bring a project on line in a shorter time than Federal agencies because the FERC has moved to simplify the procedures necessary for obtaining a license, especially for smaller projects. On the other hand, Federal procedures have been designed for larger, more complex projects and, thus, take more time to complete. Federal agencies could act as fast as non-Federal developers if Federal procedures were modified to fit the requirements for developing smaller hydroelectric power facilities at existing sites.

In budget - conscious times the use of private capital for hydroelectric power development is appealing because no direct expenditures are required by the Federal government. However, an important factor is the net fiscal impact on the U.S. Treasury. Under non-Federal development a fee is paid for the right to use a public resource to generate hydroelectric power. Taxes are paid by the developer depending upon revenue produced by the hydroelectric power facility and the system of tax credits and subsidies in effect. Under Federal development a direct expenditure is made to construct the hydroelectric power facilities, and the power is sold and revenue returned to the Federal treasury. It is difficult to compare the relative fiscal impact on the U.S. Treasury of either development option. The indirect costs of tax incentives are particularly hard to calculate. Despite the seeming advantage of no direct Federal expenditures under non-Federal development, the net fiscal impact over the life of a hydroelectric power project may be equivalent (Franklin Pierce Law Center, 1981, p. III-32-III-35). Site-specific examination is needed to determine which development option would be more beneficial for the taxpayer.

The choice of developer for undeveloped sites should consider the public interest, as in the case of development at existing dams, although the consideration of the public interest in new dam development is much more difficult.

At smaller, single-purpose hydroelectric power sites, non-Federal development would be appropriate if sufficient payment were required for the use of the hydroelectric power supplied by the river. FERC would also have to determine that the new site development was compatible with the rest of the water resources development in the basin. For Federal agencies to develop these as single-purpose hydroelectric power project sites, special authority would have to be obtained through Congress.

At larger, undeveloped sites with potential for multiple-purpose development, the developers will likely be Federal along with some state agencies as the only non-Federal developers. These developers are better able to manage the multiple-purpose aspects of such projects. Navigation, flood control, and irrigation have normally been Federal agency missions. New sites with these purposes and hydroelectric power would be better suited to Federal and state agency development.

The development of hydroelectric power at new sites requires a systems analysis of river basins to insure compatibility of all projects within the basin. The full impact of many new hydroelectric power facilities at existing dams and the construction of new dams for hydroelectric power can only be determined by system studies showing the interrelationships among all sites. This analysis will be required no matter who develops the sites and will be more critical as the number of new hydroelectric power plants increases.

b. Regulatory System

Hydroelectric power is subject to a complex regulatory system administered by many agencies at Federal, state, and local levels. The issue is whether this regulatory system can be simplified and the burden of compliance reduced while maintaining the substance of the regulations.

Regulations affecting hydroelectric power fall into a number of categories: environmental protection, economics of water and electricity, safety, commerce, and land use (Franklin Pierce Law Center, 1981, p. IV-1). Table 6-2 shows the most significant legislation affecting hydroelectric power. The regulations resulting from these laws are administered at different levels, and compliance is difficult. Extensive discussion of the legislation is included in NHS Volume V (Franklin Pierce Law Center, 1981).

The regulatory system provides opportunities for a variety of constituencies and interest groups to participate in the regulatory process. These groups have had a profound impact on the regulatory system. In particular, environmental groups have played a major role in stopping or changing hydroelectric power

TABLE 6-2

Significant Legislation Affecting Hydroelectric Power

Legislation	Purpose	Effect on Hydroelectric Power Development
Federal Power Act (PL 66-280)	To license non-Federal hydroelectric power facilities; to protect fish passage and habitat; to provide recreational benefits to the public.	FERC licensing process decides who develops non-Federal hydroelectric power resources; FERC may recommend sites for Federal study.
Public Utility Regulatory Policies Act (Titles II and IV) (PL 95-617)	To encourage small-scale power production facilities.	Exempts projects of 30 MW or less from some requirements of FPA; requires utilities to purchase small-scale hydroelectric power at their avoided cost; requires licensing reforms; provides loan and grant authority to DOE for small-scale hydroelectric power development.
Energy Security Act (PL 96-294)	Exempts small-scale hydroelectric (SSH) power from some licensing requirements.	Hydroelectric power projects of five MW or less may be exempted from some aspects of FERC licensing.
Water Resources Planning Act (PL 89-80)	To provide a comprehensive planning framework for Federal water projects.	Authorizes Principles, Standards, and Procedures; creates Water Resources Council and River Basin Commissions; authorizes planning grants.
Crude Oil Windfall Profit Tax (PL 96-223)	To provide tax incentives to SSH.	Allows tax credits for fish ladders and energy tax credits for other qualifying SSH property.
Clean Water Act (PL 92-500) Section 401	To ensure Federal and non-Federal compliance with state water quality standards.	FERC requires state certification that the project will meet state water quality standards before issuing a license.
Section 402	To regulate releases of pollutants from point sources.	May require the EPA or states to issue NPDES permits to hydro dams as point sources of pollution.*

* Will only affect hydroelectric power if dams are determined to be a point source, presently an unresolved question.

TABLE 6-2 (CONTINUED)

Legislation	Purpose	Effect on Hydroelectric Power Development
Section 404	To regulate water quality impacts of dredging and filling.	Requires dredge and fill permit before undertaking project.*
Endangered Species Act (PL 93-205)	To protect listed endangered species and their critical habitat.	Federal agencies can deny licenses or permits and Federal projects may be halted if a project threatens an endangered species or its habitat.
Fish and Wildlife Coordination Act (PL 96-366)	To ensure equal consideration of fish and wildlife protection in the activities of Federal agencies.	Federal agencies are required to consult state and Federal fish and wildlife protection agencies to mitigate impacts on fish and wildlife.
National Environmental Policy Act (PL 91-190)	To ensure that environmental considerations are systematically taken into account by Federal agencies.	Federal agencies are required to prepare Environmental Assessments or Impact Statements which integrate environmental concerns with project purposes.
Wild and Scenic Rivers Act (PL 90-542)	To protect rivers in their natural state by excluding them from consideration as hydroelectric power sites.	Forbids FERC from licensing projects that directly affect designated rivers or rivers being studied for inclusion in the system.

* Whether the Corps has independent permitting authority is still not clear. The most recent case, Monongahela Power, indicates that FERC can make the final decision. However, the district court decision may be appealed. Also, on November 2, 1981, the Department of the Army and FERC signed an agreement that the Corps will, to the extent legally possible, defer to FERC decisions on environmental and policy matters where both a 404 permit and FERC license are required.

projects through litigation. Often, however, the success of the opposition to hydroelectric projects is based on exacting procedural requirements rather than on the substance of the regulations (Franklin Pierce Law Center, 1981, p. IV-2-IV-3).

One way to reform the existing regulatory system affecting hydroelectric power development is to simplify the procedural requirements of legislation while maintaining substantive concerns. For example, developers of hydroelectric power projects are usually willing to modify project design and operation to accommodate environmental concerns. The additional costs of mitigation of environmental effects are legitimate. However, the costs of complying with regulatory procedures, including dealing with many layers of regulatory institutions and the cost of unnecessary delay, are excess costs that do not contribute to the completion of the project or provide environmental benefits; they are simply wasted. Some compliance costs are expected, but during the recent surge of interest in hydroelectric power these costs have been too high.

Both Federal development agencies and FERC have begun to examine critically all procedural requirements for hydroelectric power development. The Water Resources Council's Principles and Standards have been revised, and FERC has reduced the procedural requirements for permits and licenses. Both the Federal and non-Federal regulatory systems are attempting to retain the substantive requirements of all rules and regulations. By adopting this strategy, potential hydroelectric power projects can be judged on their merits and decisions can be expedited to proceed with or cancel plans for development.

c. Indian Rights

Indian rights are primarily an issue in the Pacific northwest, the area with the largest hydroelectric power potential in the nation. There are three types of Indian rights: reserved development rights, reserved fishing rights, and reserved water rights (Nero, 1981, p. III-20-III-24.)

Indian reservation tribes have full rights to natural resources of the reservation sufficient to sustain their needs. Recent judicial authority

supports the notion that "needs" include the right to use reservation resources for economic development purposes. These rights derive from treaties with the Federal government and from obligations on the government acting as trustee for the tribes. Hunting and fishing rights are also protected. This embraces off-reservation rights to protect the environment upon which the resource depends. Finally, Indian reserved water rights allow use of water by Indian tribes for their needs. They can be consumptive, exist regardless of whether they have been exercised, and be used for most purposes without regard to state allocation systems.

Some of these rights have been challenged, but the courts have ruled in favor of Indian rights, and the Northwest Regional Power Planning Act strengthens the existing rights (Nero, 1981, p.III-22). Hydroelectric power developers must consider these rights.

Economic Issues

a. Federal Evaluation Procedures

Federal evaluation procedures have most recently been based on the Principles and Standards (United States Water Resources Council, 1980) governing Federal hydroelectric power development. These documents have been revised by WRC under the guidance of the Cabinet Council on Natural Resources and the Environment. The issues that arose from the WRC Federal evaluation procedures were explained in Volume 6 of the NHS (Major, 1981). The major issue involves determining the value of hydroelectric power for benefit cost analysis.

Several characteristics of hydroelectric power projects affect economic evaluation (GAO, 1980, p. 43-44). Conventional hydroelectric power projects consume no fuel; the useful life of a plant is two to three times that of a thermal plant; operating and maintenance costs are low, primarily because there are no fuel costs and because the equipment is reliable and durable; and hydroelectric power plants can respond quickly to load changes, making them premium sources for utilities. On the other hand, initial investment costs are the major costs and are high compared to some other energy sources.

The most frequently used method for evaluating Federal hydroelectric power projects is to compare the costs of the hydroelectric power project to a most likely thermal alternative. The benefit of the hydroelectric power plant is the cost of the thermal alternative. Because the output of a hydroelectric power plant is rarely exactly matched by any one thermal alternative, it is necessary to examine the total production cost of a utility system with and without the hydroelectric power project to determine its real value. Such system evaluation procedures are being developed, but more testing is needed.

Another issue is the accounting of price escalation of fuel. When the cost of fuel increases more rapidly than the general inflation rate, the relative future value of hydroelectric power versus alternative sources using that fuel will increase.

b. Financing

Hydroelectric power projects typically have large capital costs and small operating and maintenance costs. In fact, most of the costs of a hydroelectric project are borne early in the project's life and the benefits are spread throughout the project's life. Consequently, considering these factors, the current high interest rates, and concern about the size of the Federal budget, there may be difficulty in raising money for either non-Federal or Federal hydroelectric power investment.

Federal development will depend on national goals and policies reflected in the budget for Federal development agencies (Nero, 1981, p. III-53). New financing arrangements with states are being made as part of a new approach to Federal-state partnership.

Non-Federal developers depend on the existing Federal tax structure, including tax credits and deferrals, to help with financing. These incentives for development are an issue. If the tax incentives are retained, continued interest in hydroelectric power development may be insured. If revoked, some developers may drop out. On the other hand, with tax incentives removed, Congress could authorize increased Federal agency development.

Recent legislated incentives which alleviate capital cost barriers to private-sector development are being challenged both within the Congress and in the courts. The Public Utilities Regulatory Policies Act (PURPA) assures avoided costs as the basis for rates paid to the small-scale hydroelectric power developer by receiving utilities and guarantees that the developer will be able to transmit power to his customers at a reasonable price. Without such assurances, venture capital for small-scale projects will be much more difficult to acquire. Furthermore, provisions of the Energy Security Act which provide an extra 11 percent investment tax credit to small-scale hydroelectric power investors are also being questioned.

c. Marketing

The marketing of power is an issue, whether for Federal or non-Federal hydroelectric power projects. PURPA represents an important factor in non-Federal power marketing, and the Federal Power Act (FPA) is the primary factor affecting Federal marketing practices. The two major issues are the pricing of hydroelectric power output and the preference to public entities in the development and marketing of hydroelectric power.

PURPA was enacted to insure that non-Federal hydroelectric power developers would receive a fair price for the electricity generated at their projects. With New Hampshire leading the way, states began to set PURPA rates. These rates acted to accelerate widespread interest in small-scale hydroelectric power development. However, a recent Mississippi court decision [FERC vs. the State of Mississippi et.al. (80-1749)] challenged PURPA, and this action threatens the guaranteed rate that was granted to small-scale developers. Without PURPA, small scale hydroelectric power developers might lose the leverage to bargain with utilities for long-term "avoided cost" rates.*

*By judgment entered 22 January 1982, the U.S. Court of Appeals for the District of Columbia ruled in favor of utilities and vacated FERC's full avoided cost rule and interconnection authority. An appeal is likely.

For Federal projects, power must be marketed and priced to encourage widespread distribution and use at the lowest rates consistent with sound business practices. The price set for this power has generated controversy.

The price is based on the cost of recovering the Federal investment required to produce the electricity. According to economic theory, this price is economically inefficient and results in an excess demand for Federally produced hydroelectric power and energy. Also, there is some question whether the price computed for Federal power using current practices actually recovers all costs of development (Nero, 1981, p.III-48). However, opponents to change in pricing procedures argue that preference customers should enjoy the benefits of public hydroelectric power and should not be required to pay more than what it costs the government to produce it. Continuation of present cost-recovery practices will accelerate Federal hydroelectric power development due to public desire to benefit from low-cost power in the face of rising energy prices. Changing to marginal pricing would depress public support for Federal development at multiple-purpose sites.

The preference clause is also an issue. The basis for preference is grounded in the principle that hydroelectric power results from the exploitation of a public resource and as such should be enjoyed by the public as represented by public entities. Since demand for low-cost hydroelectric power by legitimate public entities can greatly exceed available supply, conflict can occur between competing public entities, and progress on developing new hydroelectric power could be delayed while either the agency or the courts resolve competing claims. Preference also affects non-Federal developers. Public developers and/or non-profit developers receive a preference over private developers. Recent controversy has arisen because hybrid applications have been received at FERC. "Hybrid" applications are filed by a public entity with preference and a private developer without preference. Despite the controversy, the preference clause is likely to be retained.

Environmental Issues

a. Environmental Impacts of Hydroelectric Power

With regard to hydroelectric power development, environmental issues are significant when they render specific projects environmentally unacceptable, increase costs to an unacceptable degree, or cause significant delays. An earlier discussion highlighted the burden of complying with the environmental regulation process. This discussion concentrates on the issue of the significance of environmental impacts of hydroelectric power and development.*

The principal direct impacts of hydroelectric power development can be classified as aquatic, terrestrial, wetland, and social (NHS, Environmental Assessment, 1982, p. 3-13 - 3-28).

Aquatic impacts result from changes in the flow regime below a dam, the fluctuation in water surface level in the reservoir above the dam, and the physical structure of the dam and hydroelectric power plant. Flow change below the dam can affect downstream fisheries and change the erosion and deposition patterns of sediment. Fluctuations in reservoir levels also affect fisheries. A dam acts as a barrier to fish movement in a river. Anadromous fish, such as salmon in the Pacific northwest, are adversely affected by hydroelectric power dams, although fish passages are usually devised for salmon around such dams. Changes in water quality also can occur as a result of the dam, and these changes affect fisheries and the utility of downstream segments of river.

Terrestrial impacts result from the same changes in flow and reservoir water levels described above, as well as the inundation that follows the completion of a storage hydroelectric power project. Flow changes downstream can affect wildlife patterns and habitat. Inundation of land by storage of water for

*NHS Volume VIII is an environmental assessment for the study. This volume should be consulted for a detailed evaluation of the generic environmental impacts associated with hydroelectric power projects and an overview of the potential regional environmental impacts of developing the NHS best candidate sites.

hydroelectric power projects can destroy wildlife habitat, historic and archeological resources, aesthetically valuable land, and productive farmland. Fluctuation of established water levels can disrupt the recreational value of the water's edge.

Similarly, wetlands impacts are those associated with changes at the water's boundaries in wetlands caused by fluctuation in reservoir levels and downstream flows. Wetlands are biologically productive areas that can be altered by hydroelectric power projects.

The social impacts of hydroelectric power plants are caused by the relocation of people from lands used for the project and reservoir and the change in lifestyle faced by those living near the completed project.

The major environmental issue associated with the development of hydroelectric power is whether the environmental impacts can be compensated for by mitigation or by the benefits generated by the project.

Mitigation is the process whereby the impacts of the hydroelectric power project are either corrected or another environmental amenity is secured to replace that lost through the project. Many impacts can be corrected. For example, lower dissolved oxygen releases can be raised by selective withdrawal of water from variable elevations within the reservoir or by injecting oxygen into the penstock. Sometimes, mitigation requires purchase of land to replace habitat lost to the project.

Still, there are environmental impacts when a hydroelectric power plant is constructed. The benefits of the project can help to balance these impacts. The dam itself can provide flood control, water supply, navigation, or irrigation water. Fisheries can be developed in the reservoir and downstream of the dam; recreational opportunities can be found on the reservoirs and downstream; and regulated flow from the hydroelectric power plant can be beneficial. Thus, some environmental changes from a hydroelectric power dam and operation of the power plant are desirable.

These environmental effects must also be considered against the electricity and power potential generated by the dam. As discussed previously, hydroelectric power has advantages as an energy resource that are not easily duplicated by other sources. The availability of hydroelectric power can balance environmental impacts.

Hydroelectric power projects have varying degrees of environmental impact. While the environmental impacts of a hydroelectric power project can only be determined by a site specific examination, generalizations can be made about the relative impact. Figure 6-1 depicts the relative ranges of environmental acceptability of different hydroelectric power configurations.

The sites with the least environmental impact are likely to be potential hydroelectric power projects at existing dams. Conduits for water supply or irrigation may have the least environmental impact, followed by potential run-of-river projects at existing dams and existing storage projects. The fewer changes in the existing flow patterns at a site, the less likely the environmental impact.

The sites with the greatest environmental impact are those potential sites that would require the construction of a new dam. New dams alter the existing land use and river system and cause significant impacts. Again, new run-of-river projects may have generally less environmental impact because fewer changes are made to the existing flow regime and large reservoirs are not required as for storage projects.

Figure 6-1 depicts the likely impacts based on observation of a large number of sites. However, the impacts at individual sites can be substantial at existing run-of-river sites or minimal at undeveloped sites. Specific site analyses are needed to make that determination.

Alternative Impacts

Another issue arises when considering the environmental impacts of hydroelectric power. How important are the relative environmental impacts of hydroelectric power versus alternative forms of electricity, and how should the relative impacts affect decisions about electricity sources?

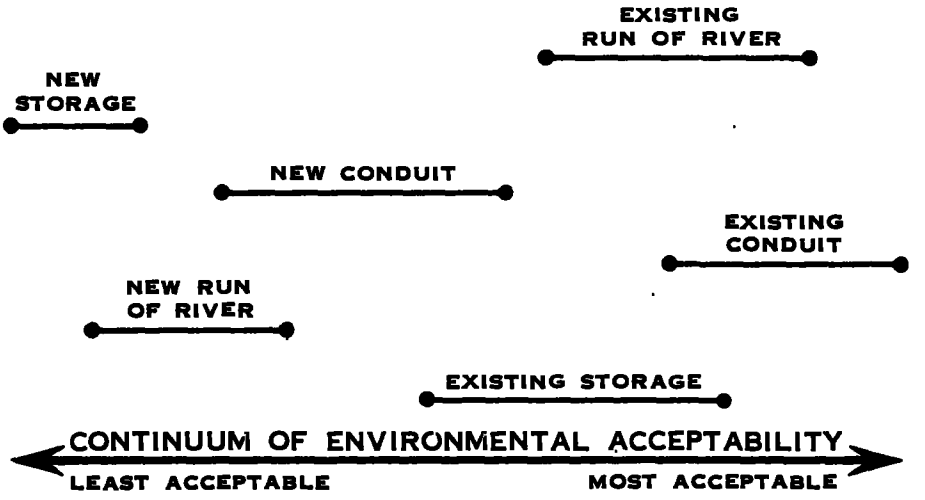


Figure 6-1 RELATIVE RANGES OF ENVIRONMENTAL ACCEPTABILITY FOR HYDROPOWER CONFIGURATIONS

Environmental impacts of hydroelectric power affect the land and people adjacent to the project and the river system in which the plant is constructed. These impacts are generally local, and most can be lessened through project modifications.

Alternatives to hydroelectric power include combustion turbines, oil-fired steam plants, and/or nuclear thermal generating plants, solar-thermal systems, solar electric systems, wind power, and geothermal sources. These alternatives all have environmental impacts that are different from those associated with hydroelectric power, and the relative impacts can not be easily compared. For example, coal-fired steam plants produce air pollutants which can create health hazards depending on climate conditions, and some of the pollutants have been linked to the formation of acid rain. Nuclear power plants have the potential for emitting radioactive contaminants, and the long term disposal of nuclear waste presents an awesome environmental challenge. A more detailed evaluation of the environmental impacts of alternatives to hydroelectric power, including the impacts of doing without additional energy, is contained in the NHS environmental assessment report (National Hydroelectric Power Resources Study Environmental Assessment, 1982).

In general, the environmental impacts and risks associated with hydroelectric power compare favorably with the impacts of other sources. However, there is no way directly to compare and evaluate the relative impacts. The impacts associated with hydroelectric power seem less significant than other sources. The impacts of alternative sources should always be considered when evaluating the direct environmental impacts of hydroelectric power. Often, hydroelectric power projects are considered environmentally unacceptable without considering the alternative.

Resource Issues

Competing Water Use

The development of additional hydroelectric power projects may conflict with other uses of water and the river in which the project is constructed.

Hydroelectric power is compatible with many other uses of water. Since hydroelectric power plants do not consume water, withdrawals of water can be made downstream from the plant with no conflict. Navigation can be accommodated with a lock at a dam structure, although some energy is lost by allowing water to flow through the lock chambers and bypass the power plant. Flood control conflicts with some hydroelectric power plants because the elevation of the reservoir must be lowered in anticipation of a flood, thereby reducing the power potential. Irrigation requirements may reduce hydroelectric power potential at some sites if the water is withdrawn from above the power plant. The Pacific northwest may face this trade-off in the next decade (Northwest Energy Policy Project, 1978, p. 24).

Instream flow requirements may affect hydroelectric power significantly. Minimum flow requirements may upset optimal operation of a project. Fish and wildlife instream flow requirements may preclude the use of hydroelectric power storage plants for generating peak power because high flows are not within standards. The resolution of these conflicts will depend upon the value of water in competing uses and the water rights.

As an example of the value of water in competing uses, consider the value of water in producing hydroelectric power versus the value of water for irrigation. When water is diverted for irrigation, the amount of energy lost is equal to that energy that would be generated by passing that water through the turbines. The value of water to the farmer is the increased crop values resulting from irrigation. If the increased value of irrigated crops is greater than the value of the energy produced by that amount of water at the power plant, then a decision based solely on economics would dictate that water be used for irrigation.

Water rights play a major role in the allocation of water to competing uses. Such rights are more readily obtained under riparian (reasonable use) systems characteristic of eastern states than under the prior appropriation systems of the west. In the east, nonconsumptive use of water for hydroelectric power is generally a "reasonable use," but in the west, "storage and release" projects may conflict with streamflow and usage rights already appropriated by prior claimants.

The resolution of competing instream and offstream flow needs and water rights appropriation will significantly affect the future development of hydroelectric power. The economic value of water in alternative uses will affect the future transfer of water rights.

The wide range of uses for water makes it difficult to plan effectively for water projects unless comprehensive river basin wide studies are conducted. The addition of hydroelectric power facilities must consider the existing uses of water at the site and potential future uses. Studies at undeveloped sites cannot be made on the basis of a single purpose. The NHS assessment of potential hydroelectric power development considered other potential uses of water, but further detailed study of the future needs of each river basin and each individual site must be conducted before any major hydroelectric power projects are constructed. This is especially critical at undeveloped sites identified as best candidates in the NHS.

Competing Land Use

The issue of whether a parcel of land should be used for a hydroelectric power plant or used for another purpose is often raised during planning stages. Construction of hydroelectric power facilities, particularly at undeveloped sites, requires a significant commitment of land to accommodate the dam, reservoir, powerhouse, switchyard, and transmission line right-of-way, and may necessitate the relocation of roads, rail lines, and agricultural, residential, and industrial development. If such disruption is severe, significant opposition can be expected at the local level. Competing pressures brought about by concern for the cumulative loss of lands for food and fiber production, preservation of natural aquatic and terrestrial wildlife habitats (particularly in ecologically sensitive wetlands), and valuable scenic and recreation resources may also create an energy versus land use conflict which is important to project decision-making. Decisions regarding hydroelectric power often involve the trade-off between conservation of natural landscape versus use for hydroelectric power facilities in water storage. Decisons of this nature depend on the value society places on the natural landscape versus the hydroelectric power. With no dollar value readily apparent for the natural land, the choices are often difficult.

The resolution of this issue will be decided on a site-by-site basis, although national policy on preservation of natural land will influence the decisions.

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CHAPTER 7

NHS CONCLUSIONS

The NHS screening process was designed to identify the best candidate sites for possible development from many thousands of existing dams and undeveloped sites. While appropriate for this level of analysis, a more detailed feasibility study of each site will be required before a determination can be made to construct any hydroelectric power facility. All sites selected as best candidates for future development by the NHS will have to undergo detailed feasibility studies. The information provided on each site in the NHS regional reports can serve as a starting point for these feasibility studies. The NHS plan does not propose that any of the best candidate sites be developed but calls for the initiation of feasibility studies only.

The NHS has developed preliminary information about the physical potential, the economic feasibility, and the environmental acceptability of the NHS best candidate sites for hydroelectric power development. The emphasis on the feasibility studies to follow should be on verifying the preliminary NHS information and developing detailed physical, economic, and environmental data on a site to support a decision about adding hydroelectric power facilities to an existing dam or building a new dam with hydroelectric power, as the case warrants. When completed, the feasibility study should leave no doubt as to the advisability of developing power at a site.

The construction of a hydroelectric power facility at an existing dam can affect other water resources purposes of the dam and, at times, can affect the operation of other water projects in the basin. Also, the installation of a hydroelectric power facility can affect the quality and quantity of water in the river and can alter natural features in the river basin. It is important to account for these possible effects during the initial planning of projects so that modifications can be made to accommodate all water and related land resource uses. Any significant increase in the number of hydroelectric power projects being constructed in a river basin may bring about unintended

cumulative impacts. At undeveloped sites, it is also important to consider other possible purposes for the proposed new dam. There may be opportunities to meet other water needs through the construction of a multiple-purpose project. Thus, any large program designed to develop this nation's hydroelectric power resources should include comprehensive river basin assessments that evaluate opportunities for the development of other water resource projects as well as hydroelectric power.

Complex regulatory and project approval processes may be one of the most important barriers to expeditious development of hydroelectric power resources. Laws enacted before to the 1970s to promote development goals were written within the plentiful and inexpensive energy context prevailing at that time. As an example, many concepts underlying the laws defining the public interest in development and distribution of Federal hydroelectric power were written to encourage the growth of electricity use and to assure that all Americans could benefit from electric service, even in rural areas. Now, Federal policy emphasizes conservation of energy and delivery systems that are already servicing even the most remote customers. Other laws have been passed to assign specific regulatory responsibilities for Federal lands to more than one agency or to both Federal and sub-Federal levels of government, only to find that this has created overlapping jurisdictions and required duplicate processes to achieve the same intended results.

In addition to context and jurisdiction problems, both the NHS institutional appendix and the NHS environmental assessment describe problems which frequently occur during the execution of state and congressional environmental quality mandates as they apply to hydroelectric power projects. Water resources development in general, and hydroelectric power development in particular, confronts a situation that stresses the environmental review process more than environmental quality results. The problem has two aspects: (1) the timely deployment of environmental mitigation or enhancement features suffers from lack of funding coincident with project construction, and (2) the environmental review process itself is inconclusive and frequently results in process-oriented court battles where opportunities for compromise and negotiation are limited. Under current conditions, no developer can ever feel comfortable about seemingly

resolving environmental mitigation issues, for the open-ended nature of the present process provides for appeal at any stage of the design and construction process.

Small-scale (less than 30 MW) hydroelectric power development at existing dams is and will probably remain a non-Federal activity. The projected increase in capacity from small-scale projects ranges from 6000 to 10,500 MW and can be thought of, under almost any likely future conditions, as the output of a flourishing industry at thousands of small, existing dams in every region of the country.

Similarily, NHS results suggest extensive development by non-Federal interests at existing dams and new single-purpose sites with potential capacity greater than 30,000 MW, simply because the power from these projects is in many cases the least expensive electric power which can be produced by any type of power plant alternative. These projects will be exploited because of the simple force of the market place.

Close examination of the NHS regional reports and data in the NHS policy and technical overview study results shows that the greatest promise for achieving a substantial hydroelectric power contribution must involve the development of new large-scale Federal multiple-purpose reservoir storage and projects. At the present time, construction activity for this kind of project is low, reflecting Federal budget constraints and present slow electric load growth rates.

A simple continuation of historic trends would result in a total of about 100,000 MW of installed conventional hydroelectric capacity by the year 2000. This increase would be realized by a combination of installations at existing dams and undeveloped sites. Since all of the existing dam projects in the NHS list of best sites have been screened against physical, economic, and environmental criteria, it seems reasonable to assume that simple market reaction to investment opportunities will ultimately develop a large number of these dams. With respect to new dams, the picture is less clear. A prudent forecaster cannot assume that the fundamental opposition to these types of

projects will disappear. However, there are a number of large-scale multiple-purpose projects which are now in various stages of planning and design, and many of these are expected to proceed to construction. A conservative forecast is that a large percentage of existing dams will be retrofitted with hydroelectric power facilities and that the construction of new dams will continue, although perhaps at a slower rate than experienced over the past 30 years. This would still leave a large undeveloped hydroelectric potential that is economically exploitable.

GLOSSARY

Abbreviations

British thermal units	BTU	kilowatt	KW
		kilowatt-hours	KWh
gigawatt	GW	megawatt	MW
gigawatt-hours	GWh	megawatt-hours	MWh

AVERAGE LOAD - the hypothetical constant load over a specified time period that would produce the same energy as the actual load would produce for the same period.

BENEFIT-COST RATIO (B/C) - the ratio of the present value of the benefit stream to the present value of the project cost stream computed for comparable price level assumptions.

BENEFITS (ECONOMIC) - the increase in economic value produced by a project, typically represented as a time stream of value produced by the generation of hydroelectric power.

BRITISH THERMAL UNIT (BTU) - the quantity of heat energy required to raise the temperature of one pound of water one degree Fahrenheit, at sea level.

BUS - an electrical conductor which serves as a common connection for two or more electrical circuits. A bus may be in the form of rigid bars, either circular or rectangular in cross sections, or in form of stranded-conductor overhead cables held under tension.

BUSBAR - an electrical conductor in the form of rigid bars, located in switchyards or powerplants, serving as a common connection for two or more electrical circuits.

CAPACITY - the maximum power output or load for which a turbine-generator, station, or system is rated.

CAPACITY VALUE - that part of the market value of electric power which is assigned to dependable capacity.

COSTS (ECONOMIC) - the stream of value required to produce the project output. In hydroelectric projects this is often limited to the management and construction costs required to develop the power plant and the administration, operations, maintenance, and replacement costs required to continue the power plant in service.

CRITICAL STREAMFLOW - the amount of streamflow available for hydroelectric power generation during the most adverse streamflow period.

DEMAND - See LOAD.

DEPENDABLE CAPACITY - the load-carrying ability of a hydroelectric plant under adverse hydrologic conditions for the time interval and period specified of a particular system load.

DIVERSION - the removal of streamflow from its normal water sources, such as diverting flow from a river for purposes such as power generation or irrigation.

DRAFT TUBE - that section of the turbine water passage which extends from the discharge side of the turbine runner to the downstream extremity of the powerhouse structure.

ENERGY - the capacity for performing work. The electrical energy term generally used is kilowatt-hours and represents power (kilowatts) operating for some time period (hours).

ENERGY VALUE - that part of the market value of electric power which is assigned to energy generated.

FEASIBILITY STUDY - an investigation performed to formulate a hydroelectric power project and definitively assess its desirability for implementation.

FEDERAL ENERGY REGULATORY COMMISSION (FERC) - an agency in the Department of Energy which licenses non-Federal hydroelectric projects and regulates interstate transfer of electric energy. Formerly the Federal Power Commission (FPC).

FIRM ENERGY - the energy generation ability of a hydroelectric power plant under adverse hydrologic onditions for the time interval and period specified of a particular system load.

FORCED OUTAGE - the shutting down of a generating unit for emergency reasons.

FORCED OUTAGE RATE - the percent of scheduled generating time a unit is unable to generate because of forced outages due to mechanical, electrical, or failure.

FOREBAY - this generally refers to the reservoir area located immediately upstream of a dam or power house.

FOSSIL FUELS - refers to coal, oil, and natural gas.

GENERATOR - a machine which converts mechanical energy into electric energy.

GIGAWATT (GW) - one million kilowatts.

HEAD, GROSS (H) - the difference in elevation between the headwater surface above and the tailwater surface below a hydroelectric power plant, under specified conditions.

HORSEPOWER - mechanical energy equivalent to 550 ft. lbs. per second of work.

HYDROELECTRIC PLANT OR HYDROPOWER PLANT - an electric power plant in which the turbine-generators are driven by falling water.

IMPOUNDMENTS - bodies of water created by erecting barriers to flow such as dams and diversion structures.

INSTALLED CAPACITY - the total of the capacities shown on the nameplates of the generating units in a hydroelectric power plant.

INTAKE STRUCTURE - a concrete structure arranged to control the flow of water from a reservoir to the ultimate point of use. This structure usually contains either intake gates, or large valves, for regulating the rate of flow and for shutoff purposes.

KILOWATT (kw) - one thousand kilowatts.

KILOWATT-HOUR (kWh) - the amount of electrical energy involved with a one kilowatt demand over a period of one hour. It is equivalent to 3,413 Btus of heat energy.

LOAD - the amount of power needed to be delivered at a given point on an electric system.

LOAD CURVE - curve showing power (kilowatts) supplied, plotted against time of occurrence, and illustrating the varying magnitude of the load during the period covered.

LOAD FACTOR - the ratio of the average load during a designated period to the peak or maximum load occurring in that period.

LOW HEAD HYDROPOWER - hydropower that operates with a head of 20 meters (66 feet) or less.

MEGAWATT (MW) - one thousand kilowatts.

MEGAWATT-HOURS (MWh) - one thousand kilowatt-hours.

MULTIPURPOSE RIVER BASIN PROGRAM - programs for the development of rivers with dams and related structures which serve more than one purpose, such as hydroelectric power, irrigation, water supply, water quality control, and fish and wildlife enhancement.

NUCLEAR POWER - power released from the heat of nuclear reactions, which is converted to electric power by a turbine-generator unit.

OPERATING POLICY (Operating Rule Curves) - the technical operating guide adopted for water resources projects to assure that authorized output of the project is achieved. Usually in the form of charts and graphs of reservoir release rates for various operational situations.

OUTAGE - the period in which a generating unit, transmission line, or other facility, is out of service.

PEAK LOAD - the maximum load in a stated period of time.

PEAKING CAPACITY - the part of a system's capacity which is operated during the hours of highest power demand.

PENSTOCK - a large water conduit which is subjected to high internal pressure and is fully self-supporting.

PLANT FACTOR - ratio of the average load to the installed capacity of the plant, expressed as an annual percentage.

PONDAGE - the amount of water stored behind a hydroelectric dam of relatively small storage capacity used for daily or weekly regulation of the flow of a river.

POWER (ELECTRIC) - the rate of generation or use of electric energy, usually measured in kilowatts.

POWER POOL - two or more electric systems which are interconnected and coordinated to a greater or lesser degree to supply, in the most economical manner, electric power for their combined loads.

PUMPED STORAGE - an arrangement whereby electric power is generated during peak load periods by using water previously pumped into a storage reservoir during off-peak periods.

REALLOCATION - the concept of changing the existing distribution in use of reservoir storage space to a new distribution. Reallocation of flood control storage to power storage would reduce reservoir storage space reserved for temporary storage of floodwater and increase the conservation storage available for power operation.

RECONNAISSANCE STUDY - a preliminary feasibility study designed to ascertain whether a feasibility study is warranted.

REVERSIBLE PUMP TURBINE - a Francis-type hydraulic turbine which is designed to operate as a pump in one direction of rotation, and as a turbine in the opposite direction of rotation. Good efficiencies can be achieved with both modes of operation.

RUNNER BLADES - the propeller-like vanes of a hydraulic turbine which convert the kinetic energy of the water into mechanical power.

SECONDARY ENERGY - all hydroelectric energy other than FIRM ENERGY.

SPINNING RESERVE - generating units operating at no load or at partial load while the generators are driven by steam.

SURPLUS POWER - generating capacity which is not needed on system at the time it is available.

SYSTEM, ELECTRIC - the physically connected generation, transmission, distribution, and other facilities operated as an integral unit under one control, management, or operating supervision.

TAILWATER LEVEL - the water level measured in the tailrace area immediately downstream from a hydroelectric plant.

THERMAL PLANT - a generating plant which uses heat to produce electricity. Such plants may burn coal, gas, or oil, or use nuclear energy to produce thermal energy.

TRANSMISSION - the act or process of transporting electric energy in bulk.

TURBINE - the part of a generating unit which is spun by the force of water or steam to drive an electric generator. The turbine usually consists of a series of curved vanes or blades on a central spindle.

Impulse Turbine - an impulse turbine is one having one or more free jets discharging into an aerated space and impinging on the buckets of the runner, means of controlling the rate of flow, a housing, and a discharge passage. The water supplies energy to the runner in kinetic form.

Francis Turbine - a reaction turbine having a runner with a large number of fixed buckets, usually nine or more, to which the water is supplied in a whirling radial direction. It can be designed for operating heads ranging from 50 feet to 2000 feet.

Adjustable-Blade Propeller Turbine (KAPLAN) - a reaction turbine having a runner with a small number of blades, usually four to eight, to which the water is supplied in a whirling axial direction. The blades are angularly adjustable in the hub.

Fixed-Blade Propeller Turbines - a reaction turbine having a runner with a small number of blades, usually four to eight, to which the water is supplied in a whirling axial direction. The blades are rigidly fastened to the hub.

UNIT EFFICIENCY - the combined overall efficiency of a hydraulic turbine and its driven generator.

UPRATING - increasing the generating capacity of a hydroelectric power plant by either replacing existing equipment with new equipment or making improvements to the existing equipment.

WATT - the rate of energy transfer equivalent to one ampere under a pressure of one volt at unity power factor.

WHEELING - transportation of electricity by a utility over its lines for another utility; also includes the receipt from and delivery to another system of like amounts, but not necessarily the same, energy.

Appendix 1

NATIONAL HYDROELECTRIC POWER STUDY

SYNOPSIS OF STUDY EXECUTION PLAN

In January 1979 the U.S. Army Corps of Engineers published the Plan of Study (POS) for the National Hydroelectric Power Resources Study. This document is a snyopsis of the 87 page POS, updated to January 1980. This synopsis presents to the interested public an overview of how Corps personnel throughout the country are conducting the National Hydroelectric Power Resources Study.

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SECTION I

INTRODUCTION AND OVERVIEW

Setting

Our current economy and standard of living have been achieved largely as a result of abundant supplies of low-cost energy. Diminishing reserves of traditional primary energy sources, oil and natural gas, have prompted a national energy policy which emphasizes both conservation and the development of new sources of energy.

Hydroelectric power is one of the nation's sources of primary energy. The potential for developing new hydroelectric power sources still exists, as do opportunities for more efficient utilization of existing hydroelectric power projects. Considerable work must be done to actually define the nation's developable hydroelectric potential, recognizing that the theoretical potential cannot be fully developed because of physical, economic, social, and environmental constraints. While some of these constraints are obvious and can be accurately estimated through rather cursory examinations, other constraints can be measured only after comprehensive engineering, economic, social, and environmental analyses.

Objectives

Six study objectives have been established:

1. Analyze and define the nation's need for hydroelectric power.
2. Assess the physical potential for increasing hydroelectric power capacity and generation.
3. Analyze the current institutional and policy setting for hydroelectric power planning, development, marketing, and utilization.
4. Determine the feasibility of increasing hydroelectric generation capacity by developing new sites, by adding generation facilities to existing water resource projects, and by increasing the efficiency and reliability of existing hydroelectric power systems.
5. Assess the general environmental and socio-economic impacts of hydroelectric power development.
6. Recommend to Congress a national hydroelectric power development program and any institutional and policy modifications which would increase the effectiveness of existing and future hydroelectric power development.

Scope

1. Time Frame. The study will collect appropriate data to determine the national potential and demands of electrical energy for the year 1978. Based on these and other historical data the study will develop projections for the years 1985, 1990, 1995, and 2000.

2. Geographic. This hydroelectric power resources study is national in scope and will include all 50 states and Puerto Rico. The study area will use electric reliability council regions[1] for study management and for development of data.

3. Areas of Investigation. The study will investigate both conventional and pumped storage hydroelectric power generation. An installed capacity ranging from fifty (50) kilowatts to one (1) megawatt will serve as the lower limit for consideration depending on the regional electrical energy supply and demand conditions. The study will assess the potential associated with both Federal and non-Federal dams, including privately owned sites.

4. Study Period. The Corps of Engineers intends to complete the study and submit its report to Congress in September 1981.

Elements

This study has been divided into two basic parts: Policy and Technical Overview Studies and Hydroelectric Power System Identification.

Policy and technical overview studies address the economic, environmental, technological, and institutional factors that affect decisions on the development, operation, and management of the nation's hydroelectric power resources. Power system identification studies assess the physical potential for developing hydroelectric power resources at existing dams and undeveloped sites. Sections II and III describe these two basic study elements in more detail.

Status

During 1978 and 1979 the main effort centered on collecting data for a comprehensive preliminary inventory of hydroelectric power sites. After an initial screening of over 65,000 existing dams and/or undeveloped sites, additional information on approximately 17,000 of the most promising dams and sites was collected by Corps division and district field offices. These data were used as input to computer models designed to calculate estimates of electric capacity and energy potential using preliminary site hydrology data. Then, regional power values developed by the Federal Energy Regulatory Commission (FERC) were used with generalized estimates of powerhouse construction costs to provide estimates of the economic benefits and costs of each site. All sites meeting minimum physical and economic criteria comprised the preliminary inventory. A six volume report entitled Preliminary Inventory of Hydropower Resources, dated July 1979, contains information on about 11,000 of the initial 65,000 dams and sites.

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[1]A reliability council is a voluntary association of utilities within a region whose purpose is to assure reliability and adequacy of bulk power supplies.

A second major activity during this period was the initiation of work on determining present and future electric energy supply and demand relationships. The study relied on a large set of available projections of national and regional electric capacity and energy needs through the year 2000, including utility plans for additions of thermal-electric generation capacity to the existing power supply system. This analysis provides a forecast of regional and national electric capacity and energy demand for each of the reliability regions for each planning period.

Several policy and technical overview studies were also initiated during 1979. Studies on the economic and legal/institutional obstacles are the major efforts underway. Work on these and other studies, such as an environmental assessment, will continue in the second half of the four-year effort.

SECTION II

POLICY AND TECHNICAL OVERVIEW STUDIES

There are four studies addressing the following policy factors: environmental impacts, economic evaluation procedures, legislative and institutional aspects, and Federal power marketing and transmission. The following descriptions outline the objectives, scope, and expected results of each policy study.

An Assessment of Environmental Impacts and Issues Associated with Hydroelectric Power Development and Operation

The objectives of this study are to analyze environmental impacts and issues of hydroelectric power project construction and operation and to evaluate the beneficial and adverse environmental effects of expanded hydroelectric power development. The assessment will identify and describe physical environmental impacts, evaluate the environmental issues arising from conflicts over interpretation and importance of impacts, and generically compare environmental benefits and costs as a basis for determining options for changes to current hydrelectric opower development and regulatory policies.

A Study of Economic Evaluation Procedures Applied to Hydroelectric Power Projects

This study will assess the criteria and procedures used to evaluate the economic benefits (and, to the extent they are not covered elsewhere, the economic costs) associated with hydroelectric power development. The study will identify major issues relating to current Federal and private criteria and procedures, will examine their impacts on the feasibility of future hydroelectric power projects, and will recommend changes to existing economic evaluation policies and procedures, if needed.

Important areas of the study include the use of alternative cost as a proxy measure of the benefits of hydroelectric power, the use of life-cycle techniques to compare the cost and value of hydroelectric and thermal plants, and the impact of the Water Resources Council Hydropower Procedures Manual on the planning and development of hydroelectric power.

Legislative and Institutional Aspects of Hydroelectric Power Development and Operation

This study will identify and assess the legislative and institutional factors and issues affecting hydroelectric power development and operation. The objective of the study is to develop a clearer understanding of the obstacles to and incentives for accelerating the development of hydroelectric resources. A major consideration during this study will be the role of the Federal, state, and local governments and private concerns in developing hydroelectric power resources.

The assessment will (1) measure the importance of Federal and state laws affecting hydroelectric power development and operation, (2) identify options to changes to current legislation and/or institutional arrangements that would remove inappropriate obstacles to hydroelectric power development and

operation, and (3) recommend legislation and/or other changes to policy that would provide incentives to development of hydroelectric power consistent with national priorities and goals concerning water and energy resources development.

A Study of Marketing and Transmission of Hydroelectric Power

This study will review current Federal hydroelectric power marketing policies and practices, examine the current status and problems related to the transmission of Federal hydroelectric power, and suggest options for resolving these problems, if needed.

This study will (1) provide an in-depth look at how Federal hydroelectric power is presently marketed, (2) determine the major constraints on hydroelectric power development associated with the existing transmission network and assess benefits of additions to this network, and (3) review the electrical transmission network for existing Federal hydroelectric power.

In addition to these policy studies, there are two other technical overview studies being performed to determine the potential for expansion of existing conventional hydroelectric power plants and the need for new pumped storage projects.

Design and Operation of Existing Hydroelectric Power Resources for More Efficient Use

The central question of this study is to what extent can improved operation, management, or technological improvement increase power and energy obtained from existing hydroelectric plants without conflicting with other project functions. This study will investigate the operating and management practices of a representative sample of existing projects. Consideration will be given to new or variable operating rules, reallocation of storage and other operating practices that could increase capacity and/or energy; technological improvements (including design modification); and the potential for coordinated management of systems of hydroelectric plants.

The study will estimate the magnitude of the impacts of operation or management changes on other project purposes and the environment.

Finally, this study will develop generalized procedures for applying changes to operating and management practices on a site-specific basis. Suggested modifications to current Corps planning procedures will be developed where appropriate.

Pumped Storage: Practice and Future Assessment

As pumped storage is the only currently available large-scale means of economically storing electrical energy, it is an important part of current national energy strategy. The objectives of this study are to examine the present and projected use of pumped storage on a regional basis; assess the beneficial and/or adverse impacts of pumped storage projects; examine the factors, such as energy management and conservation, affecting the demand for pumped storage; and, finally, determine the appropriate place of pumped storage in the nation's energy future. To synthesize the information provided

by the policy and technical overview studies and to examine the entire question of future hydroelectric power development, integrating all factors, the NHS will include a technology assessment study.

Technology Assessment of Future Hydropower Development

This study will ascertain the critical factors and issues confronting hydroelectric power development and will provide an assessment of the consequences of various development scenarios. The result of this study will enable decisionmakers to better understand the pros and cons of policy options regarding hydroelectric power. The technology assessment process is comprehensive and includes identification of problems and issues, institutions and individuals involved in conflict over the issues, the decision apparatus used to resolve problems, and exogenous variables or events affecting decisions about hydropower. Alternatives to the existing methods, procedures, and systems must be explained, and the impacts of any changes on maintaining the status quo must be evaluated. The culmination of the process is a reasoned, detailed assessment of the options available and impacts associated with these options.

SECTION III

HYDROELECTRIC POWER SYSTEMS IDENTIFICATION

The result of this element of the National Hydroelectric Power Resources Study will be the formulation of regional hydropower development plans. The plans will identify the specific project or systems of projects that warrant further study and the order in which the studies should be undertaken to achieve the most efficient utilization of our hydroelectric power resources. Plans may include existing Corps dams, existing dams owned and/or operated by other Federal or state agencies, existing privately owned dams, and promising undeveloped sites.

Hydroelectric Power Systems Identification (HPSI) will be accomplished in five separate stages and 19 separate activities. The first three stages involve different levels of screening to successively eliminate sites which do not meet increasingly severe evaluation criteria. The fourth stage is to formulate regional plans. The fifth stage is to merge the regional plans to form a national hydroelectric power plan.

HPSI Stages

Stage 1. As a first step in identifying potential hydroelectric power sites, an inventory was made of the existing dams (about 55,000) and some 10,000 undeveloped sites having the physical potential to generate hydroelectric power. The first screening deleted those sites which did not possess sufficient storage, head, or flow to generate a significant amount of hydropower (usually 50 kilowatts). Approximately 17,000 of the 65,000 sites met that first test and were retained for evaluation in Stage 2.

Stage 2. A second screening of the sites in the inventory was made to identify those sites which show some possibility of being economically feasible. The 11,000 sites which survived this screening are listed in the Preliminary Inventory of Hydroelectric power Resources, July 1979. (NTIS #ADA-075962 thru 67)

Stage 3. Sites are now being evaluated using more refined data. In the first phase, total project costs (rather than just powerhouse costs) are used to reflect economic feasibility more accurately. In the second phase, economically feasible sites will be assessed using environmental and institutional acceptability criteria. Sites without overriding adverse impacts in any of these areas will comprise the site inventory for the regional development plans.

Stage 4. Existing and forecasted regional power demands will be determined, and systems of potential hydroelectric power projects which could help meet future regional demands will be drawn from the site inventory list. There will be an assessment of the sensitivity of alternative plans to different power values and to variation in environmental constraints. Stage 4 will also include an analysis of integral conventional/pumped-storage and the overall contribution that hydroelectric power can make to meeting national electrical power needs.

Stage 5. Regional plans emerging from the previous stages will be assimilated to form a National Hydroelectric power Program. This program will be completed and presented to Congress by 31 September 1981.

HPSI Activities

The 19 study activities of the hydroelectric power systems identification process are as follow:

H-1 Generalized Power Values

FERC furnished generalized power values which were developed using existing FERC practices and procedures. These power values are based on the cost of the most likely single thermal alternatives to a hydroelectric power project.

H-2 Site Hydrology Models

The task of screening approximately 50,000 existing dams and approximately 20,000 potential dam sites based on their physical potential for producing hydroelectric power was accomplished using conservative criteria and standards. Any site with reasonable potential for development would pass this first screening process. Maximum utilization was made of existing computerized data bases and automated data processing techniques. Three levels of hydrology analysis were developed to coincide with increasingly more refined screening of sites. The first level of analysis assumed that a continuous inflow would exist at each dam or dam site sufficient to completely refill the total storage capacity at the dam every day, and that all of this flow could be passed through turbines at a head equal to the hydraulic height of the dam (considering no drawdown). This assumption relied on the consideration that rational development of a dam (height and storage) accounts for the flows available at the dam, and that this approach would indicate far more hydropower potential at each dam or dam site than could actually be developed. A dam or site had to have a potential capacity of 50 KW or more to pass this test. Screening on these initial criteria reduced the number of sites under active consideration from approximately 70,000 to approximately 17,000 sites.

The second level of analysis involved determination of at-site flow duration curves. Site-specific flow data, along with refined estimates of available net power heads, were utilized to compute an actual physical potential for hydroelectric power at each project.

The highest level of analysis required a model which used the historical sequence of the available flows at each dam or damsite to determine hydroelectric power potential. The effect of storage on site potential was considered at this level of analysis.

H-3 Stage 1, Data Collection and Screening

Data on the location, ownership, available power head, and average streamflow were collected for each site. Because of the extensive computerized data base which had been developed for existing dams for the Corps' National Program of Inspection of Dams, the preliminary hydroelectric data base was designed to follow that format and utilize the data elements of this existing inventory to the maximum extent possible.

H-4 Powerhouse Cost Curves

The large number of sites, both developed and undeveloped, in the initial inventory made it necessary to use generalized cost curves to develop cost estimates for power facilities. First, cost curves were developed for a range of capacity and hydraulic head levels for the powerhouse and switchyard facilities only. Factors to account for regional cost differences were also developed. The powerhouse cost curves developed during this activity were later updated and refined in the cost estimating manual (Activity H-6).

H-5 Stage 2, Screening

The purpose of the second screening activity was to screen out those existing and undeveloped dam sites that did not meet simplified economic evaluation standards. First, power capacity criteria were used to screen the sites in the data base. Next, those sites which met minimum capacity standards were screened according to a ratio of power benefits, measured by FERC generalized power values, and the costs of only the powerhouse facilities (powerhouse and switchyard). All sites had to attain a benefit/cost (B/C) ratio of at least 0.7 to pass this screening. Since only partial costs of power development were used, this B/C ratio was simply a device for eliminating clearly uneconomic sites from further consideration. The number of sites in the active inventory after the Stage 2 screening exceeded 11,000.

H-6 Cost Estimating Manual

The major purpose of this activity was to refine the powerhouse cost curves used in the initial screenings of sites, using new cost curves that accounted for the total cost of hydroelectric development. These curves relate all the various costs associated with hydro development to a designated capacity and head. If these two parameters are known, a total cost can be estimated.

None of the costs were site specific at this stage. Unit prices were comparable to reconnaissance level analysis. Power plant costs were based on general head/turbine size curves and include the switchyard. The costs reflected multi-unit power plants and allowed appropriate consideration for adding units to existing projects.

H-7 Stage 3, 1st Data Collection

This activity gathered the additional data required to make a more refined estimate of the total costs of the addition of hydroelectric power to an existing dam or the development of a new site. Cost estimates were expected to be no better than reconnaissance level; therefore, field inspection or studies were not required. Also, in deriving the required data, power development at undeveloped sites was assumed to be a single-purpose project for the purpose of nationwide comparison. Where previous evaluation of undeveloped sites indicated multiple purpose development, the physical size of the project was not changed, but it was simply assumed to be a single purpose power project.

H-8 Stage 3, 1st Screening: Site Evaluation

The purpose of this activity was to screen active sites on the basis of more detailed and refined economic information. The result was an evaluation of projects based only on the economics of power development. The economic data thus generated were used to delete from the active inventory less desirable projects, based solely on an estimate of economic benefits and costs.

H-9 Power Demands and Projections

A contract was awarded to Harza Engineering Company for an assessment of the magnitude and regional distribution of demand for hydroelectric power resources. Two reports resulted from the contract, one describing the existing electrical power system (as of 1978) and the other providing projections of electical power supply and demand for the years 1985, 1990, 1995 and 2000.

The study summarizes information on exisiting electric power systems, future planned generating sources, and the regional load to be carried in the projection years. The final report compares the projected supply and demand for each region. The final report also discusses the sensitivity of the projections to the following factors:

1. Population changes
2. Economic development
3. Legislative and regulatory policies
4. Load management
5. Fuel prices and sources
6. Technological advances

H-10 Stage 3, 2nd Data Collection

Additional data on environmental, social, and institutional aspects were collected for sites passing the economic screening. For each such site, both existing and undeveloped, Corps districts will complete site specific data items under categories entitled Environmental Impacts and Project Acceptability.

H-11 Stage 3, 2nd Screening: Site Evaluation

Projects having overriding adverse non-economic impacts will be removed from the active data file during this activity.

H-12 Mapping Criteria

Maps are needed for the final report and appendices to relate study results to geographic areas in an easily understood manner. Final selection of map sizes, their content, and the location in the report was made during the first part of FY 80.

H-13 Revised Power Values

Up-to-date power values which are needed during Stage 4 to refine the estimate of conomic benefits will be provided by the Federal Energy Regulatory Commission.

H-14 Regional Site Identification

Alternative hydroelectric power development plans to meet the demands of particular electric reliability areas will be formulated. The principal tasks involved in this activity include an analysis and ranking of potential sites according to economic and environmental/social/institutional criteria, formulation of alternative hydroelectric power systems to match low and high projections of regional demands for electric power, evaluation of impacts and accomplishments of each alternate plan, identification and evaluation of potential pumped storage needs and possible sites within each reliability area, and identification of system plans including both conventional and pumped storage hydroelectric power for low and high projections of electric power demands.

H-15 Report Appendices -- Regional

The purpose of this activity is to design the framework for the regional development reports. This activity also includes the preparation of all supporting appendices to the main report.

The lead division (See list on page 13.) for each reliability council area will have the responsibility for preparing the study report appendix for that area. The report will summarize existing demands and projections of future energy needs. It will address specific institutional parameters affecting the region and discuss their impact on the development of the hydroelectric resources. General and site specific evaluation procedures will be outlined. The four stages of the HPSI process will be discussed and the results of each stage will be summarized.

H-16. Stage 5, National Program Formulation

This activity will consolidate the regional plans formulated for each reliability council area into a national plan for hydroelectric power development and will make recommendations for the development of hydroelectric power in the context of a national program.

The principal tasks involved in this stage are (1) consolidation of regional system plans into a national plan, (2) integration of the findings of the policy and technical overview studies, and (3) development of recommendations for future Corps involvement.

SECTION IV

PUBLIC INVOLVEMENT

The public involvement program is being carried out in three phases: information-sharing, issue discussion, and regional proposals.

Phase 1. The information-sharing phase ran from approximately November 1978 through December 1979. It concentrated on building public understanding by:

- Supporting and participating in the Engineering Foundation Conference in March 1979, to give Federal and non-Federal parties an opportunity to discuss their views on major issues for the development and operation of hydroelectric power.

- Co-hosting "Waterpower 1979," an three-day international conference on small-scale hydroelectric power which was attended by 1,200 participants and focused on development opportunities and problems.

- Publishing and distributing 20,000 copies of a brochure on the study.

- Speaking to or participating in discussions with approximately 100 groups.

Phase 2. January 1980 through October 1980 concentrates on issue discussion:

- Identifying and discussing the major study issues with representatives of national public interest organizations through a series of policy workshops (the first in April 1980).

- Presenting regional issues in several public meetings throughout the country.

Phase 3. By October 1980 the Corps will have put together tentative proposals for the regional and national hydroelectric power plans. These tentative proposals will take into account the comments received during Phases 1 and 2. The purpose of Phase 3 is to seek public reaction to the tentative proposals. The format will be in a series of public meetings, both regional and national.

NATIONAL HYDROPOWER STUDY

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*A lead division has been designated for each Regional Reliability Council (RRC). Lead division responsibilities include management of the regional plan development process for the assigned RRC, coordination with other lead divisions and coordination and direction of efforts of supporting divisions.

Appendix 2

ABSTRACTS OF ALL NHS VOLUMES

The National Hydroelectric Power Study will consist of 23 volumes arranged into five major categories as listed below:

A. Study Findings (2 Volumes)

B. Electric Power Demands (2 Volumes)

C. Policy and Technical Overview Studies (7 Volumes)

D. Hydroelectric Power Inventory (2 Volumes)

E. Regional Investigation (10 Volumes)

A. STUDY FINDINGS: (Volumes I & II)

Volume I, Executive Summary: This volume is a brief (20-30 pages) discussion of the purpose, findings, conclusions, and recommendations of the study. All information will be stated succintly and cross-referenced to the National report and appendices for further details.

Volume II, National Report: The National Report presents a summary of the results of the hydroelectric power resources assessment conducted under the NHS. The report summarizes the amount of hydroelectric power physically available, the economically feasible sites, and the hydroelectric power that is economically feasible and environmentally compatible and, therefore, most suitable for further study. Issues affecting hydroelectric power development are discussed.

B. ELECTRIC POWER SUPPLY AND DEMANDS (Volumes III & IV)

Volume III, 1978 Electric Power Demand and Supply: This report, prepared under contract by the Harza Engineering Company, Chicago, Illinois, provides a baseline description of the existing (1978) Electric Power Supply and Demand System for each of the nine National Electric Reliability Council Regions in the contiguous United States, Alaska and Hawaii.

Volume IV, Future Electric Power Demand and Supply: This volume, also prepared by Harza, shows a range of future electric demand growth rates and examines the magnitude and regional distribution of needs for hydroelectric power in the future supply system.

C. POLICY AND TECHNICAL OVERVIEW STUDIES (Volumes V - VI)

The policy and technical overview studies are designed to address the economic, social, environmental, technical and institutional factors and issues that affect decisions about hydroelectric power development and operation. Information gained during the conduct of these studies will be the basis for recommendations to modify current hydro-related policy, legislation and institutional procedures and arrangements.

The following is a synopsis (in order of final presentation) of each of the Policy and Technical Overview Studies.

Volume V - Legal and Institutional Aspects of Hydroelectric Power Development and Operation: This study was completed under contract to the Energy Law Institute, Franklin Pierce Law Center, Concord, New Hampshire. The study identifies and assesses the legislative and institutional factors and issues affecting hydroelectric power development and operation. It discusses the obstacles to and/or incentives for increasing the output from hydroelectric resources. A major consideration is the role of Federal, state and local governments and private concerns in developing hydroelectric power resources.

Volume VI - Economic Evaluation Procedures Applied to Hydroelectric Power: The economic study was performed by David Major, a private consultant. The study defines the criteria and procedures used to evaluate the economic benefits associated with hydroelectric power, identifies the major issues relating to the current criteria and procedures and examines their impact on the feasibility of future hydroelectric power projects. The study recommends changes to the current criteria and procedures.

Volume VII, Marketing and Transmission of Hydroelectric Power: The Department of Energy's Office of Power Marketing conducted this study. The study focuses on current Federal hydroelectric power marketing policies and practices and assesses the need for, and changes that are necessary, in the light of new national priorities regarding energy. In addition, the study examines the current status of, and problems related to, the transmission of hydroelectric power and suggests options for resolving these problems.

Volume VIII, NHS Environmental Assessment: This volume contains the Environmental Assessment. The report describes the technology of hydroelectric power in terms of its environmental impact, describes the generic environmental impacts of hydroelectric power facilities, and examines potential regional impacts of development of the sites selected in the NHS as best candidates for development.

Volume IX - Potential for Increasing the Output of Existing Hydroelectric Plants: This study was conducted by the Corps' Hydrologic Engineering Center. Existing conventional hydroelectric power facilities account for over 60,000 MW of generating capability. The central question of this study is: To what extent can improved operation, management or technological improvement increase power and energy obtained without conflict with other water uses: HEC investigated the operating and management practices of a representative sample of projects. Models are being used to test new or variable operating rules, reallocation of storage and other operating practices that could increase capacity and/or energy. New power gains resulting from technological improvements and design modifications such as new turbines or generators, penstock design and downstream modifications are being identified. The impact of coordinated management of systems of hydroelectric plants will be estimated. The key elements of the final report will: (1) estimate the significance of increasing the potential of existing hydroelectric resources by changed design, operation or management practice; (2) determine the trade-offs between increased power potential and other water uses; (3) recommend procedures for implementing change; and, (4) evaluate major obstacles to implementing changes.

Volume X, Pumped Storage Assessment: This study was conducted under contract to Dames and Moore, Washington, DC. As pumped storage is the only currently available large scale means of storing electrical energy, it is an important part of the current national energy strategy. The study:

(1) examined the present and projected use of pumped storage on a regional basis; (2) determined the amount of pumped storage that might be needed to meet demand, giving full consideration to the impact of conservation and load management on future loads; and, (3) assessed the beneficial and/or adverse impacts associated with pumped storage development on a regional basis. A major component of this study is an analysis of regional projections for pumped storage development needed to meet future energy demand for each region. High, medium, and low energy scenarios were used consistent with projections developed during the NHS study. For each region an estimate was made of the need for future pumped storage capacity and potential sources of pumping energy. Other sources of stored electric energy will be compared to pumped storage.

Volume XI, Technology Assessment: The technology assessment was conducted under Nero and Associates, Inc., Portland, Oregon. Technology assessment is a form of policy analysis. It goes beyond feasibility studies and conventional cost/benefit analyses to ask "what else is likely to happen if we engage in this technological initiative?" and "who will be affected by it, and how?" Technology assessment tries to identify the unplanned, unintended, and sometimes unanticipated outcomes of the use of a technology, as it facilitates or interferes with the goal-seeking activities of individuals and groups, and as it reinforces or conflicts with national, regional, community, economic sector, and institutional goals and priorities. It tries to assist in and improve public policy formulation and public decision making by giving decision makers and the public more comprehensive information about the possible social costs and benefits of a technological initiative, and a better "map" of the unanswered questions, uncertainties, risks, and opportunities which may flow from that initiative.

The technology assessment provides a thorough, analytical overview of hydropower development, the issues and problems associated with further development, the societal benefits and costs it may entail, the alternative for development available to the nation, and the potential consequences of those alternatives. The results of the technology assessment were used in the formulation of the final NHS report and recommendations to the Congress.

D. HYDROELECTRIC POWER INVENTORY (Volumes XII & XIII)

Volume XII, Data Base Inventory: The hydroelectric power inventory will address the chronological development of the inventory to include organizational structure, major problem areas encountered in its development and how these problems were resolved. It will address methodologies used in the development of the inventory data, and discussion of the types of information collected during the four stages of development. A final printout of all sites meeting the screening evaluation criteria will be published as an appendix to this volume. Site-specific information in this printout will include, but not be limited to: Project name, Primary State and County; I.D. Number, Name of Stream; Project Purpose; Owner; Latitude; Longitude; Average Annual Inflow; New Power Head; Height of Dam; Maximum Storage, Capacity; and Energy.

Volume XIII, Data Base Inventory Support Studies: Support studies to the inventory will include Hydrologic Engineering Center (HEC) programs, A Cost Estimating Manual by North Pacific Division (NPD), and Federal Energy Regulatory Commission (FERC) power values.

E. REGIONAL INVESTIGATIONS (Volumes XIV - XXIII)

Volumes XIV - XXIII Reliability Council Appendices: A separate volume will be prepared for each of the nine National Electric Reliability Council Regions. Alaska and Hawaii are combined into one volume bringing the total number of regional volumes to 10.

All regional volumes follow the same format, which includes, but is not limited to, discussion on: Specific Regional objectives; Existing Socio-Economic and Physical Conditions Existing, Energy Systems and Mixes and Their Relationship to

Hydroelectric Power; Demand Summaries; Methodologies; Public Involvement Activities; The Regional Inventory and Evaluation of the Inventory.

Appendix 3

PUBLIC INVOLVEMENT IN THE NATIONAL HYDROPOWER STUDY

"Public involvement" is an organized process for informing people about and seeking their contribution to government decisions which affect the public interest. The main value of public involvement is that it contributes to better decisionmaking: the public can give information and perspectives which decisionmakers don't have. Public involvement has been an integral, ongoing part of the National Hydropower Study--particularly in those studies considering future demand and hydropower's potential and the overriding policy issues affecting hydropower development and operation throughout the nation. For the National Hydropower Study, the "public" included all government agencies, private organizations, and citizens interested in the study.

This appendix states the objectives of the public involvement effort in the study, presents the strategy pursued to achieve those objectives, summarizes the public involvement events, describes the participating public and discusses the major issues raised by the participants.

OBJECTIVES OF THE PUBLIC INVOLVEMENT EFFORT

There were five objectives:

- To create full understanding of the purposes, scope, and expected outcomes of the study and the major issues requiring resolution.
- To provide forums for the full discussion of issues, alternatives, and proposals.
- To obtain public comments on major study issues.
- To obtain reaction to alternatives and proposals.
- To consider fully the views expressed by the public.

PUBLIC INVOLVEMENT STRATEGY

At the national level, the study team wanted to focus public attention on the legal, institutional, environmental, and economic issues in the public arena affecting hydropower's future. The study team decided to work mainly with a broad range of national interest groups--those concerned with national issues in hydropower affecting the people they represent. Since the study did not involve a detailed analysis of or planning

for specific sites, the study team felt that there would be little interest expressed from the general public.

At the regional level, the study team wanted public involvement to address the development of regional plans, focusing mainly on regional demand forecasts for electrical energy and the study's inventory of potentially feasible sites for new or added hydropower capacity.

The strategy also included presentations to organizational conferences and informal meetings with public and private organizations.

PUBLIC INVOLVEMENT EVENTS

Three National Policy Workshops. The workshops were held in April 1980 (in Washington, D.C.); November 1980 (in Portland, Oregon); and May 1981 (in Washington, D.C.). For each workshop the study team mailed invitations to over 3,000 organizations and individuals and distributed advance informational materials to all persons expressing interest.

Over 400 people participated in the three workshops. They represented architectural and engineering firms, electric power and generation institutions, electric power equipment manufacturing firms, environmental and natural resources groups, fish and wildlife organizations, different levels of government, educational institutions, and Native American organizations. In addition, the study team received comments from about 50 persons via letter. The largest involvement came from the hydropower industry and government.

The focus of the three policy workshops was on policy issues (legal and institutional, environmental, economic, power marketing, and technology assessment) and supply and demand projections.

Eighteen Regional Public Meetings. Nine divisions of the Corps of Engineers held these public meetings in the spring and summer of 1980. Over 20,000 notices were mailed. Over 1,300 persons attended; there were about 100 formal public presentations, several hundred informal comments, and more than 100 telephone calls and letters.

The focus of these 18 public meetings was on regional projections for electric power and the study's inventory of potential hydropower sites.

Conferences. Study team members participated in nine national or regional conferences to present and discuss hydropower issues.

In March 1979, the Engineering Foundation, in cooperation with the Institute for Water Resources, sponsored a week-long national conference: "Hydropower: A National Energy Resource." There were about 75 participants representing Federal and state agencies; architectural and engineering firms; power production and marketing groups; the hydropower industry; public and private utilities; and the academic, environmental, and

legal communities. They discussed hydropower's role in meeting national energy needs, and they suggested changes in Federal hydropower policy.

The Corps of Engineers and the Department of Energy jointly sponsored two international symposia in Washington, D.C., on the potential of small-scale hydropower: "Waterpower '79" and "Waterpower '81." There were over 1,000 participants in each, including representatives of policy-making, industrial, and professional organizations involved in hydropower around the world. They shared information and experiences on financing and marketing, planning, funding, licensing, engineering, safety, environmental, policy and legal issues. Study team members were participants in these symposia, which did not specifically consider the National Hydropower Study. But the team members had the opportunity to present information on the study and hear reactions from experienced professionals in hydropower.

Study team members made presentations to six other conferences sponsored by engineering, university, and governmental organizations.

Informal Meetings and Discussions. National and regional study team members held over 50 meetings with environmental organizations, university groups, utility companies, industry representatives, and state and local government officials. The purpose of these informal discussions was to share information of importance to the study.

THE PARTICIPATING PUBLIC

In total, over 2,000 people participated in the public involvement events. The largest participation was from representatives of the electric power industry: investor-owned, public, and cooperative utilities; associations of those utilities; consulting engineers; developers; investment bankers; and power equipment manufacturing firms. They participated actively in the national workshops and the regional public meetings. The industry's main concerns are:

- The study inventory should be used only as a projection of hydropower's potential and not as a basis for specific project decisions.
- There should be a balance between environmental and economic considerations in project development.
- The Federal development role should be limited to large projects (generally, greater than 25 MW).
- Non-Federal project processing should be streamlined and accelerated, with the Federal Energy Regulatory Commission (FERC) clearly designated as the lead (if not controlling) approval agency.

- Federal economic analysis should not be applied to non-Federal projects.

People representing public and cooperative utilities said that the Federal Government should not alter its traditional form of ratemaking. It should not make a profit, but should continue to sell power at the lowest possible rate. Some investor-owned utilities and private developers said that they should be able to compete equally with public and cooperative utilities in obtaining permits to develop specific sites.

Environmental and natural resource organizations participated mostly in informal meetings and discussions. The most active participant, particularly at the beginning of the study, was the National Wildlife Federation. With a membership of over three million people, the Federation encourages the intelligent management of the earth's natural resources. Among national environmental groups, the Federation has been the most active in the hydropower arena, arguing that future development should proceed cautiously since hydropower can cause major environmental problems. Other national environmental groups participating included the Sierra Club and the National Audubon Society. Overall, these groups expressed negative feelings about the development philosophy and power marketing practices of utility companies, the Corps of Engineers, and the Bureau of Reclamation. They said that there is a lack of sophistication in forecasting future power demands, and they wanted strong environmental criteria included in determining hydropower's potential. Some groups challenged the exemption of small projects from FERC's licensing procedures. In general, public natural resource agencies such as the U.S. Fish and Wildlife Service and state fish and game agencies associated themselves with these comments.

Several Indian tribal organizations participated in the national workshops and regional public meetings. They stressed that there are potential instream conflicts between hydropower and anadromous fish protection which must be addressed. They also said that the study must recognize Indian treaty rights with respect to fishing, hunting, gathering, and water. One tribal organization said that the study's environmental and social analysis is inadequate. There was no attempt to quantify environmental and social costs, and the criteria for site screening was very narrow.

State agencies testified at the regional public meetings. State departments of energy spoke in favor of hydropower at existing dams. One natural resource agency pointed out potential water quality problems, saying that diverting the stream flow to a hydropower facility may adversely affect dissolved oxygen in a stream. Another natural resource agency argued that the study process for Federal development is too drawn out. Feasible projects should be funded or dropped from further consideration so that non-Federal development might proceed. Other agencies said that hydropower must be analyzed in relation to other water uses.

Many Federal agencies involved in energy participated in the workshops and regional public meetings. These included the Department of Energy, the FERC, regional power administrations, the Bureau of Reclamation, and the U.S. Fish and Wildlife Service. There official comments are part of the interagency review.

PUBLIC ISSUES

In the various events described above, people raised issues in 17 areas on the study scope, process, findings, or recommendations. Below we summarize the public comments on each issue, indicating which public interests seem to hold certain views. The summary is the study team's synthesis and interpretation of statements which people made in a variety of ways and what the major issues are. The study team does not know the extent to which the comments made are broadly representative of the views of the general public. The summary does, however, give some indication of what some of the most interested members of the public think about future hydropower development.

Study Scope. Some private developers and an Indian tribal organization said that the National Hydropower Study exceeded its authority. They said that the Water Resources Development Act of 1976 limited the National Hydropower Study to those water resource development projects under the jurisdiction of the Secretary of the Army, which meant only existing dams. The Corps, however, chose to look at all potential dam sites. The Corps' critics apparently fear that the Corps' interpretation of the study's scope would result in pressure to build hydropower projects at undeveloped sites, which the critics generally oppose.

Demand Projections for Electric Power. Two general views were expressed about the study's projections of demand growth rates for electric power over the next 20 years. One view, set forth by many in the hydropower industry, was that the projections were "about right." However, given the dynamic nature of the energy picture and the relatively recent record of slower growth due to energy conservation, the forecasts should be constantly reevaluated. The other view, presented by some environmental groups, is that the demand projections are too high because they do not take into account the record of, or the potential for, energy conservation. These critics say that overstated demand projections will increase pressure for hydropower development which is not needed.

The Inventory of Potential Sites. Many people in the hydropower industry said they did not understand the purpose of the inventory: Is it to be used as a basis for project investment decisions? Or is it simply to set the framework for what the realistic potential is and what changes might be necessary to realize at least a portion of that potential? Some people criticized the inventory because their favored sites were not

included and wondered if omitting those sites might prevent their licensing. Other people complained about some of the sites that were included, feeling that those sites would receive preferential treatment even though detailed site evaluation might reveal severe environmental and social limitations. Some environmental groups and a tribal organization said that the criteria for eliminating sites from the inventory were very narrow. And early in the study process, a few environmental groups expressed strong opposition to including any sites on wild and scenic rivers.

Programmatic Environmental Impact Statement (EIS). Some environmental groups and a tribal organization argued that the National Hydropower Study must include a programmatic EIS. They said that the study is a major Federal action as defined by the National Environmental Policy Act (NEPA) and therefore requires an EIS. The apparent concern is that the study does not adequately treat environmental impacts from hydropower development. One example cited was the Western Systems Coordinating Council's draft regional report: it did not mention the Regional Power Act, which gives equal protection to anadromous fish runs.

Environmental Standards and Guidance. Some environmental groups suggested that the study make recommendations on environmental standards to be followed in developing hydropower projects. They said that guidance is needed on how to determine what the most important impacts are and on how to measure and quantify cumulative impacts. They also said that methodologies should be refined in environmental and social analysis.

Environmental Statutes. Representatives of the hydropower industry criticized current environmental protection statutes as being too strict, not permitting project decisions which balance environmental with other national goals. They said that while most of the environmental laws call only for full and adequate consideration of environmental factors, the agencies administering those laws have tried to make full environmental protection a requirement. Some people also argued for economic analyses of environmental factors.

Environmental groups, tribal organizations, and some state agencies strongly defended the current environmental statutes as administered, saying that they were needed to ensure that important environmental values are not treated cavalierly in the "rush" to hydropower development. A few of these statute defenders also critized legislation proposed to exempt projects of 25 megawatts (MW) or less from the licensing process of the Federal Energy Regulatory Commission (FERC). They said that such an exemption could cause severe damage to a small river basin (although not necessarily to a larger one).

Important Environmental Issues. A research organization mentioned the most important environmental issues in hydropower development as fish passage, water quality, minimum flow requirements, and (particularly in the West) water rights. They should be fully considered in the study. Environmental groups and a tribal organization said that more research is needed on fish runs. Not enough is known about how fish pass through turbines and hydropower plants.

Environmental Mitigation. Some environmental groups questioned whether mitigation technology is adequate to truly compensate for environmental losses. The implication is that if it is not, some projects which would cause environmental damage should not be built even though known mitigation measures might appear to be adequate.

Federal Processing of Non-Federal Development. There was strong and consistent criticism from representatives of the hydropower industry of the long processing time for project licensing because of overlapping authorities and the many agencies involved in the review and approval process. The long delays cost the developer both time and money and could make an otherwise attractive project not feasible. A strong desire was expressed for one-stop licensing, with FERC as the ultimate authority for all non-Federal development and other agencies in a commenting role only. Many people argued that FERC should receive this authority by statute rather than through interagency agreements. The problem with the latter, an official from a U.S. Department of Agriculture field office said, is that interagency agreements rarely receive widespread publicity, and agency field personnel may not know of them. A few people acknowledged, however, that giving FERC this authority could be inconsistent with the legislative proposal to exempt smaller projects from the FERC licensing process altogether. This would still subject developers to the current requirements of other agencies.

Some people from Federal, state, and local agencies opposed giving FERC the overriding authority. Critics said that relegating other agencies to a "comment role" could only result in less promotion and protection of other important national interests. Some people with this view also argued for giving river basin commissions greater authority: in particular, to develop comprehensive long-range plans for allocations among competing water uses.

Selecting Non-Federal Developers (at Federal and Non-Federal Sites). Some representatives of the hydropower industry expressed support for letting the market decide who the developer should be. Others argued for continuing to let FERC decide. Reservations about letting the market decide on the developer centered on the role of the states and the potential constraint of the preference clause. Some people said that if the market decision must be consistent with applicable state law, in some cases the state law might constrain a fully free market decision. And

the preference clause may also prevent developer selection "in the market" in some situations.

Federal Hydropower Development. Several representatives of developers and utilities criticized projects which were authorized by Congress long ago, but for which no money has been appropriated for their construction. Critics argue that Congress should either appropriate the money or deauthorize the projects so that the private sector might have a chance to develop them. Another concern expressed was that Federal agencies should not build any projects of less that 25 MW. The smaller projects should all be left to private and other public sector interests.

Other Federal Hydropower Roles. Some people in the hydropower industry argued that Federal agencies should have hydropower roles which extend beyond development, operations, and licensing. Suggestions were for adopting a national hydropower plan, establishing priorities on water use, expanding the dam inspection and insurance program to include non-licensed dams, training power plant operators, and delivering other technical assistance. Other developers countered, however, that a Federal role in technical assistance is not needed.

Economic Analysis. A few people in the hydropower industry said that the study report should make it clearer that project economic analysis applies only to Federal development. Non-Federal developers do financial analysis to determine a project's profitability, and this is different from Federal economic analysis.

Many people involved in Federal projects criticized current economic analysis procedures. They said that the Water Resources Council's Principles and Standards, which focus project decisions only on the national objectives of national economic development and environmental quality, are inadequate for hydropower project analysis. There is a need to incorporate into the analysis other national objectives such as national security, balance of payments, energy independence, employment, and tax beneits. Some state representatives also said that hydropower does not fare well when evaluated with other water uses; almost every other use is more valuable. Other suggestions were to make life-cycle costing easier and to change the current economic criteria which are based ("unrealistically") on 30 years of real fuel cost.

Capital for Non-Federal Development. Several developers said that the time of the highest financial risk is the period until the license is issued. Venture capitalists will provide financing at this stage only for a large equity position. The long delays between completing a feasibility study and obtaining a license make the problem worse. Larger developers may be able to absorb the costs over this period; smaller entrepreneurs cannot. People argued for some type of fund to support them during this pre-licensing stage. They also recommended that hydropower should receive the same Federal financial incentives available in developing other renewable energy sources.

Public Interest Improvement Costs. Public participants were divided on who should pay for required project features not necessary for hydropower operation (such as fish ladders). One point of view, expressed by many in the hydropower industry, is that government should pay since the benefits of those features accrue to the public at large. And, if the government doesn't pay, some projects will not be financially feasible. The other point of view, heard from environmental groups and some state agencies, is that the developer should pay since he is using a public resource. He is already subsidized through such measures as tax incentives, and he should be required to pay for the added public benefit.

Indian Treaty Rights. One tribal organization criticized the Western Systems Coordinating Council's draft regional report for not acknowledging Indian treaty rights in hydropower development, particularly with respect to fishing and water use rights.

Public Involvement in Federal Development. Several people supported a tentative study recommendation for giving the public more formal standing in the planning and development of Federal hydropower projects. Some representatives of Federal agencies argued against any change, saying that the recommended approach would actually reduce the amount of public access now available.

Appendix 4

Data for sites listed in the National Hydroelectric Power Resources Study were collected and reported by Electric Reliability Council Region in nine separate volumes. Detailed information contained in the reports can not be shown in the National report. However, an attempt is made in Appendix 4, to show some of the regional characteristics. More detailed information can be obtained from the regional reports themselves.

Appendix 4 contains two sets of figures showing electric power characteristics by electric reliability council region. The first set, Figures A4-1a through A4-1k, shows two graphs per region projecting Total Energy Demand in GWH and Peak Power Demand in GW by the year 2000. The second set, Figure A4-2a through A4-2k, shows the range of future generating capabilities for meeting load projections by fuel type by the year 2000.

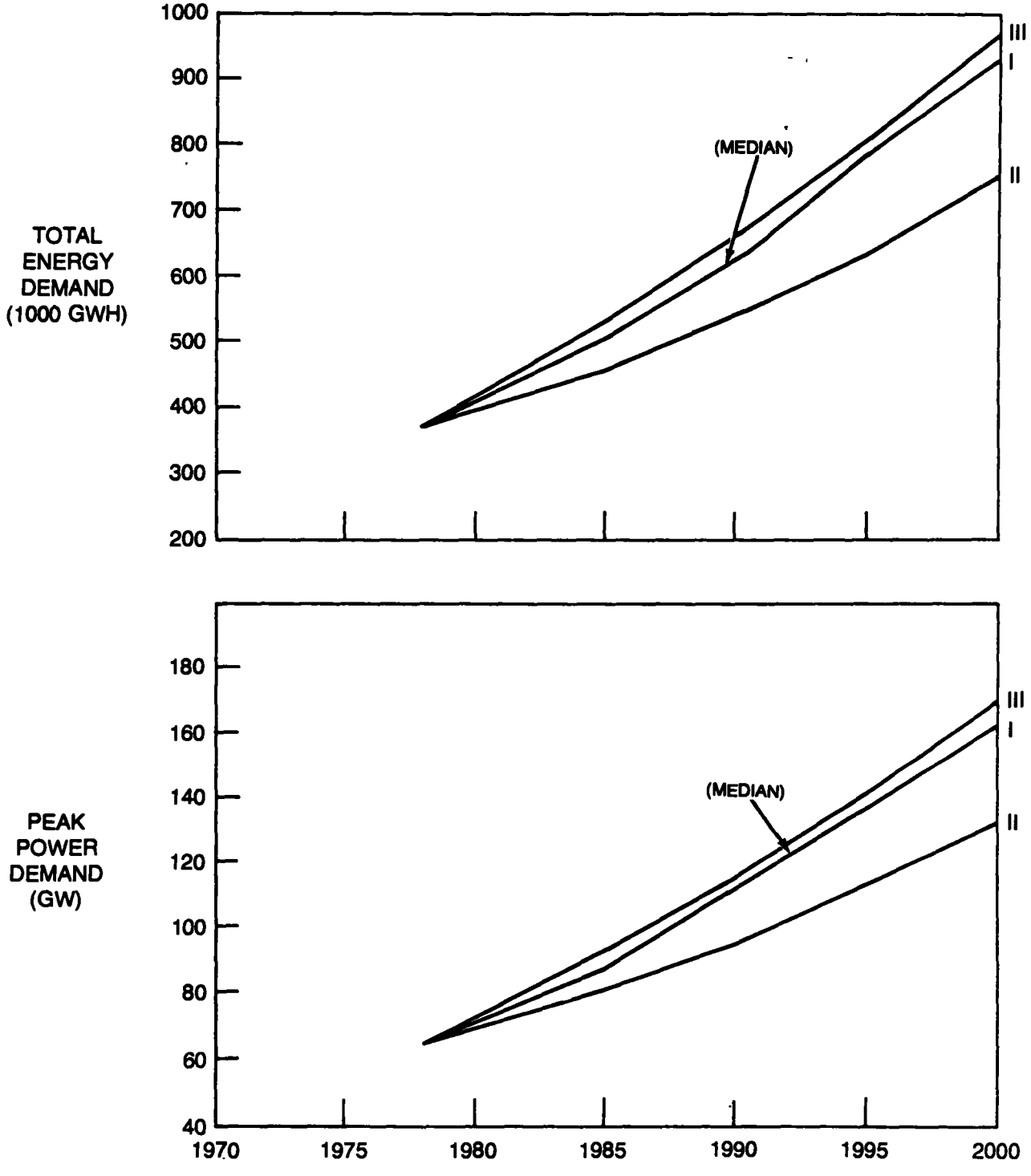

Figure A4-1a: REGIONAL CHARACTERISTICS, ECAR

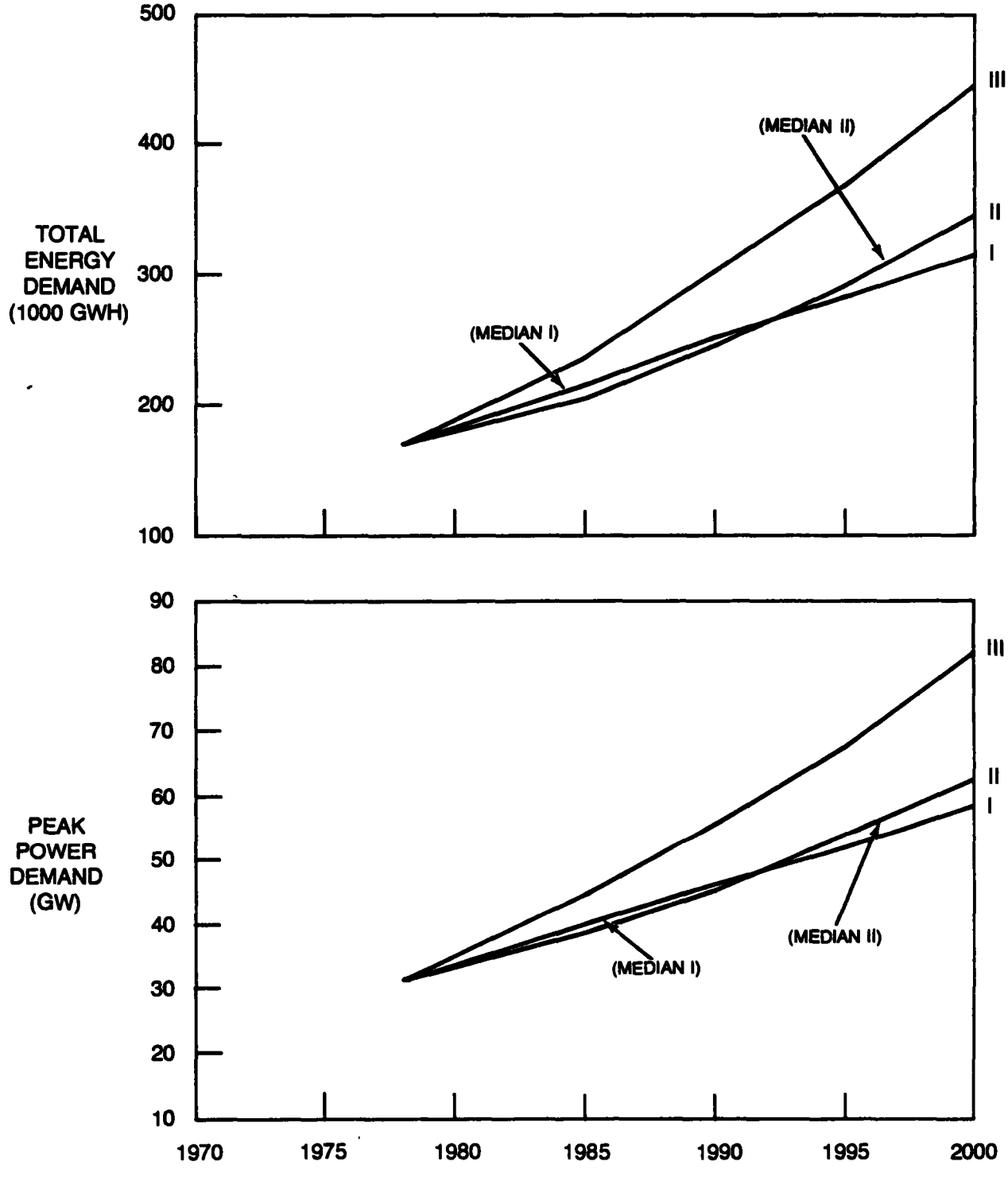

Figure A4-1b: REGIONAL CHARACTERISTICS, MAAC

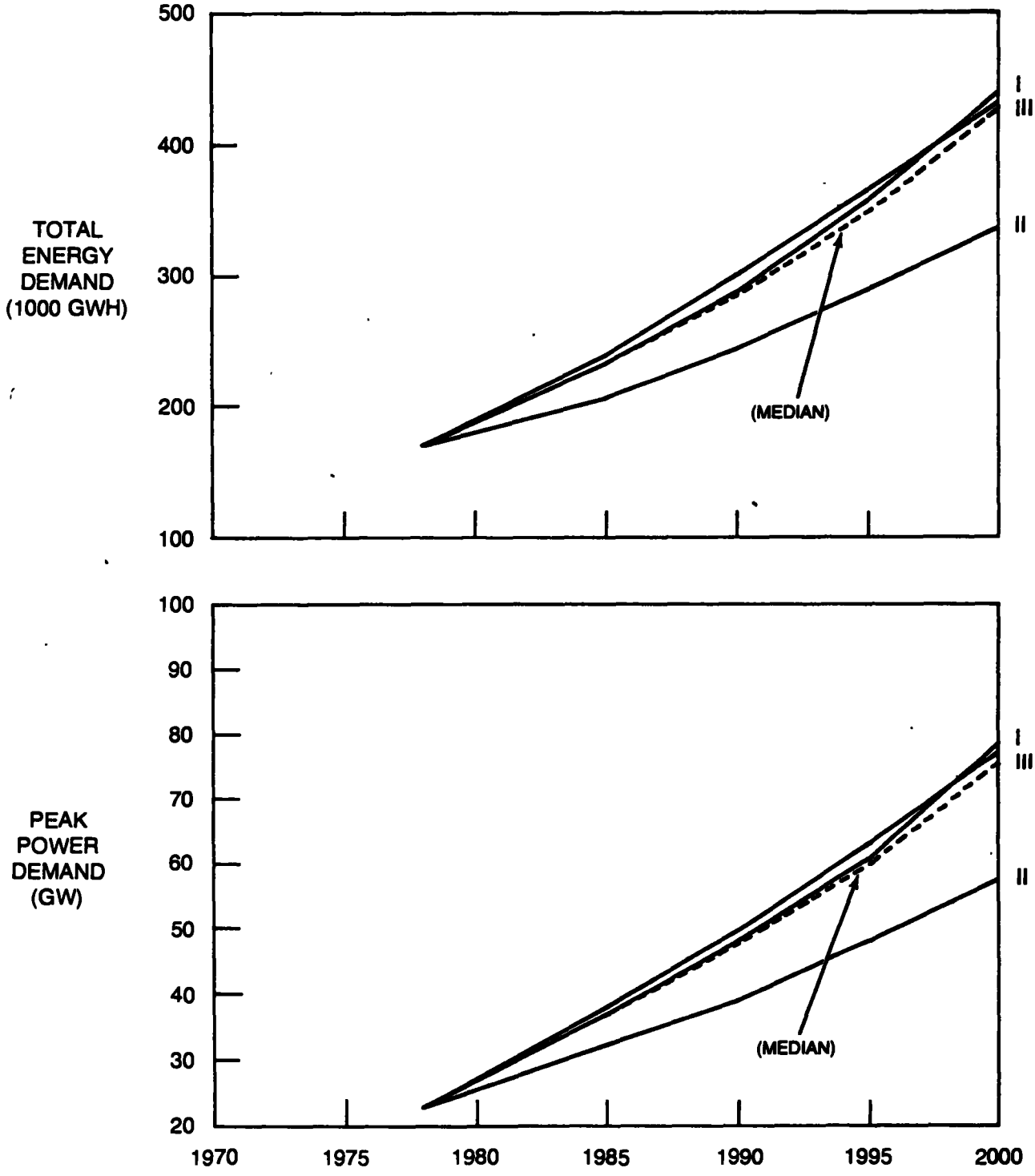

Figure A4-1c: REGIONAL CHARACTERISTICS, MAIN

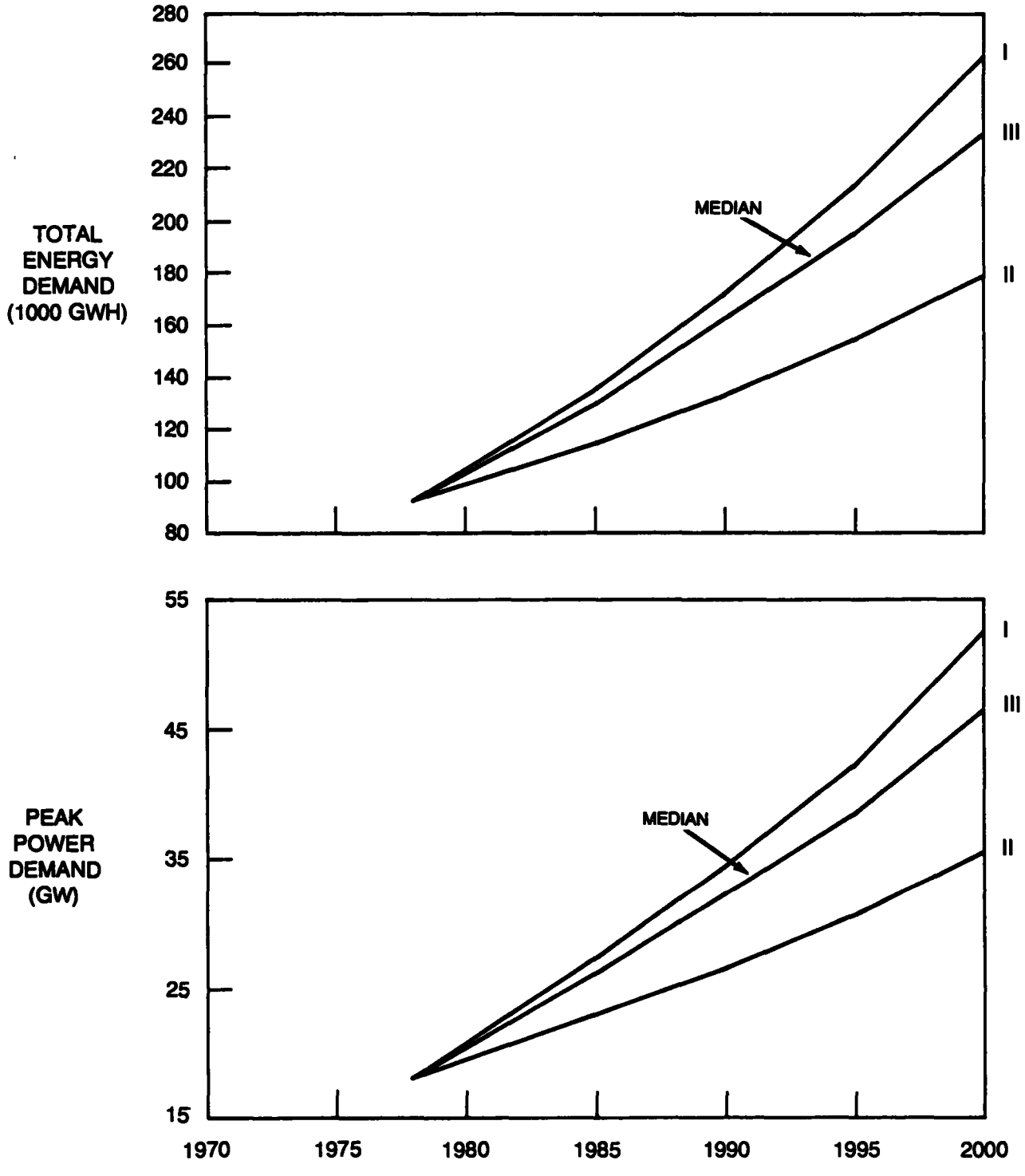

Figure A4-1d: REGIONAL CHARACTERISTICS, MARCA

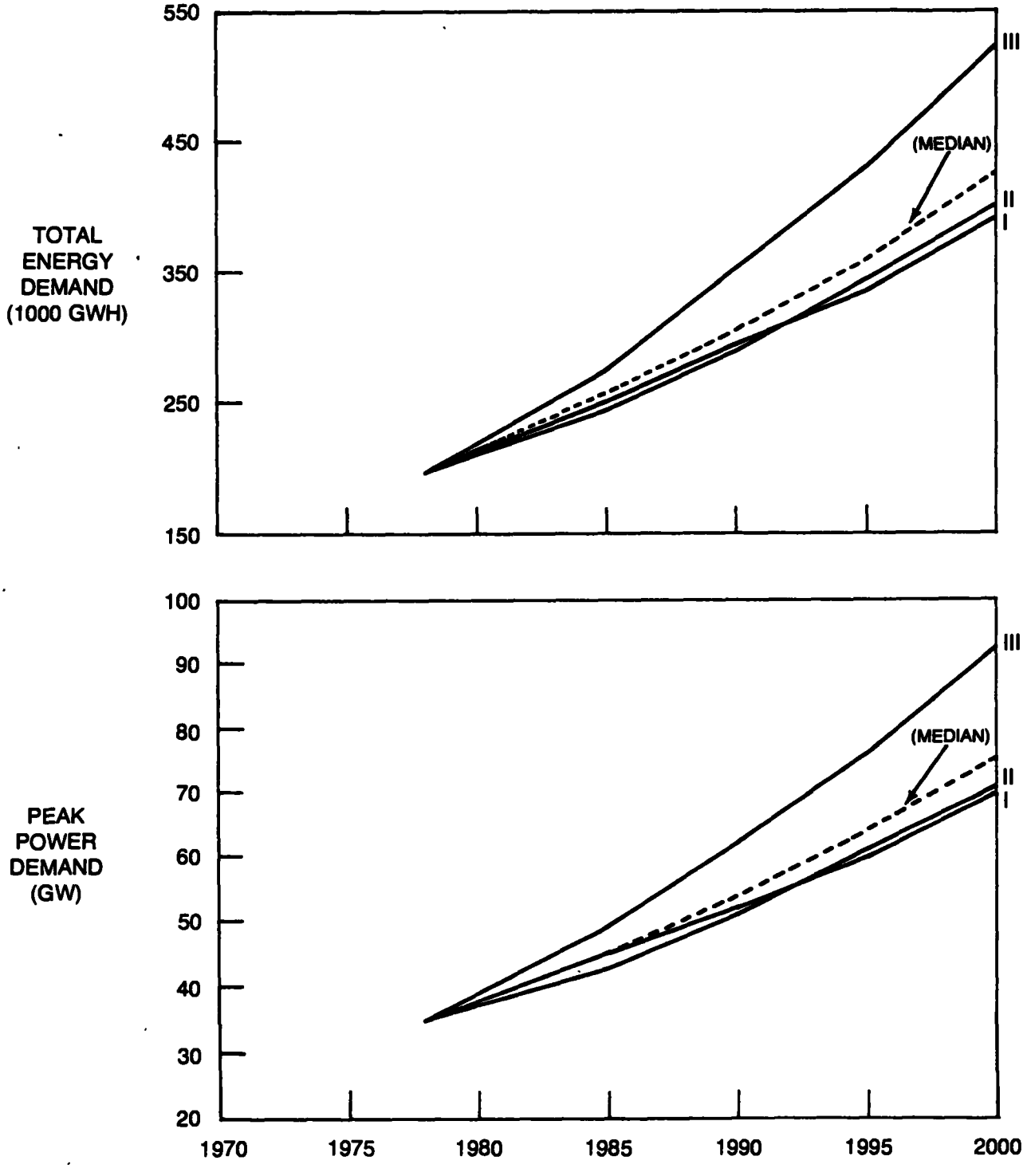

Figure A4-1e: REGIONAL CHARACTERISTICS, NPCC

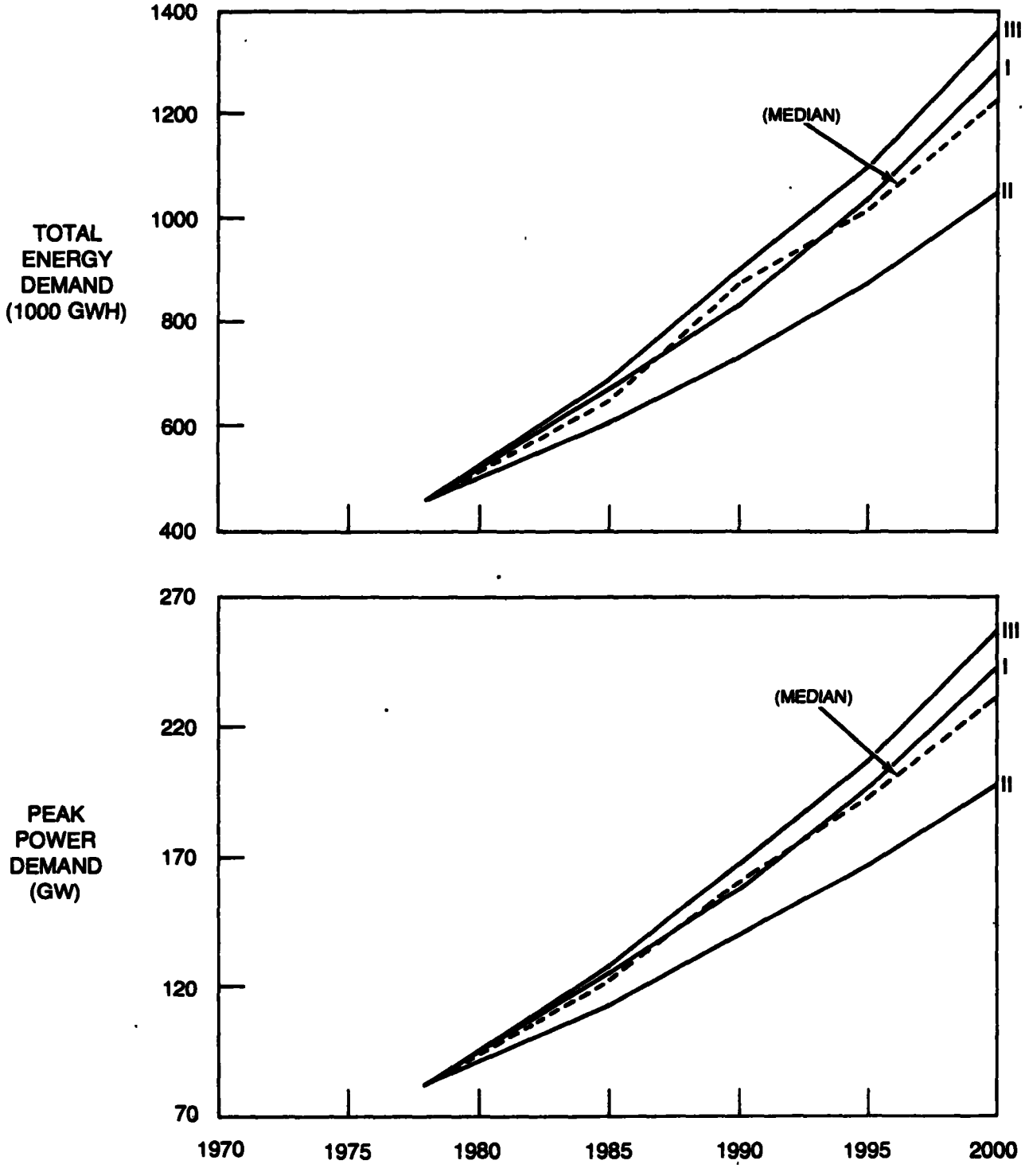

Figure A4-1f: REGIONAL CHARACTERISTICS, SERC

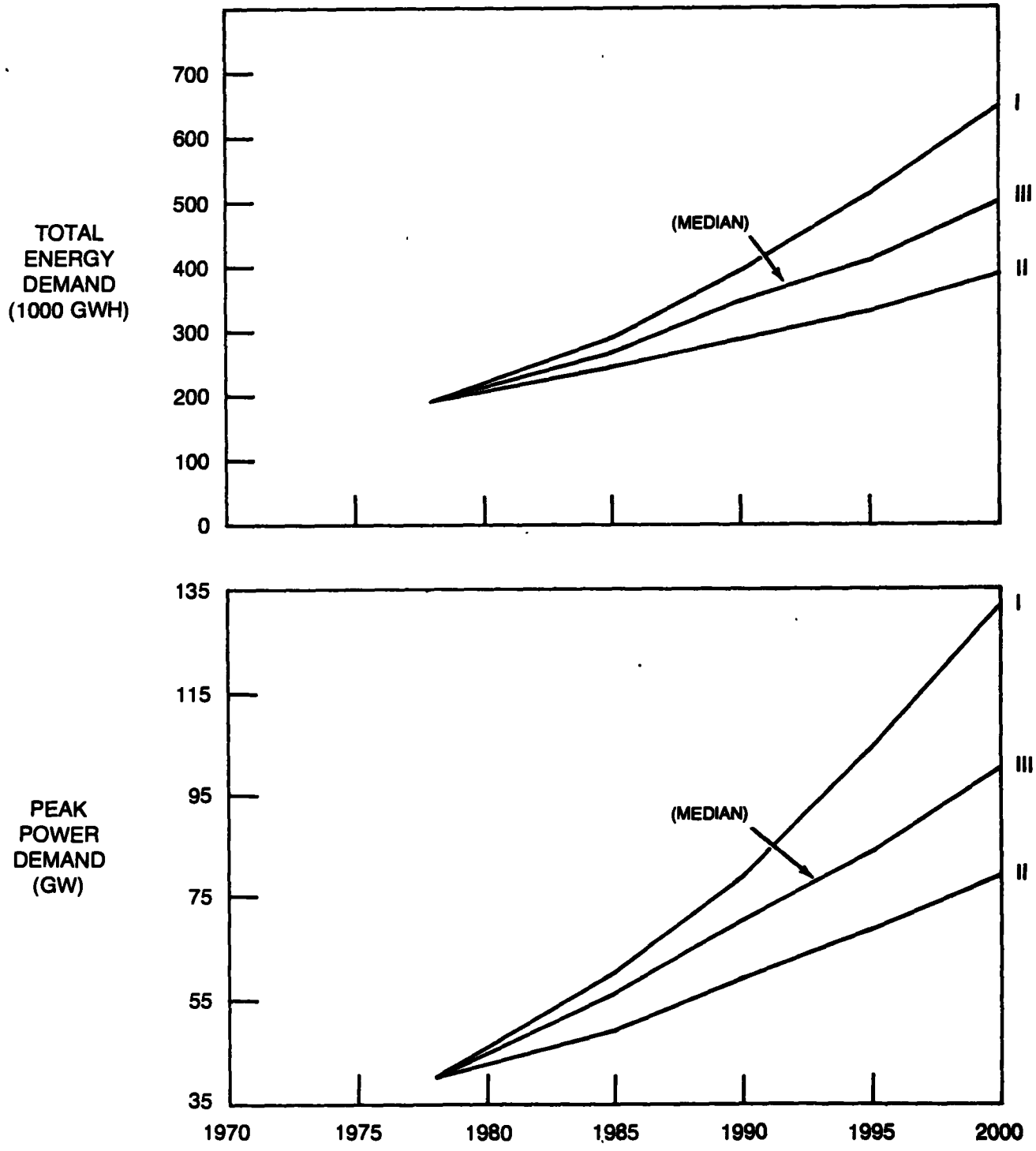

Figure A4-1g: REGIONAL CHARACTERISTICS, SWPP

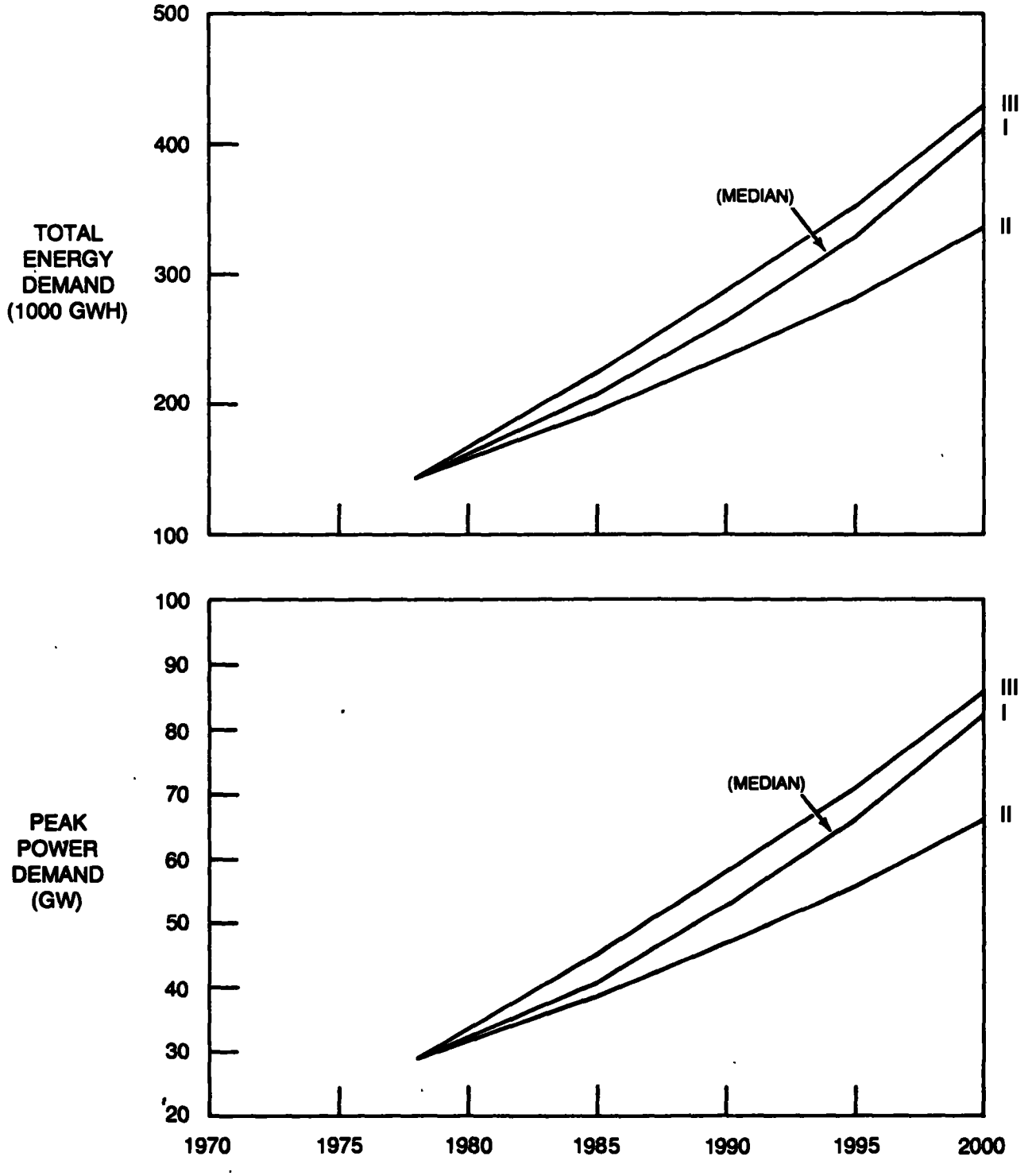

Figure A4-1h: REGIONAL CHARACTERISTICS, ERCOT

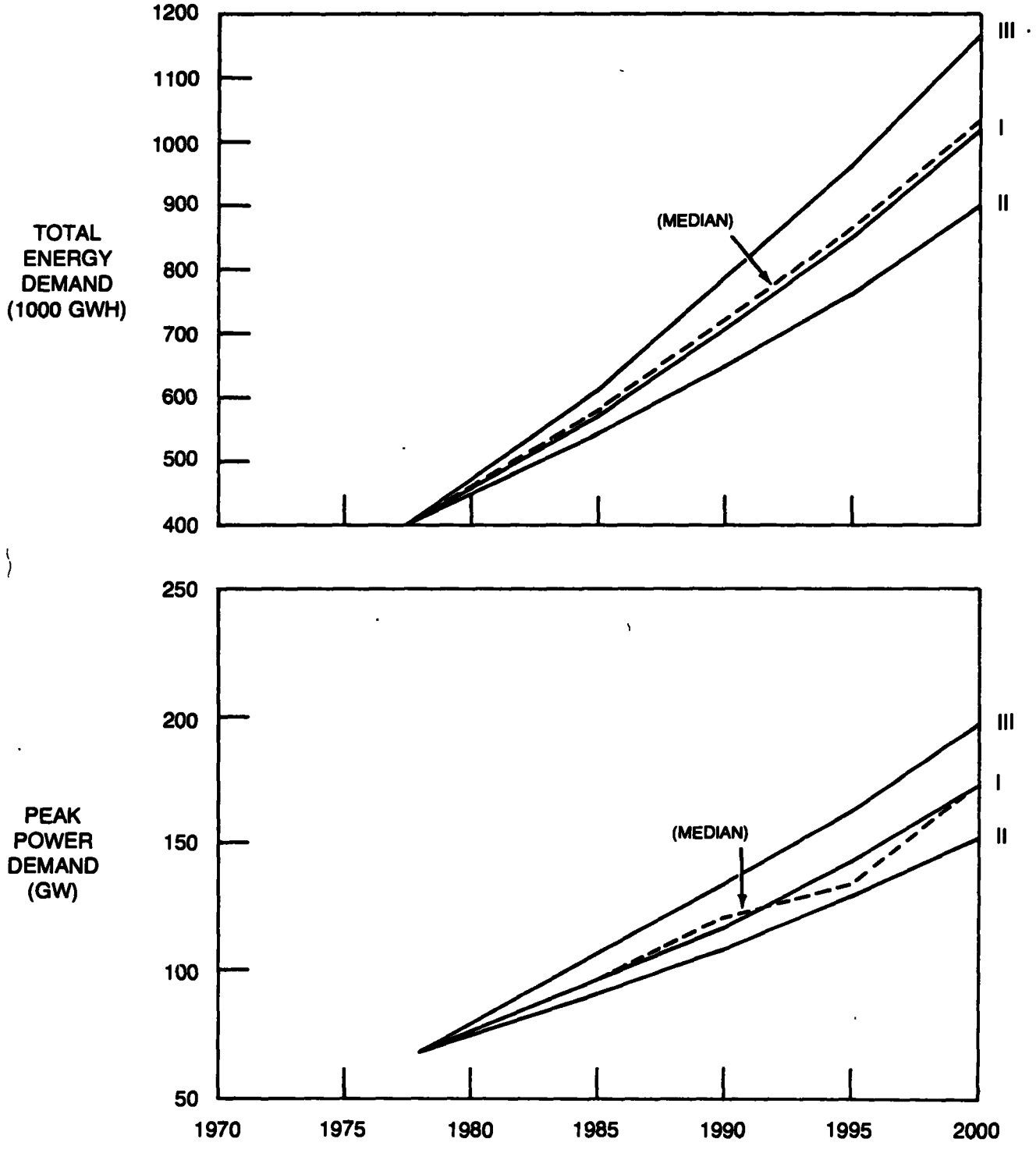

Figure A4-1i: REGIONAL CHARACTERISTICS, WSCC

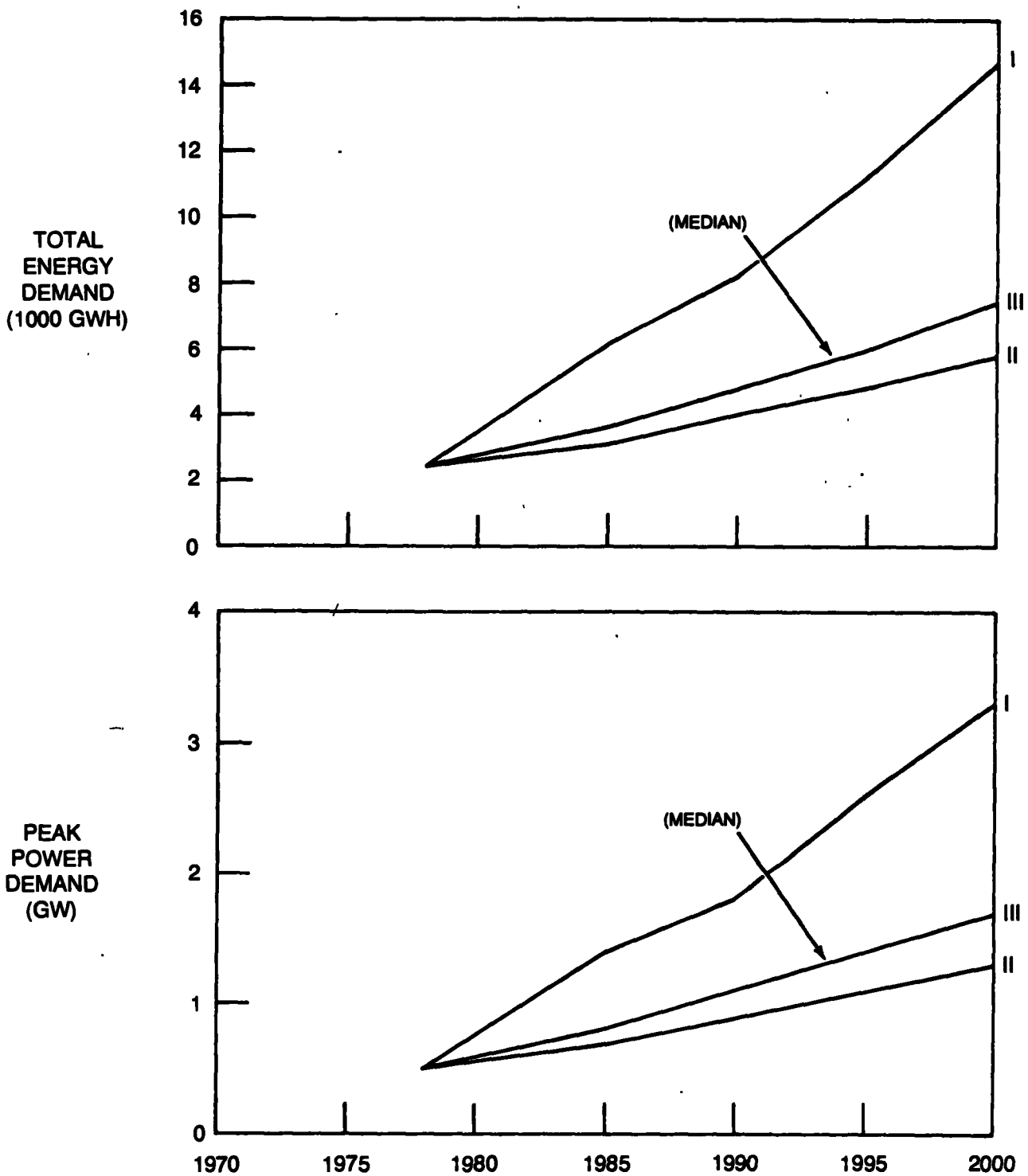

Figure A4-1j: REGIONAL CHARACTERISTICS, ALASKA

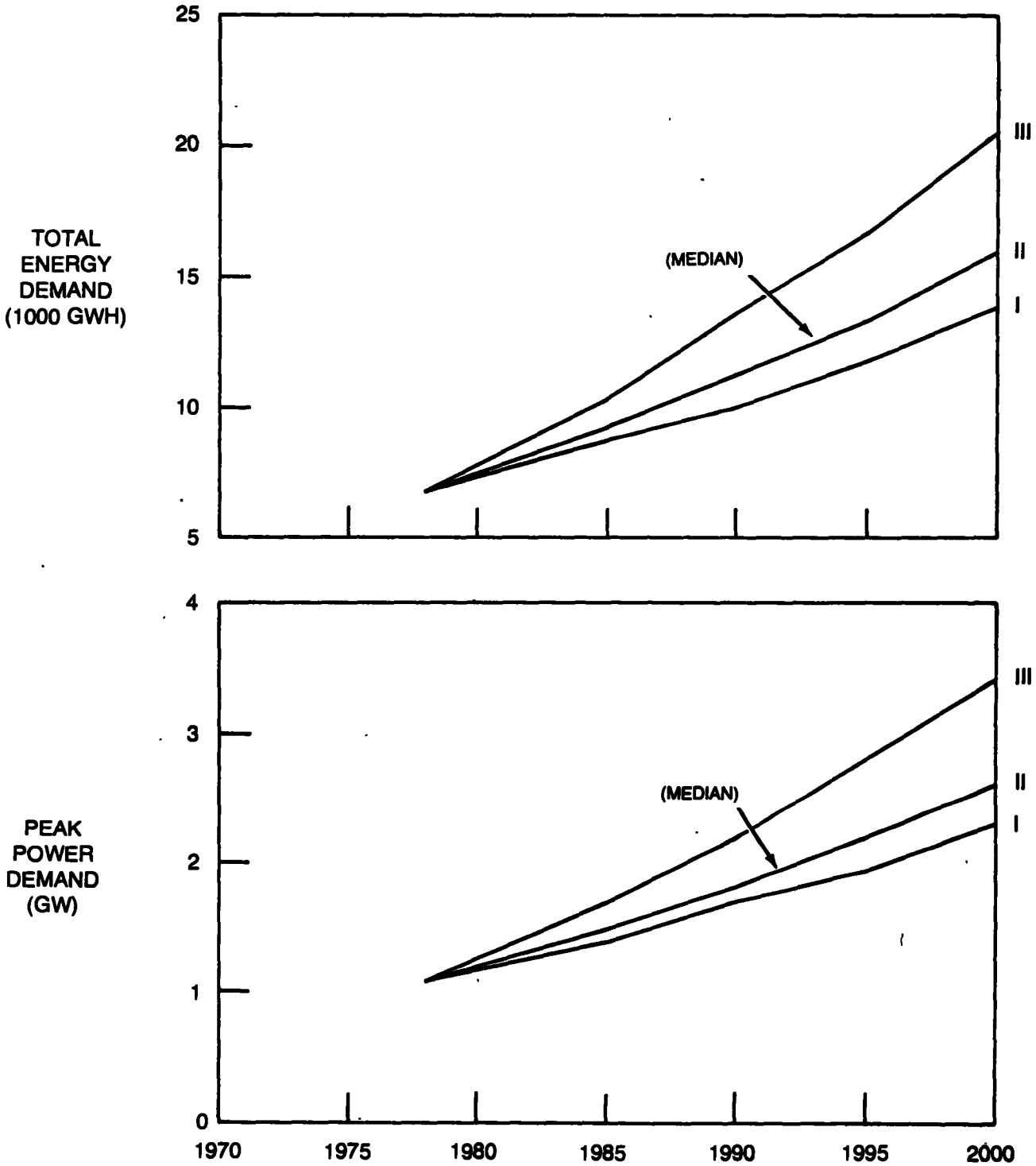

Figure A4-1k: REGIONAL CHARACTERISTICS, HAWAII

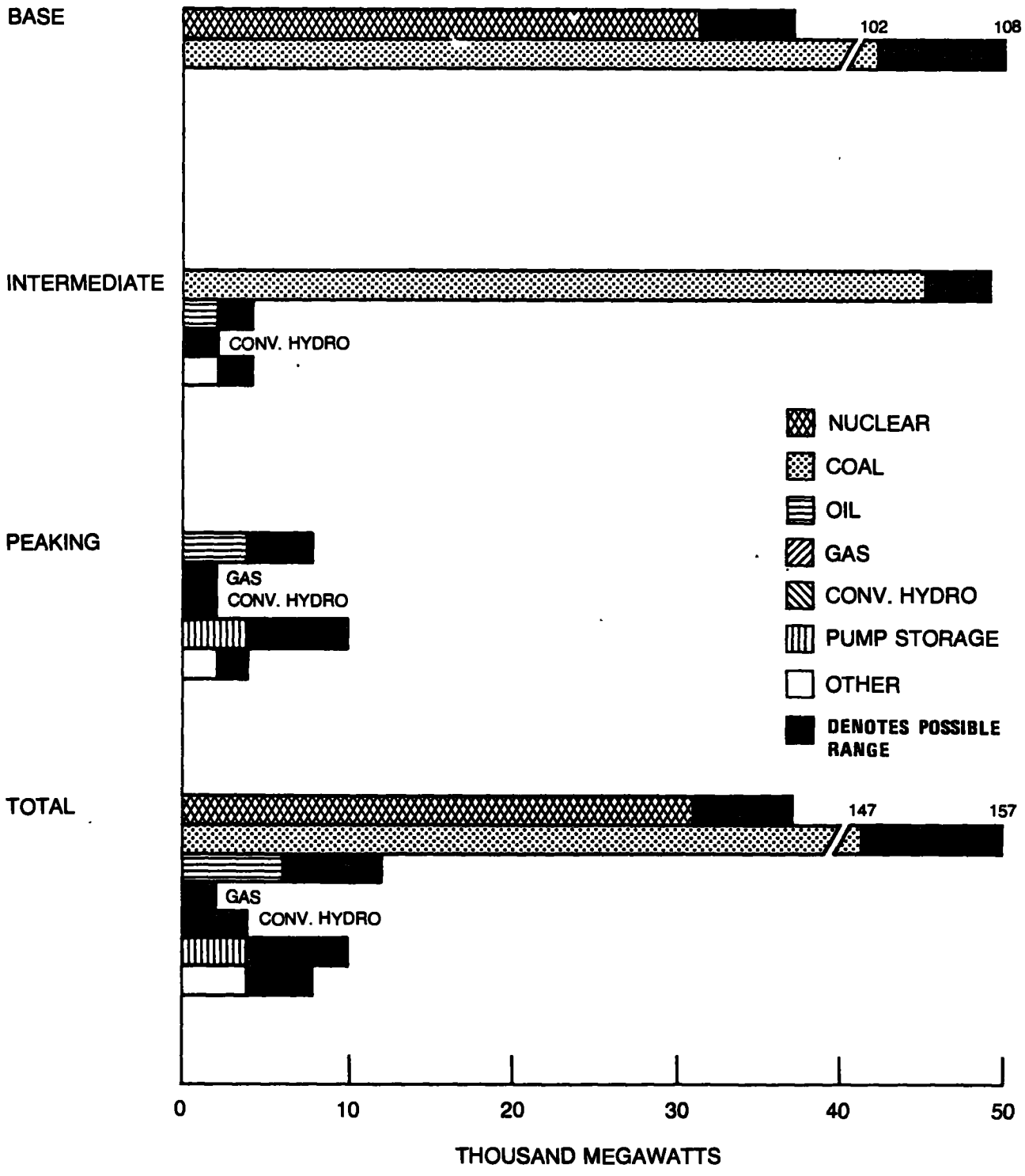

Figure A4-2a: RANGE OF FUTURE GENERATING CAPABILITIES FOR MEETING LOAD PROJECTIONS, ECAR (2000)

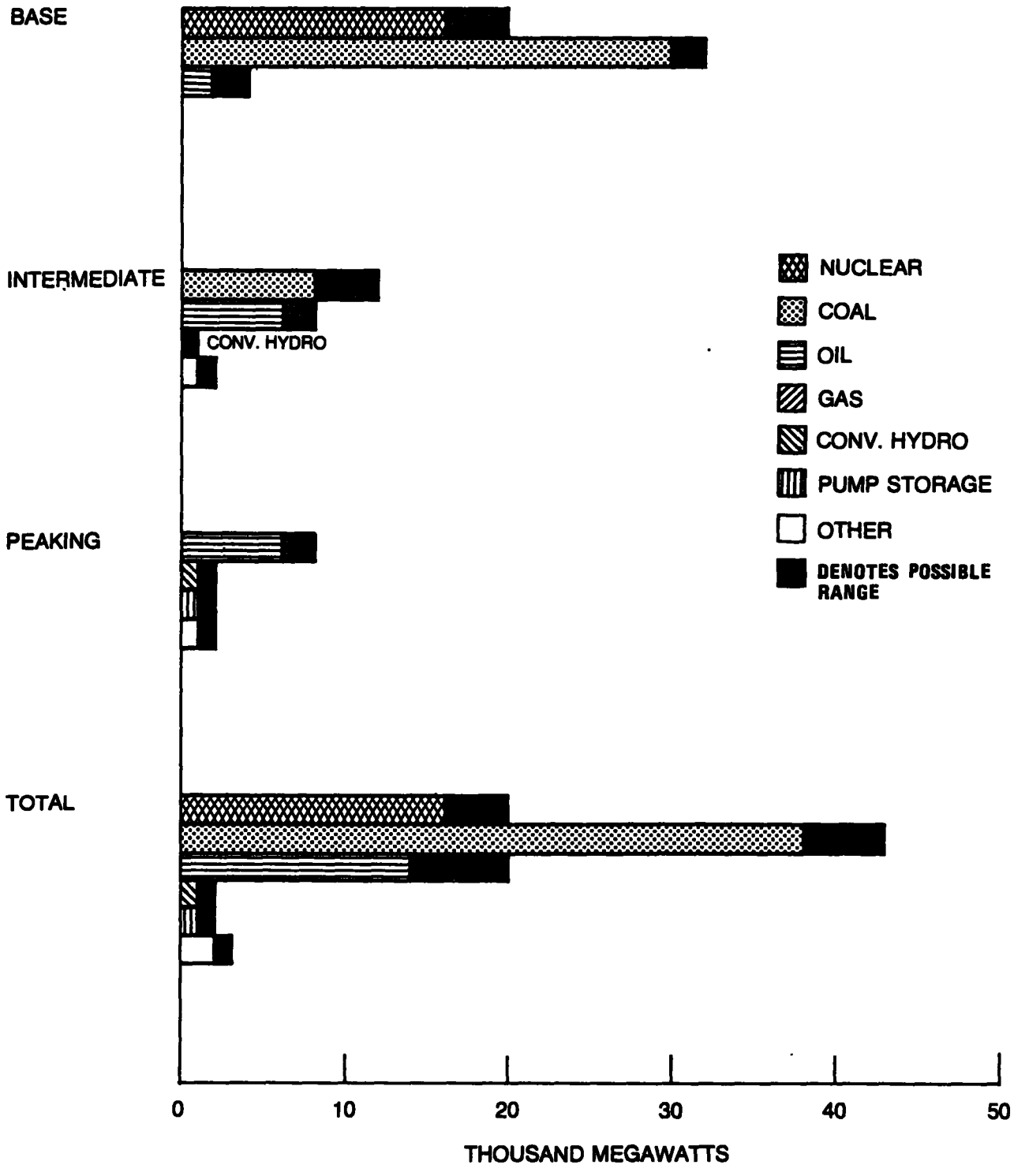

Figure A4-2b: RANGE OF FUTURE GENERATING CAPABILITIES FOR MEETING LOAD PROJECTIONS, MAAC (2000)

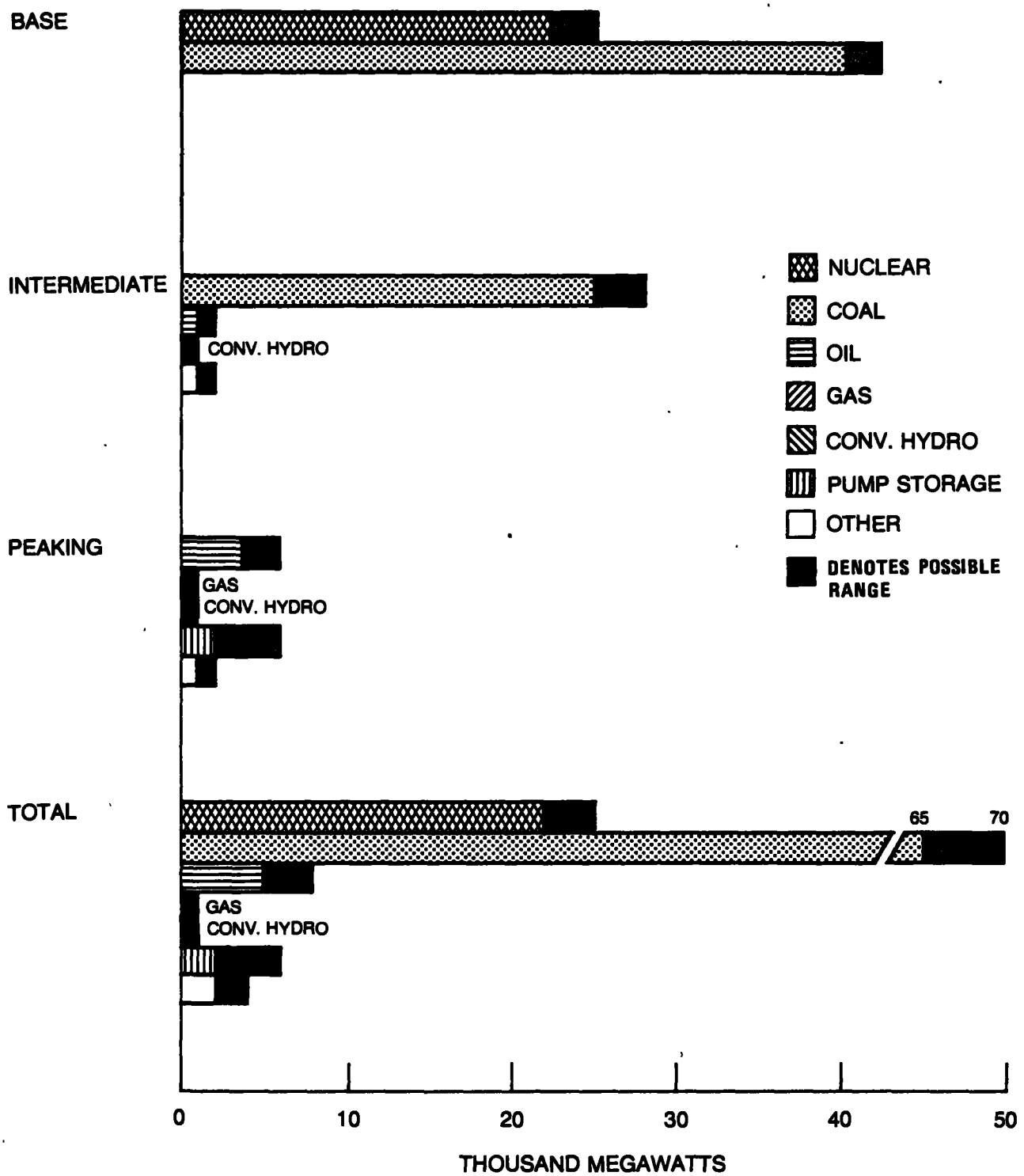

Figure A4-2c: RANGE OF FUTURE GENERATING CAPABILITIES FOR MEETING LOAD PROJECTIONS, MAIN (2000)

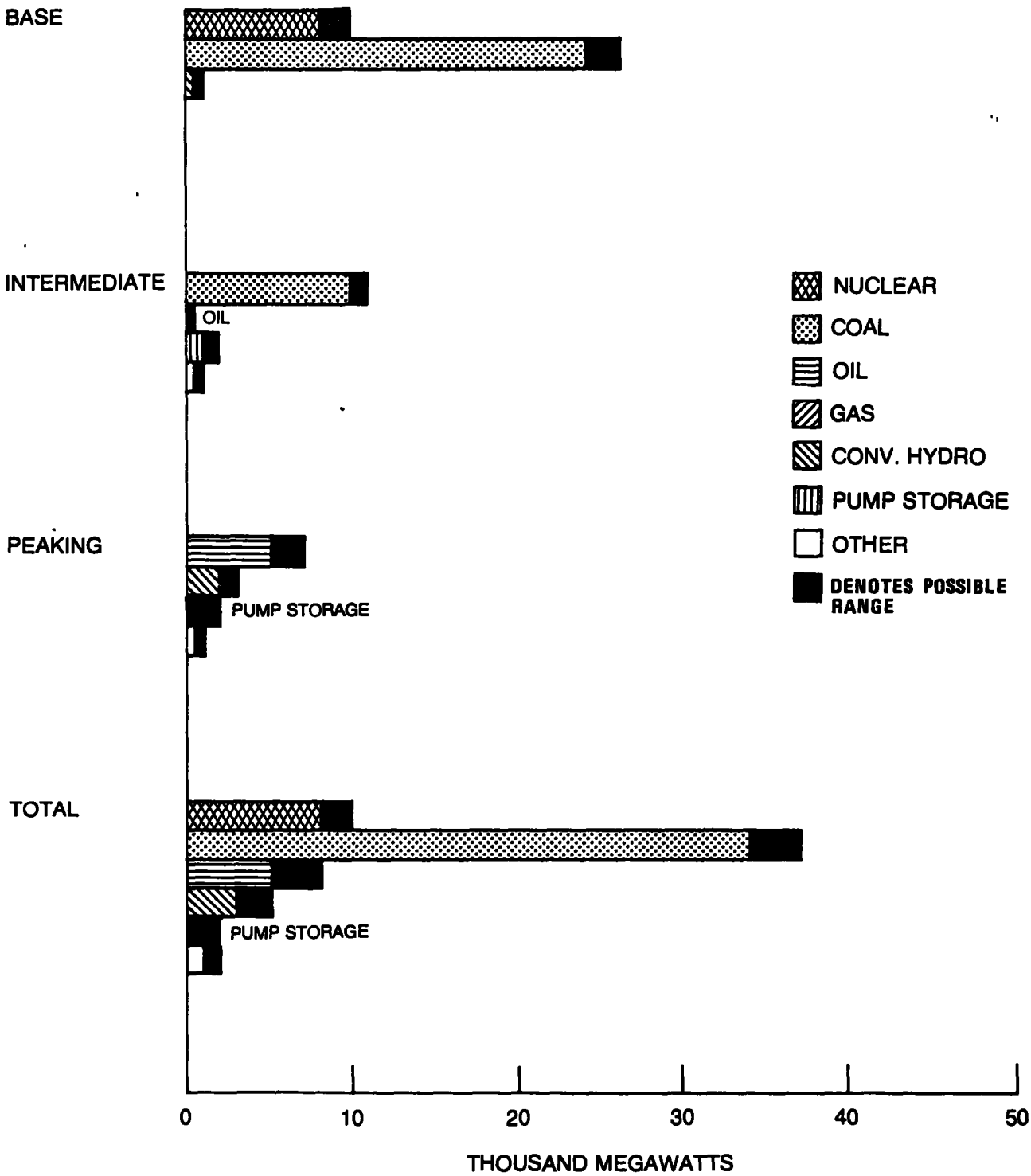

Figure A4-2d: RANGE OF FUTURE GENERATING CAPABILITIES FOR MEETING LOAD PROJECTIONS, MARCA (2000)

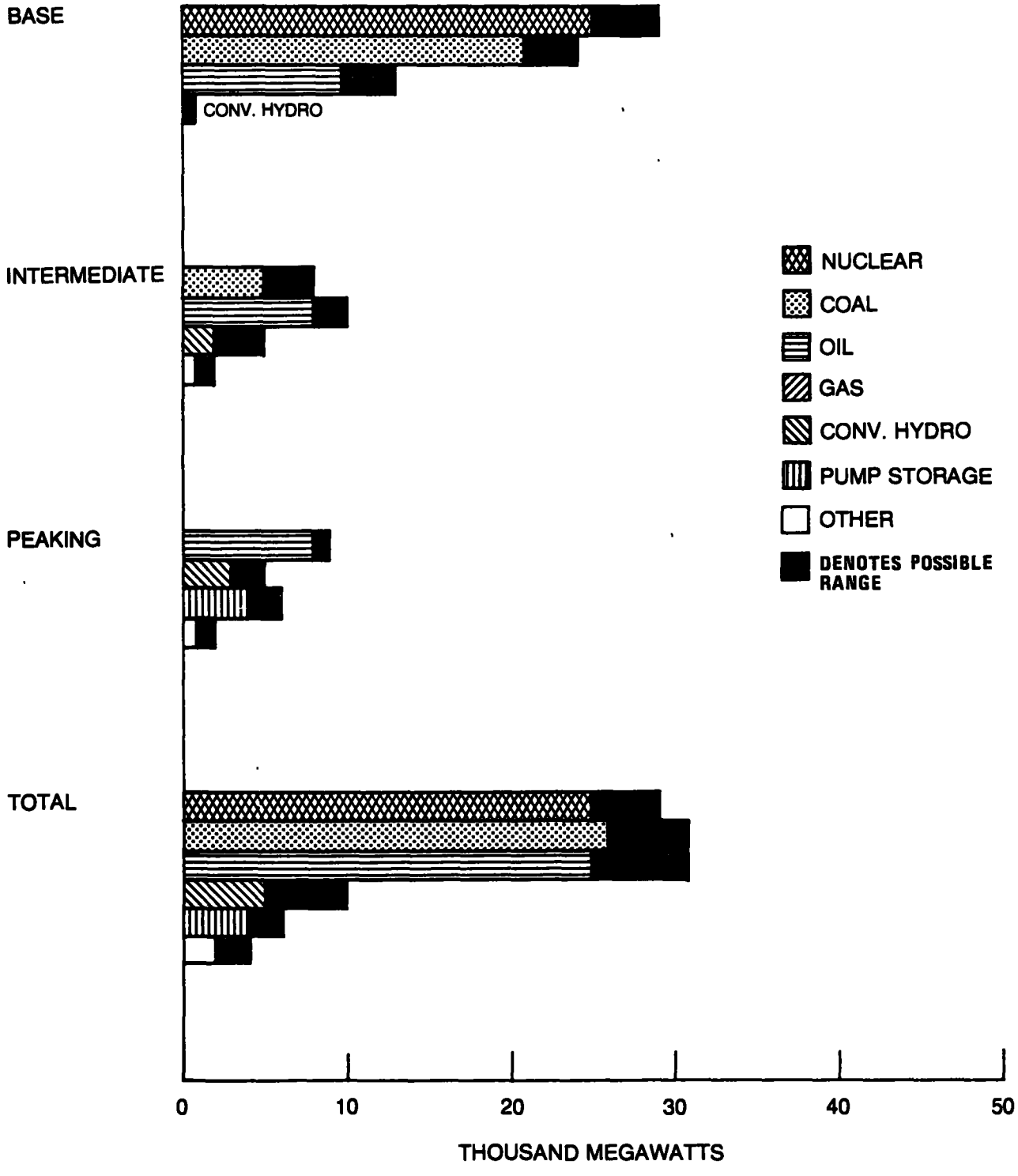

Figure A4-2e: RANGE OF FUTURE GENERATING CAPABILITIES FOR MEETING LOAD PROJECTIONS, NPCC (2000)

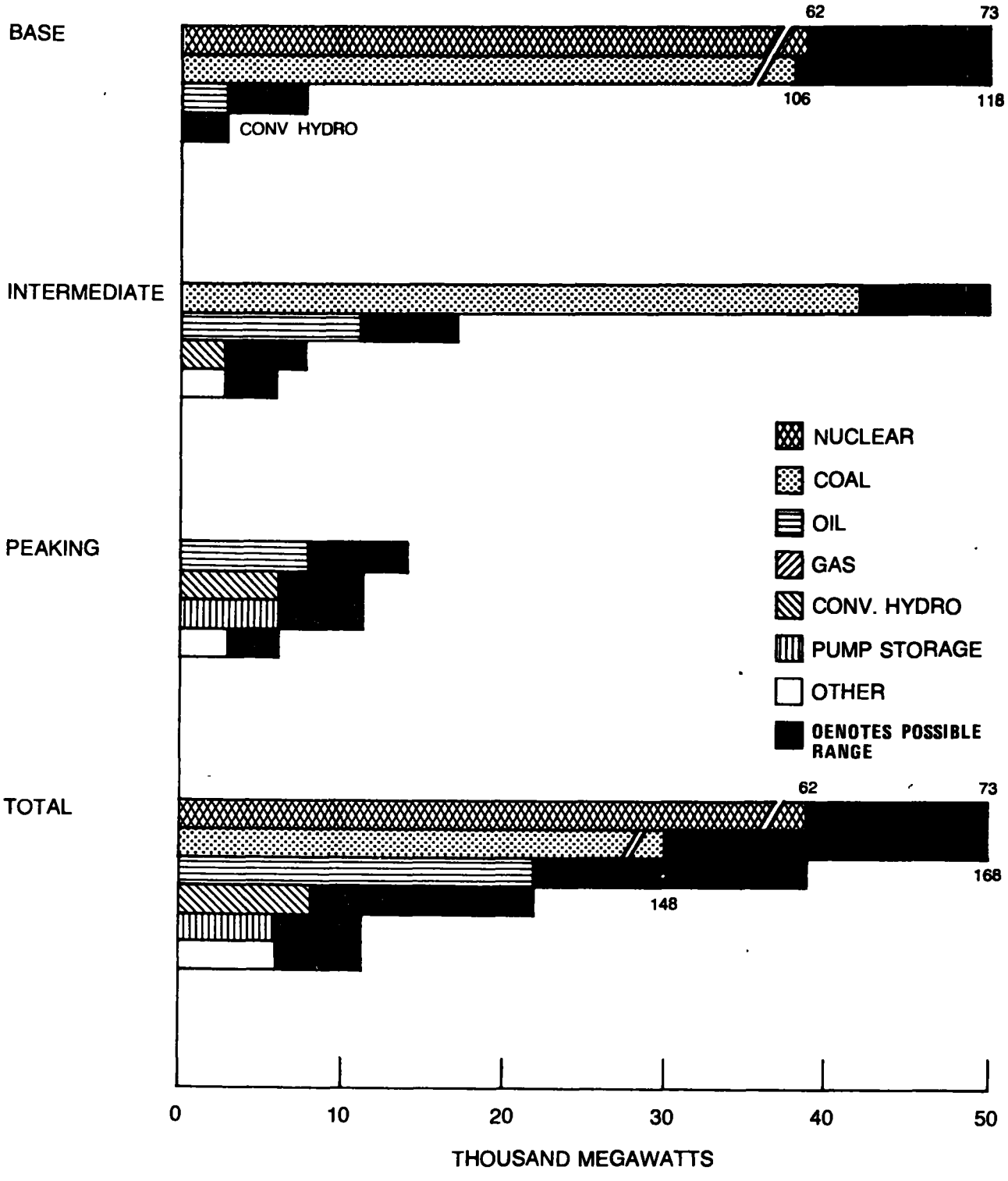

Figure A4-2f: RANGE OF FUTURE GENERATING CAPABILITIES FOR MEETING LOAD PROJECTIONS, SERC (2000)

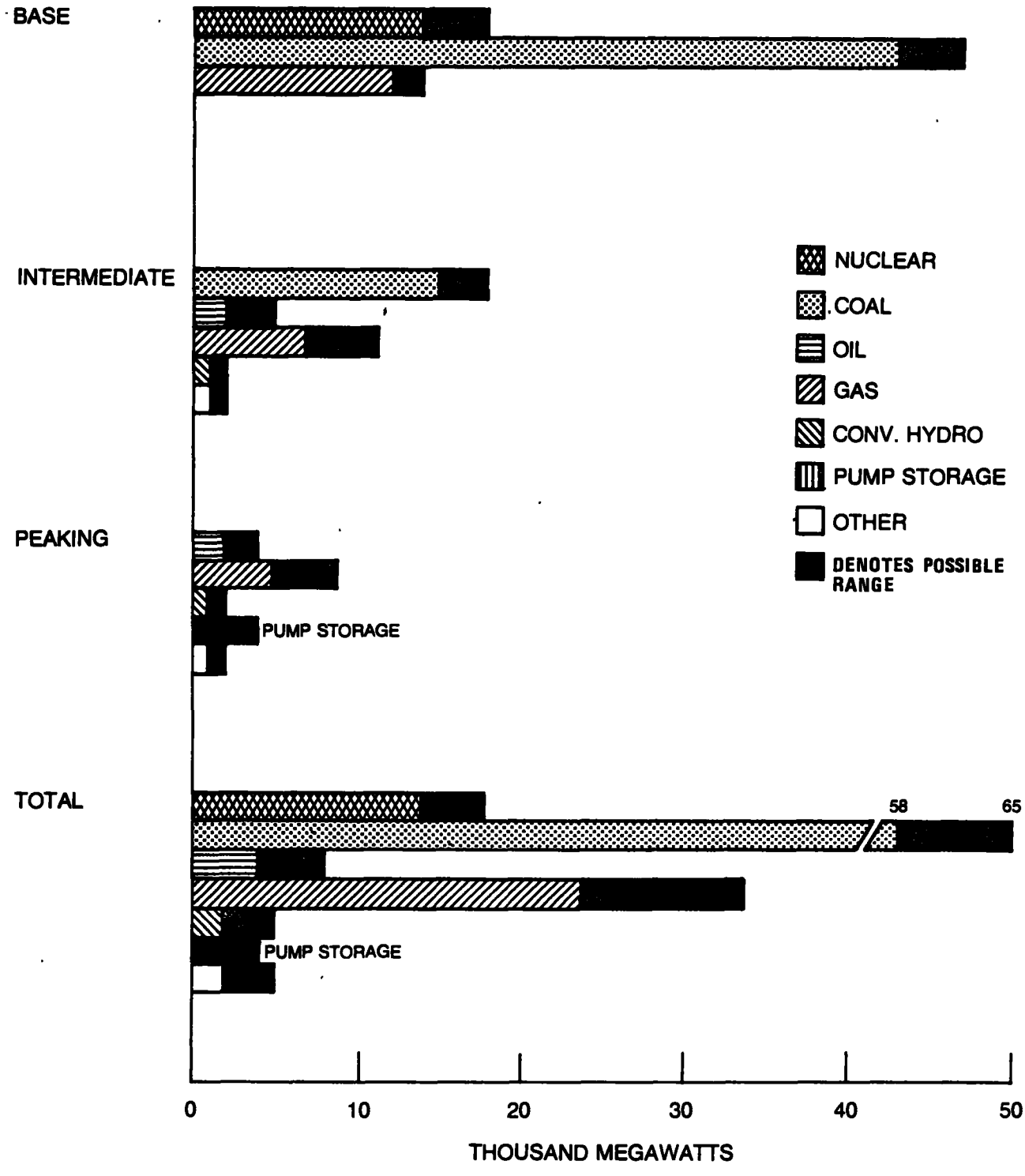

Figure A4-2g: RANGE OF FUTURE GENERATING CAPABILITIES FOR MEETING LOAD PROJECTIONS, SWPP (2000)

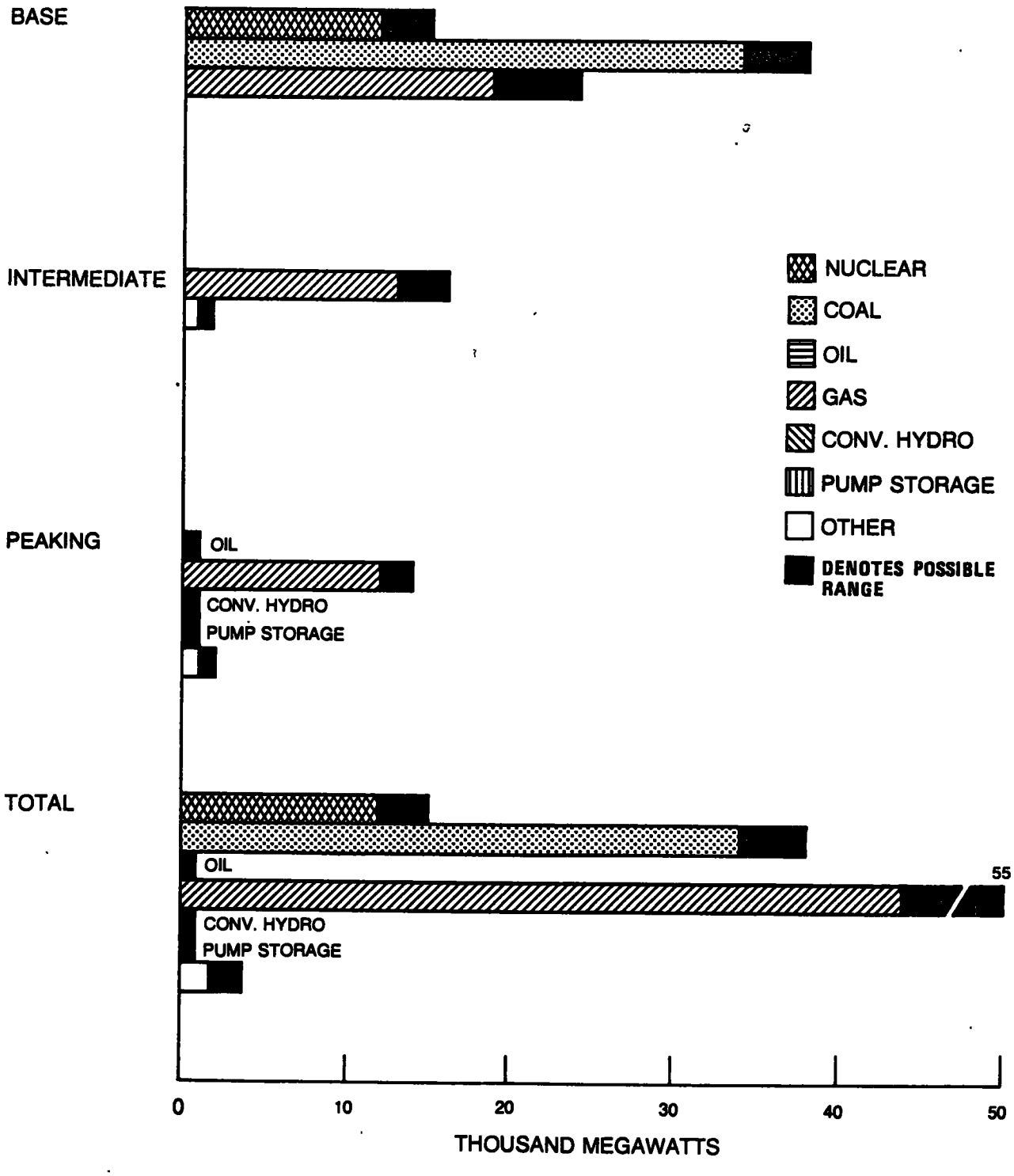

Figure A4-2h: RANGE OF FUTURE GENERATING CAPABILITIES FOR MEETING LOAD PROJECTIONS, ERCOT (2000)

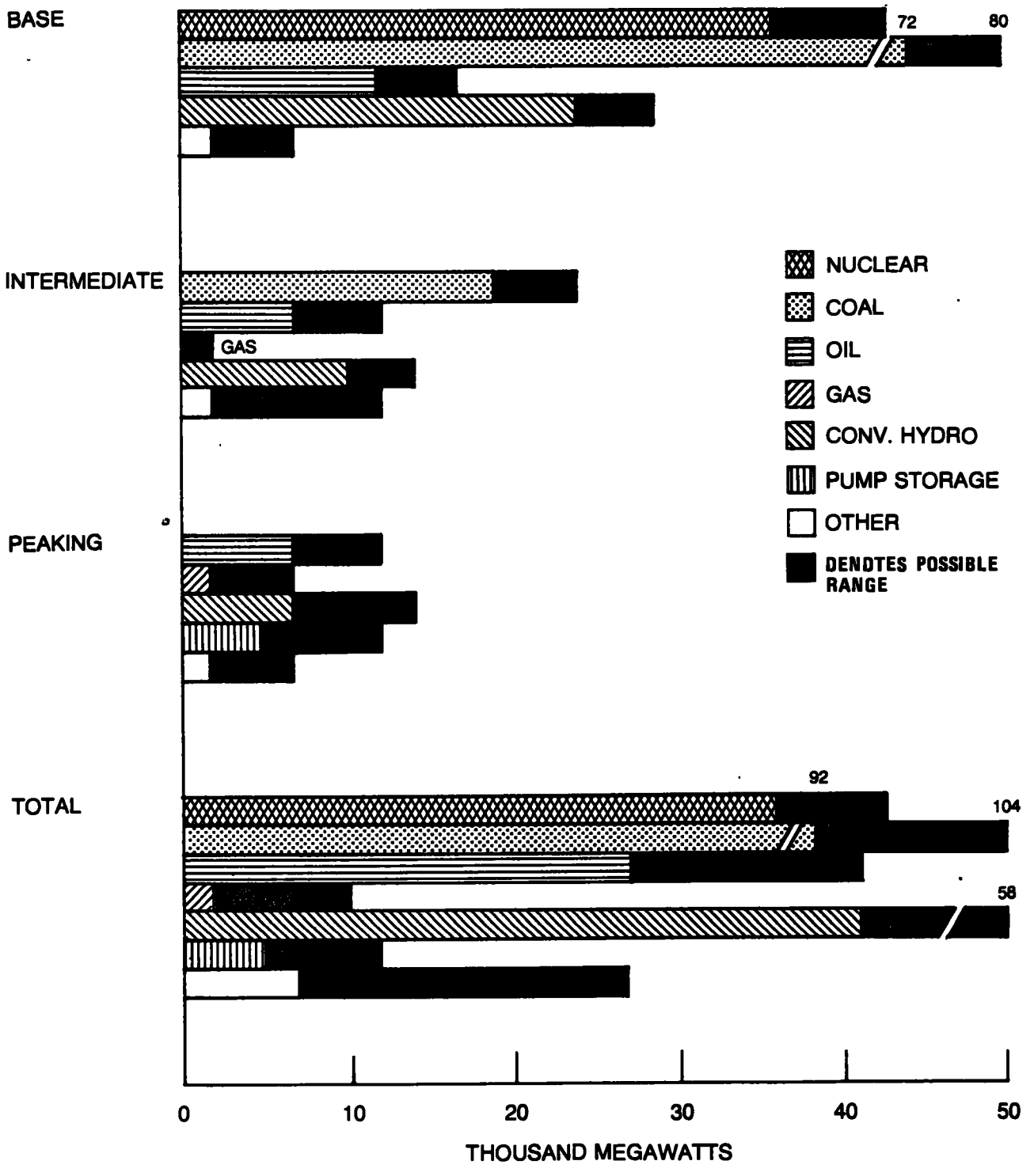

Figure A4-2i: RANGE OF FUTURE GENERATING CAPABILITIES FOR MEETING LOAD PROJECTIONS, WSCC (2000)

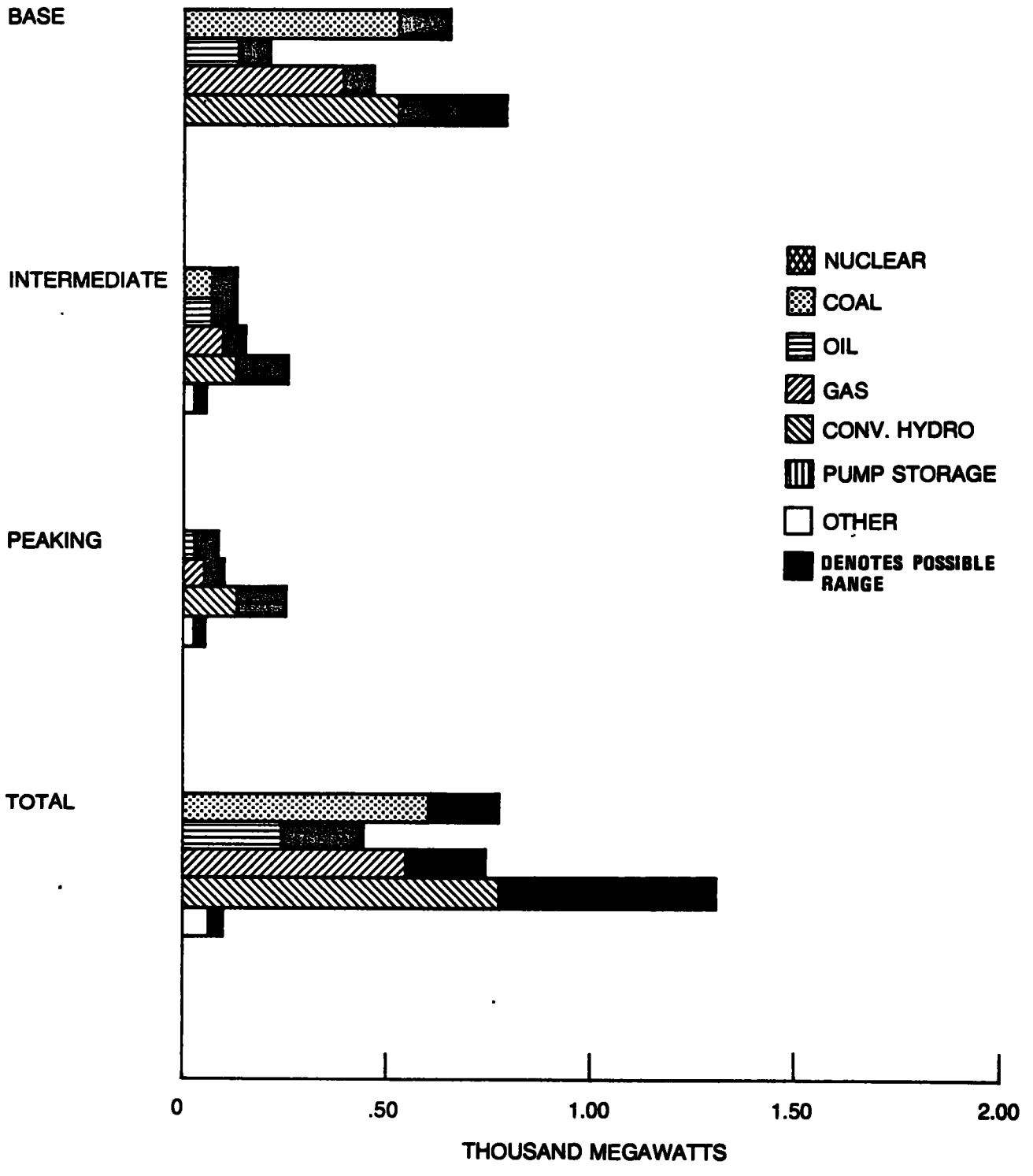

Figure A4-2j: RANGE OF FUTURE GENERATING CAPABILITIES FOR MEETING LOAD PROJECTIONS, ALASKA (2000)

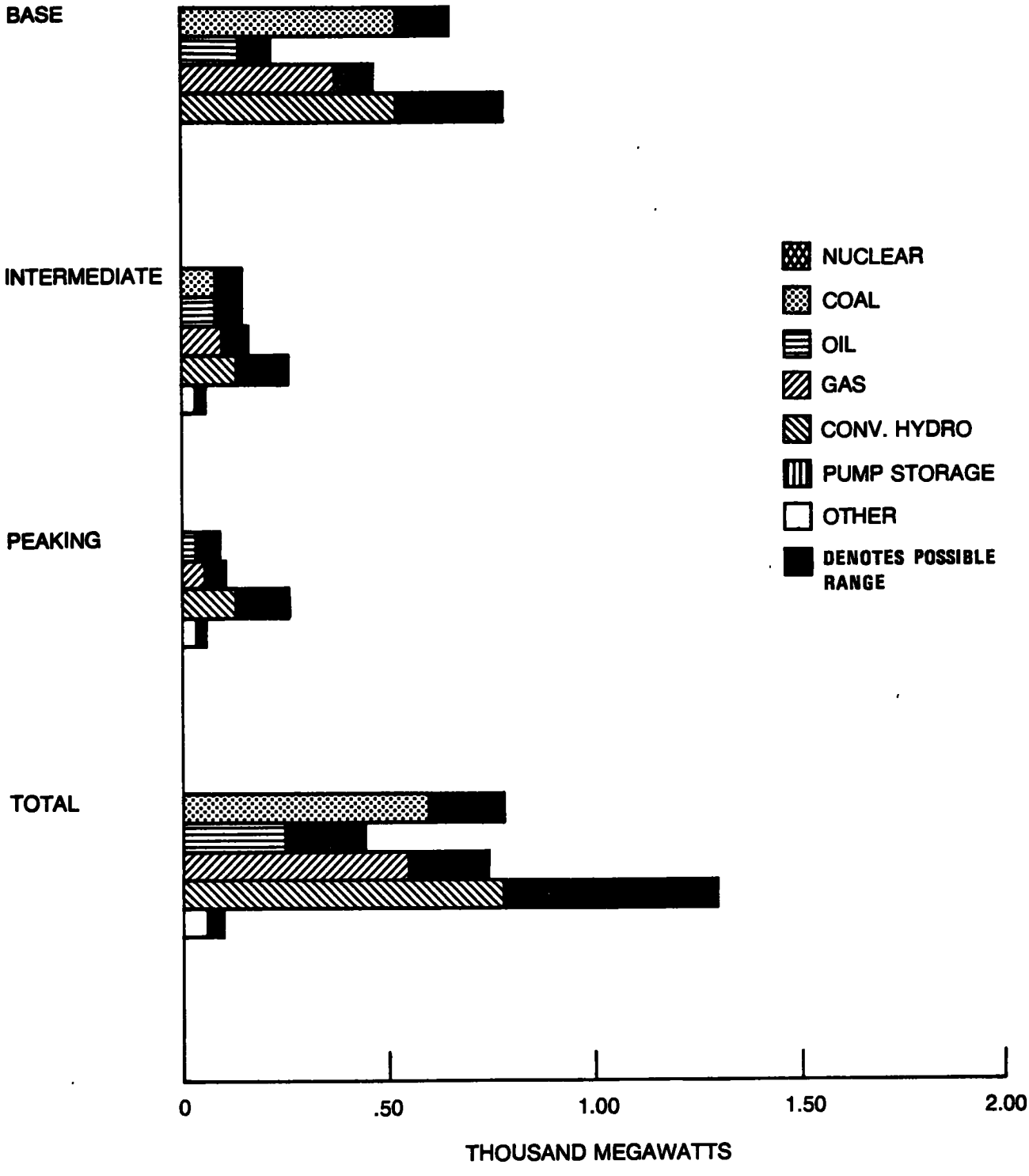

Figure A4-2k: RANGE OF FUTURE GENERATING CAPABILITIES FOR MEETING LOAD PROJECTIONS, HAWAII (2000)

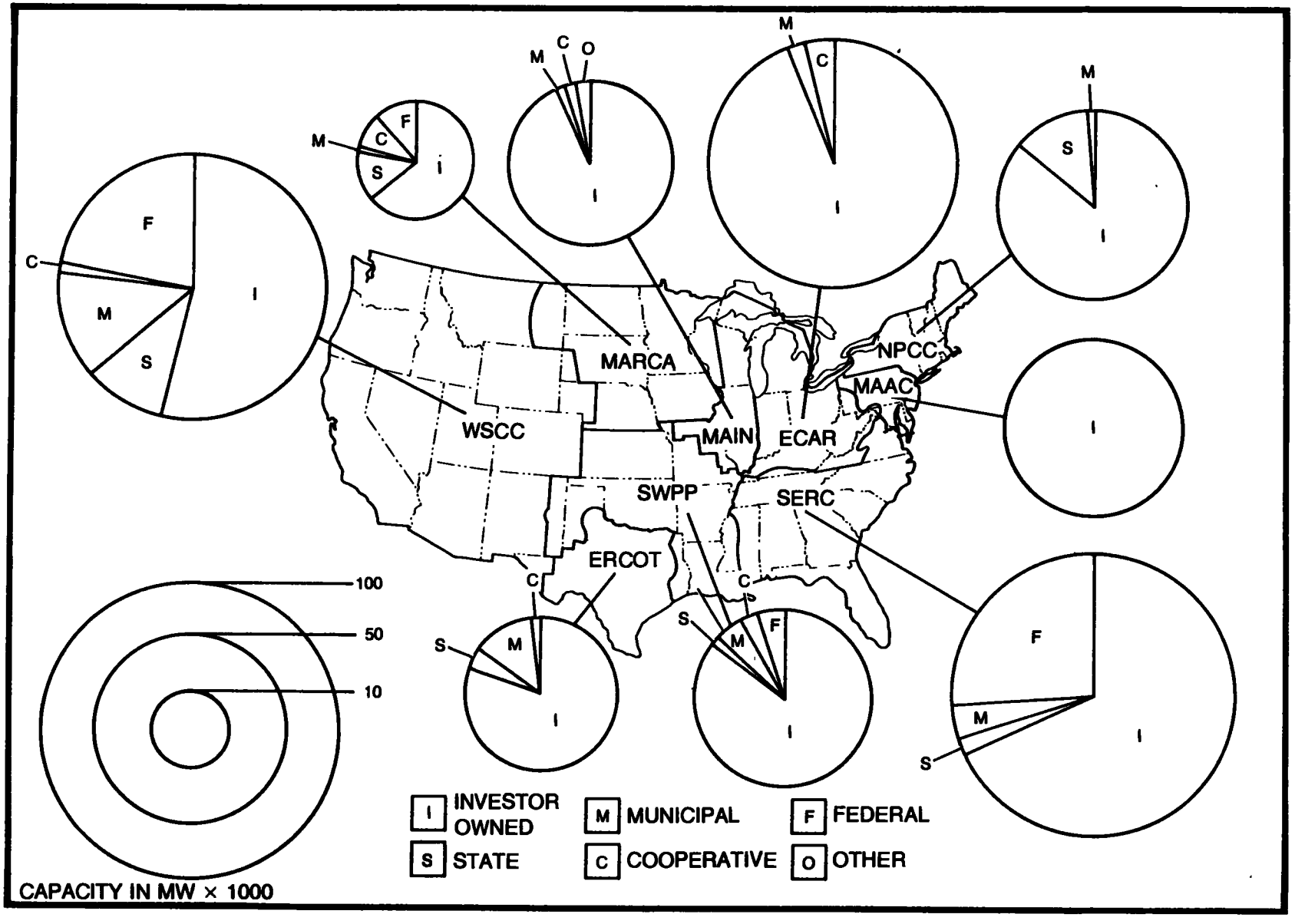

Figure A4-3 .: OWNERSHIP OF ELECTRIC GENERATION SOURCES BY NERC REGION (1977)

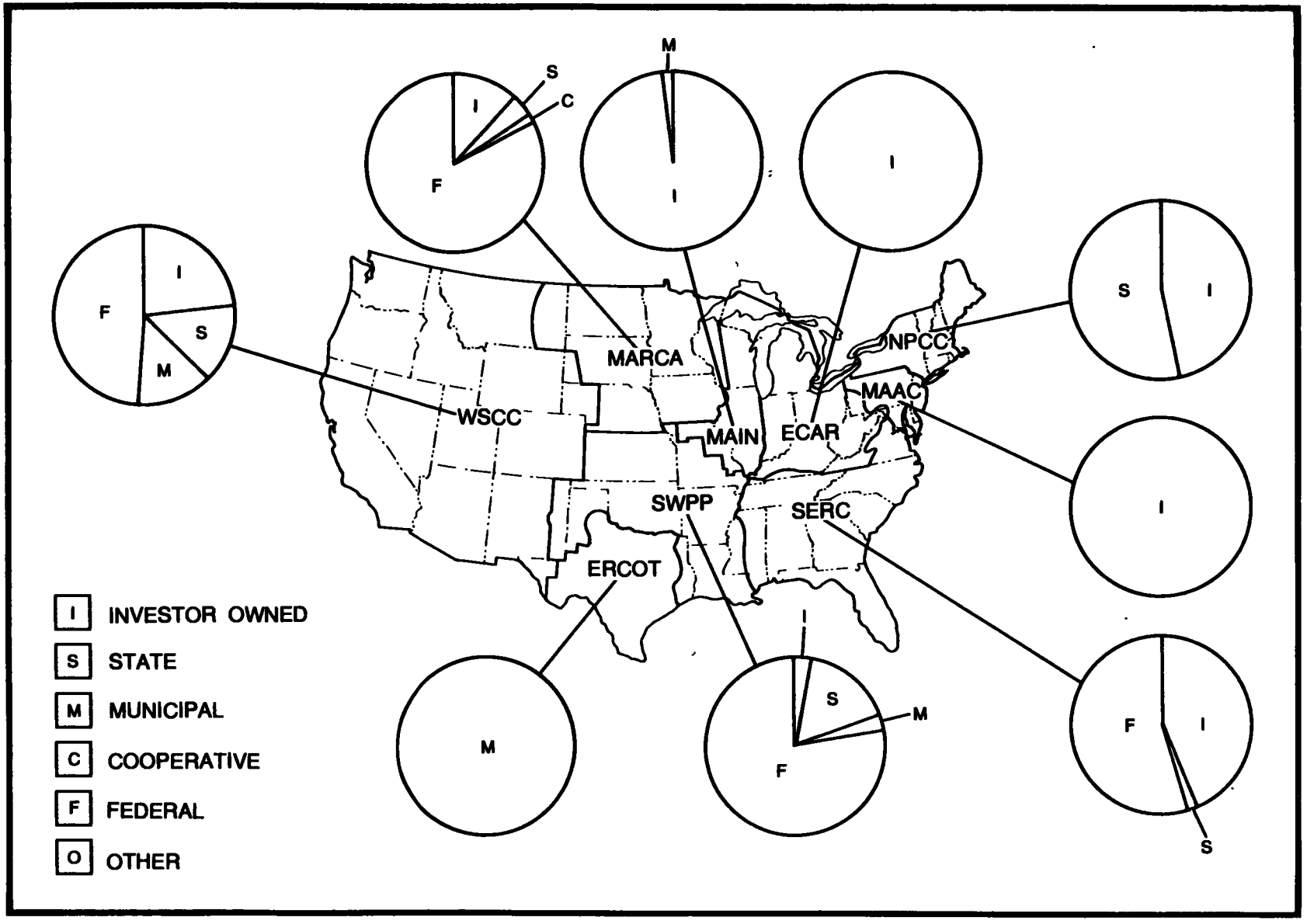

Figure A4-4 : OWNERSHIP OF HYDROELECTRIC GENERATION SOURCES BY NERC REGION (1977)

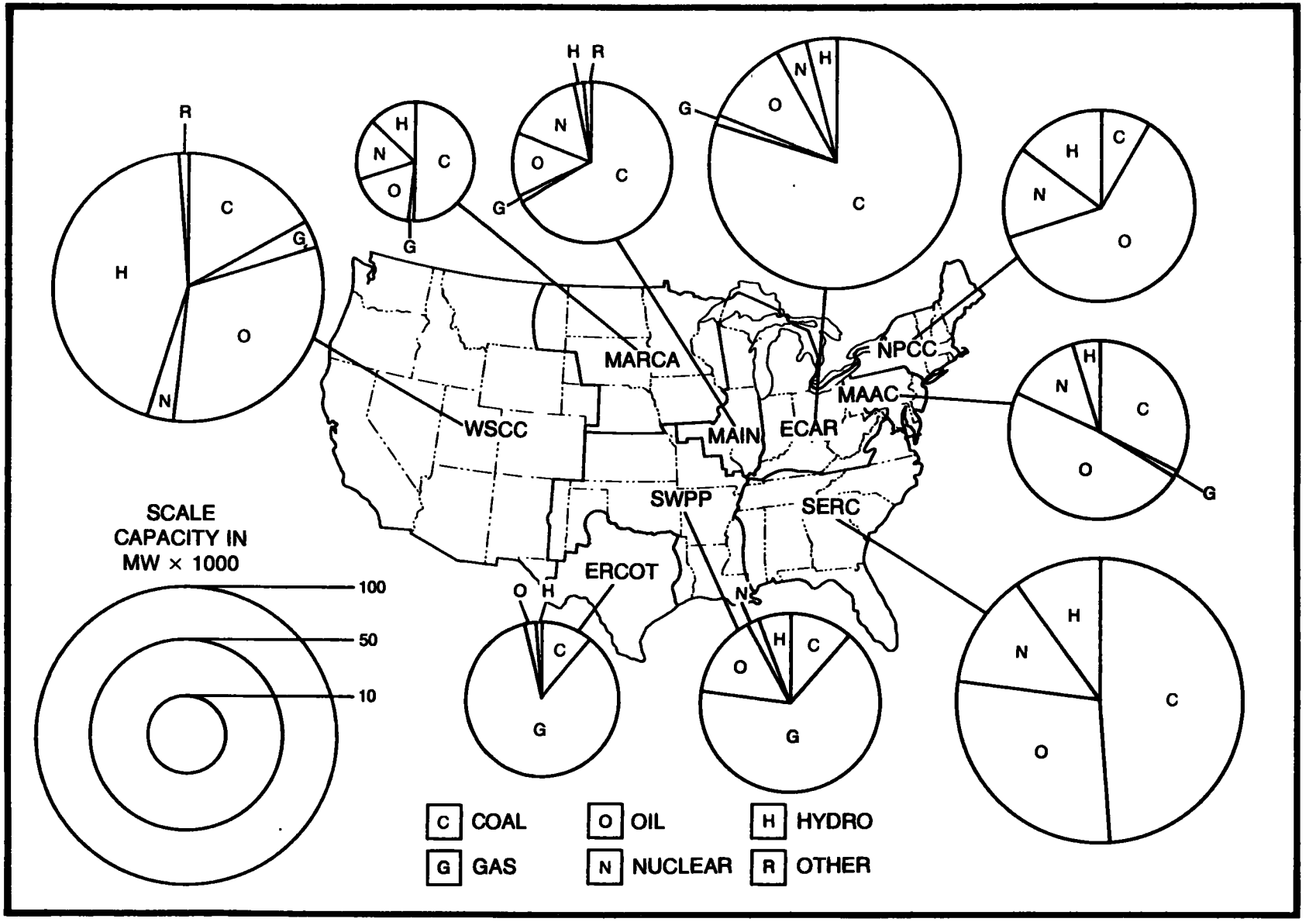

Figure A4-5 : INSTALLED CAPACITY BY FUEL TYPE, NERC REGIONS (1977)

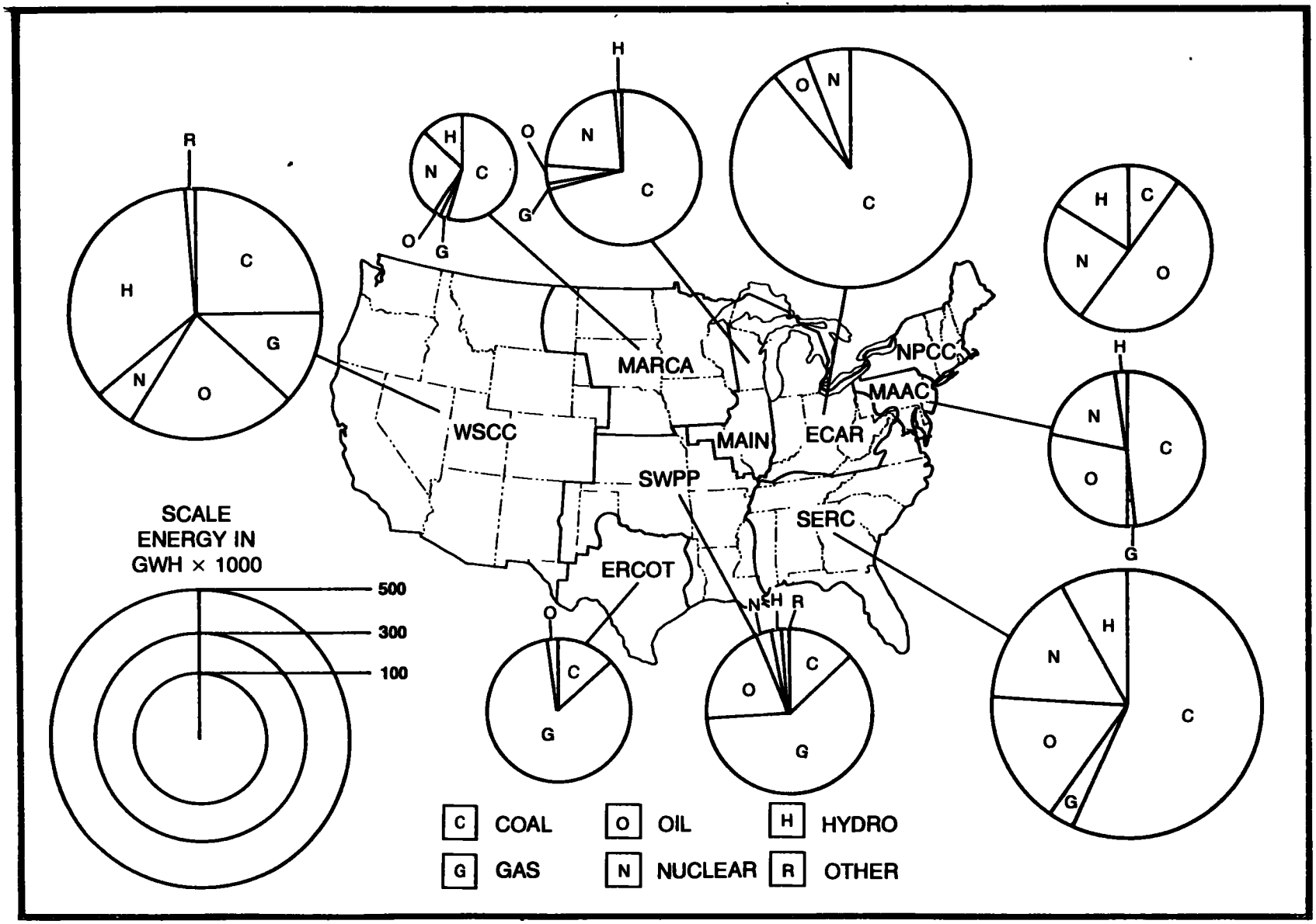

Figure A4-6 : NET ELECTRIC ENERGY GENERATION BY FUEL TYPE, NERC REGIONS (1977)

* U.S. GOVERNMENT PRINTING OFFICE: 1983-408-981